Plastic Surgery Essentials for Students

Tenth Edition

AMERICAN SOCIETY OF PLASTIC SURGEONS®

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Table of Contents

Chapter 1
Introduction

Catherine L. Ly, MD
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Plastic surgery had its beginning nearly 3,000 years ago, when Sushruta, an Indian surgeon, reconstructed the nose by transferring a flap of cheek and then forehead skin. It is a modern field, stimulated by the challenging reconstructive problems of the unfortunate victims of the World Wars. The advent of the operating microscope has thrust the plastic surgeon of today into the forefront of advances in small vessel and nerve repair, culminating in the successful replantation of amputated parts as small as distal fingers and bypassing of lymphatic vessels, only a few millimeters in diameter. These techniques have even been utilized to perform the first composite tissue transplantations of both hands and partial faces. Plastic surgery is ultimately a specialty of innovation in which surgeons are continually pushing the limits of what is possible. The breadth and constant change, however, can also make it daunting to students who may not have had previous exposure to the field. Our goal for *Plastic Surgery Essentials for Students* is to make it more approachable, so that more students can fall in love with the specialty, just as we did.

Seven years ago, this book was thoughtfully revised and updated by our predecessors, for the benefit of students seeking to better understand the incredible field of plastic surgery. Some of the students who studied its pages are now chief residents in plastic surgery, or maybe even in practice. A person's first experience of plastic surgery is pivotal, often profoundly affected by the residents on service, their willingness to teach, and even the provided texts. What students encounter on the wards, in the operating room, and in the textbooks they read in preparation for cases, can tip the scale in terms of specialty choice. In this updated edition of *Plastic Surgery Essentials for Students,* we seek to provide the best possible resource for students to experience, and perhaps choose, plastic surgery.

This book represents the hard work and collaboration of the American Society of Plastic Surgeons (ASPS) Young Plastic Surgeons Steering Committee and Residents Council, representing plastic surgery residents, fellows, and attendings from across the country. All prior chapters have been updated. The book was written primarily for medical students and other students of plastic surgery to obtain a brief introduction into the specialty and provide references for further reading. It is not designed to be a comprehensive text, but rather an outline that can be read in the limited time available in a burgeoning curriculum. It is designed to be read from beginning to end. ASPS is proud to provide complimentary online copies of the *Plastic Surgery Essentials for Students* handbook to all medical students in the United States and Canada.

Continually updated information that relates to plastic and reconstructive surgery and other information of use to students and other physicians can be found at both the main ASPS website at *www.plasticsurgery.org* and the ASPS Education Network website at *ednet.plasticsurgery.org.*

Chapter 2
Careers in Plastic Surgery

Jessie Kolkonen, MD
Kate Krucoff, MD

Plastic and reconstructive surgery is one of the most diverse specialties within the field of medicine. Unlike many other fields, plastic surgery is not confined to a single organ system, region of the body, or patient population. The Greek term "plastikos" means to mold or to shape. By reshaping, remolding, and manipulating both soft and hard tissues, plastic and reconstructive surgeons help patients with a myriad of issues. The goal of our specialty is to restore form and function while adhering to aesthetic principles.

The first known plastic surgery procedures on living patients date back to 600 BCE, when the Indian surgeon, Sushruta, offered reconstruction to patients whose noses had been surgically removed as a form of punishment. As early as 100 BCE, the Romans began performing procedures to improve self-image and cosmetic appearance. Since then, plastic surgery has become integral to the treatment of patients requiring reconstruction due to trauma, burns, scarring, cancer, infection, and more. Rather than treating specific conditions with a limited set of procedures, plastic surgeons use skills and principles based on anatomy, physiology, and tissue transfer when managing patients, from head to toe.

The plastic surgeon must use his or her foundational knowledge of plastic surgical principles, judgment, problem-solving abilities, and surgical technique in order to approach the reconstructive needs of the patient. Because of this, the plastic surgeon often acts as a "last resort" surgical consultant to other physicians in the treatment of many wound problems and is often called "the surgeon's surgeon."

While plastic surgeons may offer life-saving procedures in many situations, our specialty also plays a key role in quality-of-life improvement for patients. Plastic surgery not only restores body function but also helps to renew or improve a patient's body image and sense of self-esteem.

Consistent with these far-reaching goals, the scope of the operations performed by plastic surgeons is broad. As outlined by The American Board of Plastic Surgery (ABPS), the specialty of plastic surgery "deals with the repair, reconstruction, or replacement of physical defects of form or function involving the skin, musculoskeletal system, craniomaxillofacial structures, hand, extremities, breast and trunk, external genitalia, or cosmetic enhancement of these areas of the body." Plastic surgeons use aesthetic surgical principles not only to improve undesirable qualities of normal structures, but also to reinstate "normal" in reconstructive cases. One of the most common procedures in reconstructive plastic surgery is reconstruction of the breast following mastectomy. Breasts may be reduced in size, increased in size, or changed in shape to improve the final aesthetic appearance. Operations of this type are sometimes cosmetic in purpose, but in cases where the patient has a significant asymmetry or surgical defect, the procedure serves important therapeutic purposes.

Microvascular surgery is an important subspecialty within plastic surgery. This involves performing delicate procedures connecting small blood vessels – often several millimeters or less in diameter – to provide a blood supply to tissue used to reconstruct a defect. Using microsurgical techniques, tissue can be moved from one part of the body to another. This is an important option for patients suffering from defects secondary to trauma or cancer resection.

Another area of expertise for the plastic surgeon is hand surgery, including the management of acute hand injuries, the correction of hand deformities, and reconstruction of the hand. This includes injuries or congenital anomalies to the skin, soft tissues, muscles, tendons, bones, nerves, and blood vessels of the hand and fingers. Microsurgery is also a necessary skill in hand surgery, often used while replanting amputated fingers or even entire limbs.

The subspecialty of craniofacial surgery involves correcting both congenital and acquired deformities of the head, neck, face, and skull. Clefts of the lip and palate are the most common, but many other head and neck congenital deformities exist. In addition, the plastic surgeon treats injuries to the face, including fractures of the craniofacial skeleton. Craniofacial surgery can help to reposition and reshape the bones of the face and skull through inconspicuous incisions. Severe deformities of the cranium and face, which previously were uncorrectable or corrected with great difficulty, can now be reconstructed. Such deformities may result from a tumor resection, congenital defect, previous surgery, or previous injury.

The most highly visible area of plastic surgery is aesthetic or cosmetic surgery. Aesthetic surgery includes facelifts, breast augmentations, nasal surgery, body sculpting, and other similar operations to enhance one's appearance. The plastic surgeon takes pride in utilizing his or her precise technical and artistic skills to enhance patient quality of life through aesthetic procedures. Notably, the results of the plastic surgeon's expertise and ability are highly visible, leading to a high degree of professional and personal satisfaction.

Plastic surgery is an innovative specialty. Advances such as transplantation, microvascular surgery, fat grafting, and various medical devices have been spearheaded and advanced by plastic surgeons. Ultimately, the discipline requires meticulous attention to detail, sound judgment, and technical expertise in performing the intricate and complex procedures associated with plastic surgery. In addition, plastic surgeons must possess a flexible and adaptable approach that will enable them to work daily with a wide variety of surgical problems. Most importantly, the plastic surgeon must have creativity, curiosity, insight, and a deep understanding of human psychology.

Students interested in a career in plastic and reconstructive surgery would benefit from rotating on their institution's plastic surgery service to gain experience in, and exposure to, the field. In addition, finding a mentor within the field to help guide one's development, decision-making, and to answer questions is advised.

The pathway to a career in plastic surgery can follow in one of two ways. The first is through an integrated plastic surgery residency program which starts after medical school. Programs are six years in duration; however, several programs also dedicate one or more years to research. The other route, known as the independent route, is to complete a residency in general surgery, otolaryngology, urology, orthopedic surgery, or neurosurgery followed by an additional three-year independent plastic surgery residency. After the completion of either the integrated or independent pathway, one is eligible to sit for the plastic surgery board examination. In addition, one can attain further training in a plastic surgery fellowship program. Fellowships are typically one year in duration and are offered for specialty training in hand surgery, craniofacial surgery, microsurgery, aesthetic surgery, body contouring surgery, and burn surgery. Newer fellowships in peripheral nerve surgery and gender-affirming surgery have also emerged in recent years.

Traditionally, plastic surgeons have established their practices in large urban settings. However, there is an increasing need for plastic surgeons in smaller communities and rural areas of the country—many metropolitan areas with populations of 65,000 to 268,000 have no plastic surgeons. There are approximately 7,750 board certified plastic surgeons in the United States; many of those currently certified by the ABPS received certification in the past 10 years. There are opportunities for plastic surgeons in private, hospital-based, and academic practices.

Plastic surgeons also have numerous opportunities to use their skills to improve global health. Plastic surgeons can perform direct patient care through short-term missions where they can help treat a wide variety of conditions including congenital birth defects, burns, and traumatic deformities. Plastic surgeons can also contribute to global health through long-term commitments involving the education and training of local surgeons in addition to performing research on issues affecting countries with limited resources.

Plastic surgery is a specialty that dates back thousands of years. It has survived and flourished because it is a changing specialty built by imaginative, creative and innovative surgeons with a broad background and education. The future of this specialty is bright and will continue to progress because of students like you who choose to enter this special field.

Students interested in plastic surgery can find more information from the following:

I. Nagarkar P, Pulikkottil B, Patel A, Rohrich R. So, you want to be a plastic surgeon? What you need to do and know to get into a plastic surgery residency. *Plast Reconstr Surg.* 2013;131(2):19-22.

II. The American Council of Educators in Plastic Surgery (ACEPS)
aceplasticsurgeons.org

III. American Society of Plastic Surgeons
plasticsurgery.org
facebook.com/PlasticSurgeryASPS

IV. Plastic Surgery Education Network
plasticsurgery.org/for-medical-professionals/education/asps-education-network

V. Plastic Surgery Research Council
ps-rc.org

Chapter 3
History of Plastic Surgery

Yasmeen Byrnes, MD
Rajendra Sawh-Martinez, MHS, MD

"We restore, rebuild, and make whole those parts which nature hath given, but which fortune has taken away. Not so much that it may delight the eye, but that it might buoy up the spirit, and help the mind of the afflicted."

Gaspare Tagliacozzi (1545-1597)

The origins of plastic surgery as a distinct field follows the history of scientific advancements, influenced by the scourge of need from social influences and wartime atrocities. Key historical figures and milestones are described in the long and illustrious history of the development of the modern innovative field of plastic surgery.

PLASTIC SURGERY ORIGINS IN ANTIQUITY

- The term "plastic" in plastic surgery comes from the Greek "plastikos" which translates to "moldable"
- Ancient plastic surgery has its origins in the management of wounds, with historical reference to sewing wound edges with fibers or wound edges approximated with insect mandibles
- References in the Edwin Smyth Papyrus (~3000 to 2500 BC) to plastic surgery cases include descriptions of treating fractures, wounds, dislocations, sores and tumors
    - Early wound healing remedies included use of grease, honey, linen and swabs
- The first semblance to modern reconstruction is found in India with nasal reconstruction
    - Ancient cultures often punished adulterers, thieves and prisoners of war by mutilating their noses as a way of public shaming
    - Famed Indian surgeon Sushruta wrote in the Ayurvedam (Indian sacred book of medical knowledge) descriptions of transposed flaps for nasal reconstruction (~600 BC)
    - He is often credited with descriptions of the first forehead flap for nasal reconstruction, but this is controversial and unknown as the first published report of the forehead flap appears to be in 1794 (Fig. 1)

Figure 1. Depiction of the first reports of the forehead flap for nasal reconstruction. *From BL. Letter to the editor. Gentleman's Magazine 1794;64:891–892.*

- Greek medical influence is grounded in the writings of Hippocrates in the Corpus Hippocraticum (~460 BC) where descriptions of cauterization of raw surfaces, reduction of displaced fractures and trephination for hematoma evacuation are described
- Roman influence in plastic surgery can be found in the famous volumes De Medicina (~30AD) by Aulus Cornelius Celsus with descriptions of vessel ligature, lip flap reconstruction and wound closure by an advancement flap
- Writings by Claudius Galen (~129-201 AD) are famed for their intricate anatomical descriptions of muscles and cranial nerves

PLASTIC SURGERY IN THE MIDDLE AGES

- Series of medical texts written by Oribasius (325-403 AD) titled *Synagogae Medicae* describe reconstructive procedures aimed at rebuilding the cheek, nose, ears and eyebrows
- The middle ages brought about the first independent surgical treatise in the form of *Al Tasrif – On Surgery*, written by Abu-l-Qasim or Albucasis (~936-1013 AD) in which surgical instruments, cautery, and the first description of a syringe with a piston was given
- This time period also brought about the advent of Western universities, which introduced anatomical classes and cadaver dissections, and anatomists as surgeons
- The advent of the printing press (1440 AD) also allowed for the widespread dissemination of medical texts and exchange of ideas

PLASTIC SURGERY AND THE RENAISSANCE

- Andreas Vesalius published his anatomical treatise *De Humani Corporis Fabrica* (1543)
- French surgeon Ambrose Pare (1510-1590) compiled his works in *Les Oeuvers*, in which cleft lip and cleft palate repairs are described, in addition to disputing the practice of "wound cleansing" by hot cautery and pouring boiling oil into wounds
- Gaspare Tagliacozzi (1544-1599) is widely considered the founder of plastic surgery as a distinct discipline
    - He is credited with systematizing surgical approaches to nasal reconstruction
    - His book *De Curtorum Chirurgia per Insitionem (On the Surgery of Injuries by Grafting)* in 1597 provided step-by-step guidance and illustration to perform nasal repairs (Fig. 2)
- After these landmark achievements, there were limited new advances until the 19th century

Figure 2. Nasal reconstruction with the arm flap. *From Tagliacozzi G. De Curtorum Chirurgia per Insitionem. Venice: Bindoni, 1597.*

GOLDEN AGE OF PLASTIC SURGERY

- English surgeon Joseph Carpue composed a letter to the editor in 1794 that first described the forehead flap
    - His successful use of this procedure in 1814 marked the rebirth of plastic surgery
- Multiple surgeons throughout Europe compared and advanced techniques in rhinoplasty, facial reconstruction, cleft lip and cleft palate repairs including key surgeons such as Carl von Grafe (1787-1840), Johann Dieffenbach (1794-1847) in Germany, and Jacque Delpech (1777-1832) in France
- The advent of anesthesia in 1846 introduced new capabilities for all surgical fields and allowed for the blossoming of the golden age of plastic surgery

- Key achievements in the golden age of plastic surgery:
    - Giuseppe Baronio (1758-1811) from Italy first described the use of autologous skin grafting in 1804
    - First attempts at closing cleft palate defects were performed by Roux and Von Grafe in France in 1819 and 1820, respectively
    - Pietro Sabattini described lip reconstruction with the "lip switch" technique in 1838 (Fig. 3)
    - Bernhard Von Langenbeck (1810-1887) outlined two mucoperichondrial flaps for cleft palate closure in 1862

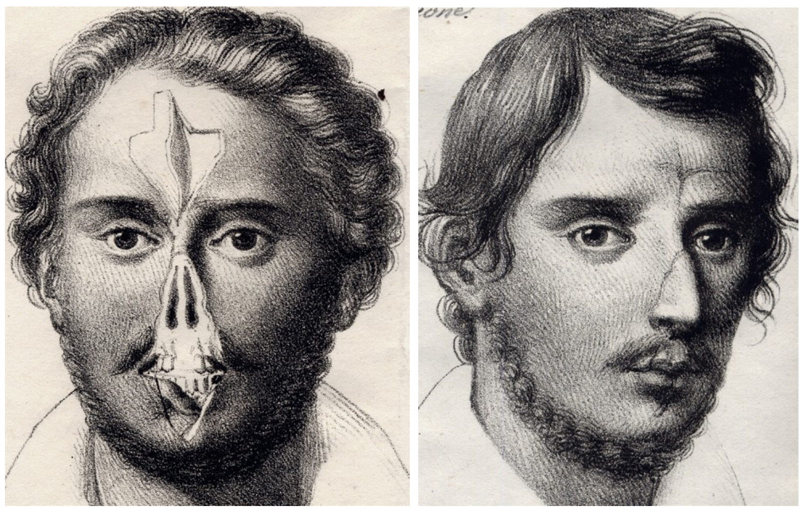

Figure 3. Lip switch technique described by Sabattini (1838).

KEY FIGURES AND ACHIEVEMENTS IN MODERN PLASTIC SURGERY

- World War I created a tremendous amount of disfigured casualties with devastating reconstructive challenges, which catalyzed the formation of our modern conceptualization of plastic surgeons as specialists focused on restoring bodies ravaged by war
    - Hippolyte Morestin (1868-1919) and Charles Valadier (1873-1931) worked together, pioneering facial reconstructive surgery
    - Sir Harold Gilles (1882-1960): father of the modern era of plastic surgery, developed a referral center in Europe for casualties of facial disfigurement
        - Developed and systematically applied flap reconstructions of facial injuries
            - Employed the tubed flap and skin flaps; bone, cartilage and skin grafts
        - Published landmark text *Plastic Surgery of the Face* (1920)
    - Between 1916 and 1918, Johannes Esser (1877-1946) reported on local flaps commonly used today: cheek rotation, bilobed, island, and "arterialized" flaps
- Training programs and organizations dedicated to plastic surgery began developing after World War I, and spread throughout Europe and North America
    - 1931: the American Society of Plastic Surgeons was founded by Jacques Maliniac
    - 1937: the American Board of Plastic Surgery was created
    - 1946: the Plastic and Reconstructive Surgery Journal was founded
    - 1948: the Plastic Surgery Foundation was established
- Since the 1960s, new discoveries have brought about a new wave of reconstructive options including modern craniofacial approaches, microsurgical techniques, and more
- In the era of modern plastic surgery, subfields began to develop; landmark achievements occurred within multiple areas
    - Breast and aesthetic surgery:
        - The field of aesthetic surgery was initiated with the description of the correction of prominent ears in 1881 by Edward Ely

  - John Roe (1848-1915), Robert Weir (1838-1927), Jacques Joseph (1865-1934) were early pioneers in rhinoplasty
  - Czerny is credited with performing the first breast augmentation using a lipoma in 1895
  - In the following decades, various substances were used unsuccessfully for breast augmentation including rudimentary injectables and plastic sponges, until the invention of silicone breast implants in the early 1960s by Cronin and Gerow
- Craniofacial surgery:
  - Paul Tessier (1917-2008) is hailed as the father of modern craniofacial surgery, and developed a revolutionary combination of intra- and extra-cranial approaches for complex cranial deformities
  - René Le Fort (1869-1951) was a French military surgeon whose cadaver studies led to crucial discoveries in facial bony anatomy and trauma
- Flaps and microsurgery:
  - Jacobson and Suarez performed the first microvascular anastomosis with an operating microscope in 1960 (Fig. 4)
  - Harry Buncke is recognized as the “father of microsurgery” for his critical role in developing the field, including device innovation and multiple successful animal studies
  - Angiosome concept by Taylor and Palmer in 1987 led to the development of perforator flaps (Fig. 5)

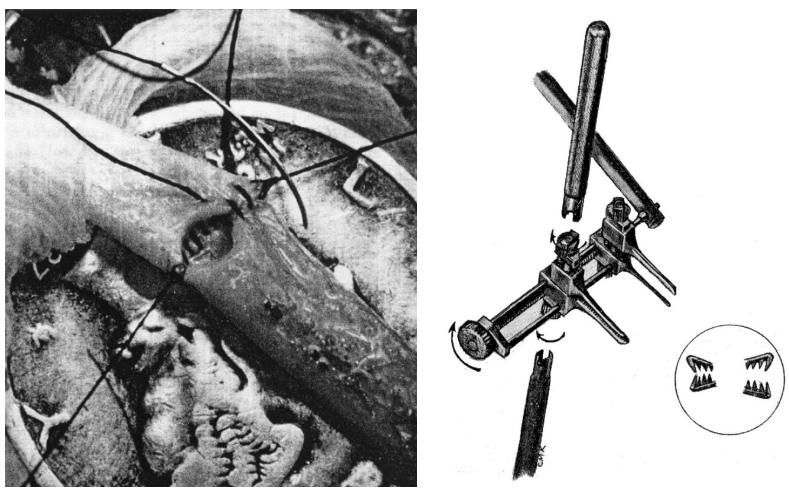

Figure 4. (Left) Arterial anastomosis with 7-0 silk by Jacobson. (Right) Early version of a microvascular double clamp. *From Tamai S. History of microsurgery. Plast Reconstr Surg. 2009 Dec;124(6 Suppl):e282-e294.*

- Hand and extremity:
  - Malt and McKhann are credited with the first human extremity replantation (arm) in 1962, followed soon after by Kleinert and Kasdan (incompletely amputated thumb), and Chen (hand)
  - The first modern peripheral nerve surgeries were developed alongside microsurgery by pioneers including Smith, Bora, Haksitan, and Ito
- Gender affirmation:
  - The earliest reports of “sex reassignment surgery” (as it was called at the time) were from Europe in the early 1900s
  - In 1952, American veteran Christine Jorgenson, formerly known as George Jorgenson, underwent gender affirmation surgery in Denmark; her case drew international attention
  - Intestinal vaginoplasty was invented in 1974 and free radial forearm flap phalloplasty in 1982

1837	Horner	Z-plasty principle
1848	Stein	Bilateral upper lip vascular pedicle flaps to the lower lip
1872	Estlander	Repair of lateral defects of the lower lip using lateral upper lip and corner of the mouth on a labial artery pedicle
1889	Manchot	Definition of vascular patterns of cutaneous circulation by dissection
1898	Halsted	"Waltzing" flaps
1898	Abbe	Bilateral cleft lip reconstruction with cross-lip flaps
1906	Tansini	Latissimus dorsi musculocutaneous flap for breast reconstruction
1912	Blair	Osseocutaneous flap
1916	Filatov	Tubed pedicle neck flap for lower eyelid reconstruction
1917	Gillies	Tubed pedicle neck flaps
1917	Aymand	Tubed pedicle chest flap for nasal reconstruction
1917	Ganzer	Tubed pedicle flaps from the cheek, shoulder, and back for nasal reconstruction
1919	Davis	First published observations on pedicle flap principles; reviewed Manchot's work on vascular territories; described compound flaps for mandibular reconstruction
1921	Blair	Delay phenomenon in nonpedicle flaps
1937	Webster	Thoracoepigastric tubed pedicles
1942	Converse &	Median forehead flap
1946	Kazanjian	
1946	Shaw & Payne	Hypogastric tubed pedicle flaps
1955	Owens	Compound sternocleidomastoid muscle-skin flap
1960	Littler	Neurovascular flap
1965	Bakamjian	Deltopectoral flap
1968	Ger	Muscle flap
1972	McGregor & Jackson	Groin flap
1973	Daniel, Taylor, O'Brien, Harii	Microvascular free flap transfers
1975	McCraw & Furlow	Dorsalis pedis flap
1976	Radovan	Tissue expansion for breast reconstruction
1977	McCraw	Description of numerous independent musculocutaneous vascular territories and musculocutaneous flaps
1977	Mathes	Rectus abdominis flap
1981	Nakayama	Arterialized venous flaps
1981	Ponten	Fasciocutaneous flaps
1987	Taylor & Palmer	Angiosomes

Figure 5. History of flap development.

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Chapter 4
Techniques and Principles

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Plastic surgery is a specialty defined by principles and techniques, rather than by organ system or disease process. Plastic surgeries are generally divided into two types of surgical procedures — reconstructive and cosmetic. While the dividing line between the two is sometimes very clear, there is often a significant amount of overlap. The goal of reconstructive surgery highlights this overlap: "the restoration of *form* and function." Both reconstructive and aesthetic surgery rely on a detailed knowledge of anatomy and the foundational principles and techniques outlined below.

EVALUATION AND PLANNING

- Define the defect
    - What is missing or abnormal?
        - Tissue layers
        - Critical exposed structures or hardware?
- Disruption of vascular or neural network
- What is left behind and what can be used?
- Is the surrounding tissue healthy, or has it been compromised (i.e., radiation therapy, burns, traumatic injury)?
- What is the best way to restore form and function?
    - What works for the patient and their lifestyle?
- Replace like with like: the best reconstruction will utilize tissues similar to the missing tissues (i.e., glabrous skin for reconstruction of the weight-bearing sole or fingertips)
- "Don't throw anything away"
    - Spare parts surgery
    - Composite grafts
    - Biological dressings
- Designing incisions: Incision design is critical, as the location of scars impacts both their visibility as well as their ability to heal.
    - Ideal incision placement
        - Langer's lines: Langer, a 19th-century anatomy professor in Vienna, first studied and described the relationship between resting skin tension and wounds. However, his studies were carried out on cadavers and were never intended to serve as a guide for surgical technique.
        - Borges described relaxed skin tension lines in 1962
            - Lines follow the furrows formed when skin is relaxed and are revealed by pinching the skin (Fig. 1)
            - Relaxed skin tension lines are perpendicular to lines of maximum extensibility and reduces tension on the closure
        - Best incision designs usually involve a combination of factors
            - Allowing for appropriate access
            - Taking advantage of pre-existent scars or wrinkles
            - Placement with respect to aesthetic subunits
            - Reducing tension on closure
    - Aesthetic units and subunits (Fig. 2)
        - Have been described for multiple anatomic regions, including breast, face, and lower extremity
        - Defined by naturally-occurring concave and convex surfaces

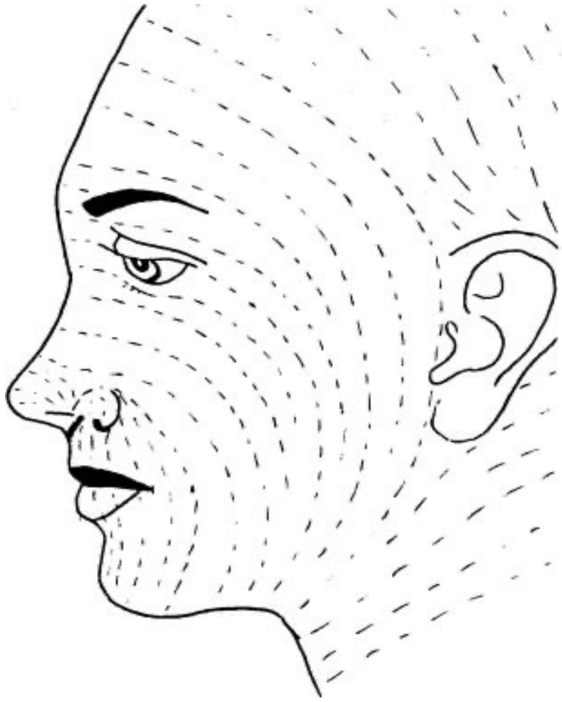

Figure 1. Relaxed skin tension lines (RSTL) versus other skin lines. *From Borges A. Relaxed skin tension lines (RSTL) versus other skin lines. Plast Reconstr Surg. 1984;73(1):144-50.*

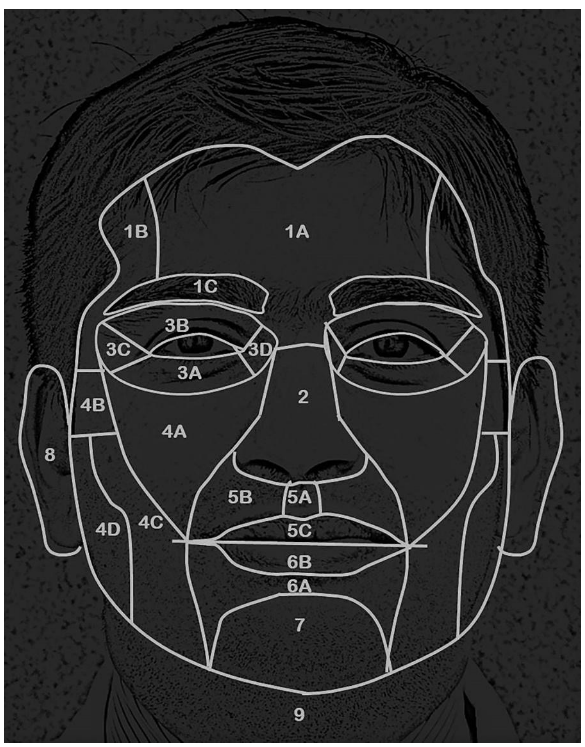

Figure 2. Aesthetic units and subunits of the face. 1, forehead unit (1A, central subunit; 1B, lateral subunit; 1C, eyebrow subunit); 2, nasal unit; 3, eyelid units (3A, lower lid unit; 3B, upper lid unit; 3C, lateral canthal subunit; 3D, medical canthal subunit); 4, cheek unit (4A, medial subunit; 4B, zygomatic subunit; 4C, buccal subunit; 4D, lateral subunit); 5, upper lip unit (5A, philtrum subunit; 5B, lateral subunit; 5C, mucosal subunit); 6, lower lip unit (6A, central subunit; 6B, mucosal subunit); 7, mental unit; 8, auricular unit; 9, neck unit. *From Sabapathy R, et al. Postburn Reconstruction of the Face and Neck. Plast Reconstr Surg, 2022;150(6).*

        - Scars that cross aesthetic subunits are more noticeable than those that are hidden in the boundaries between subunits
- Methods of excision
    - Elliptical
        - Most common method
        - Usually designed with length: width ratio of 3:1
    - Wedge
        - Used for lesions located at or near a free tissue margin

- Circular
    - May be utilized when shorter scar is desired
- Serial
    - For large lesions which cannot be excised in one stage (i.e. congenital nevi)
    - Frequently used in conjunction with tissue expansion

THE RECONSTRUCTIVE LADDER

- Conceptual framework for understanding reconstructive options (Fig. 3)
    - Starts with most simple option (i.e., healing by secondary intention)
    - Progresses to more complex options in a step-wise fashion

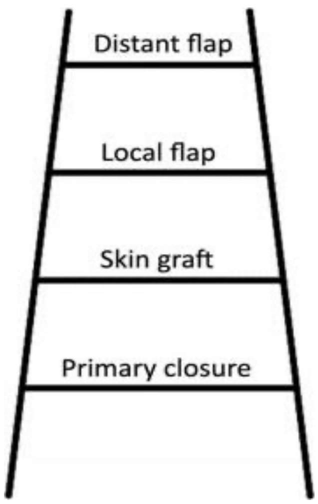

Figure 3. An early version of the reconstructive ladder. *From Janis J, et al. The new reconstructive ladder: modifications to the traditional model. Plast Reconstr Surg. 2011 Jan;127 Suppl:205S-212S.*

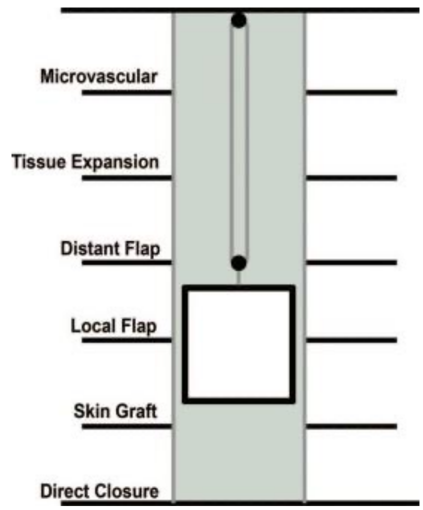

Figure 4. The reconstructive elevator, as proposed by Gottlieb and Krieger. This formulation emphasizes the importance of selecting the most appropriate level of reconstruction as opposed to defaulting to the least complex. *From Gottlieb L, et al. From the reconstructive ladder to the reconstructive elevator. Plast Reconstr Surg. 1994;93:1503-1504.*

- The “reconstructive elevator” (Fig. 4)
    - Proposed by Gottlieb and Krieger in 1994
    - Best reconstructive option is not always the least complex
        - Consider other factors: radiated tissue, possible cancer recurrence, hardware or implants present, complex or high-risk areas, need to plan for back-up options

PRINCIPLES OF SUTURING

- Layered closure: any wound deeper than skin should be closed in layers
    - Eliminate dead space
    - Prevent dehiscence while wound healing is occurring
    - Precisely approximate skin edges without tension
- Wound edge eversion
    - Takes advantage of scar contraction
    - Allows for optimal wound healing
- Choosing suture
    - Permanent versus absorbable
    - Monofilament versus multifilament
    - Suture size

- Needle type
    - Cutting
    - Taper
  - Surgical glue
  - Staples
- Timing of suture removal
  - Sutures should be removed from face within 5-7 days
  - Sutures in other anatomic areas should be removed within 7-14 days
  - Exceptions include wounds that cross joints, wounds that are under significant tension, wounds in irradiated or otherwise damaged surgical fields

SUTURING TECHNIQUE

- Simple interrupted sutures: most commonly used suture technique (Fig. 5a)
  - Needle enters epidermis at 90-degree angle
  - Needle turned to exit immediately below deep dermis
  - Care must be taken to enter and exit at same levels on opposite side
- Running simple sutures
  - Rely on well-approximated wound edges
  - Not as precise as interrupted sutures, but faster
- Subcuticular sutures
  - Needle passed horizontally through the superficial dermis, parallel to skin surface
  - Can be running or interrupted
  - Allows close approximation of skin edges without need for external skin sutures
- Horizontal mattress sutures (Fig. 5b)
  - Everting sutures that spread tension across a wound edge
  - Needle passed across the wound and then back the other way
  - Useful in fragile tissue
  - Also useful in suturing glabrous skin of hands/feet
  - Can be performed as a running suture
- Vertical mattress sutures (Fig. 5c)
  - Used for increased wound eversion
  - Far-far near-near suture placement

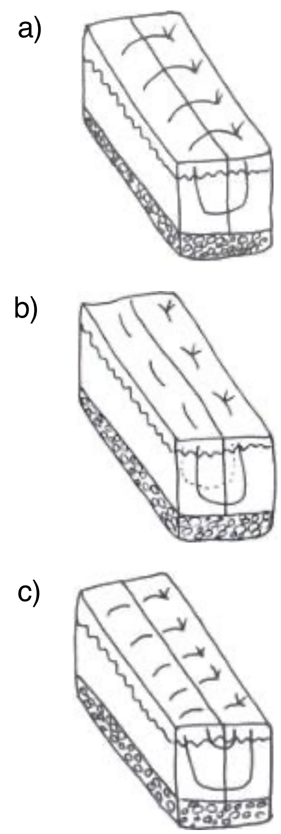

Figure 5. a) Simple interrupted.
b) Horizontal mattress. c) Vertical mattress.

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Chapter 5
Wounds

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A wound can be defined as any disruption of the integrity of living tissues. A wound can occur due to various causes such as trauma, thermal injury, ischemia, infection, and other miscellaneous etiologies.

WOUND CLASSIFICATION

- Wounds can be broadly classified in multiple ways
- Etiology: traumatic, infectious, ischemic, thermal, pressure, neuropathic and surgical wounds
- Time to heal:
  - Acute wound (<4-6 weeks)
  - Chronic wounds (>4-6 weeks)
    - Further classified into three major categories: vascular (arterial or venous) ulcers, diabetic ulcers, and pressure ulcers
- Skin integrity:
  - Open wounds: skin integrity was broken
  - Closed wounds: skin remains intact, but the underlying tissue is damaged
- Depth of wound:
  - Superficial: only involves the epidermis
  - Partial thickness: involves epidermis and part of the dermis
  - Full thickness wound: entire thickness of skin and deeper structures
- Surgical wounds are classified based on contamination:
  - Clean wound: uninfected surgical wounds with no inflammation or involvement of the respiratory, gastrointestinal, or genitourinary tracts
  - Clean contaminated: clean wounds with a slightly increased risk of infection, such as those involving the respiratory, gastrointestinal, or genitourinary tracts
  - Contaminated wounds: visible contamination, such as spillage from the gastrointestinal tract or a break in sterile technique.
  - Dirty/infected wound: infection, abscess

STAGES OF WOUND HEALING

Wound healing is a complex, highly regulated, dynamic process involving three phases: inflammation, fibroblast proliferation, and remodeling. Wounds may progress or even regress through these stages based on local and systemic factors. It is imperative to have a proper understanding of the wound type, etiology, chronicity, and patient health status to provide appropriate treatment.

I. Inflammatory phase (immediately to 2-5 days)

- The functional priorities during this phase of wound healing are attainment of hemostasis, removal of devitalized tissues, and prevention of colonization and invasive infection by microbial pathogens, principally bacteria
- Following injury, vasoconstriction and coagulation occur by activation of the clotting cascade and platelets; this creates a provisional matrix to provide a scaffold
- Cytokines (TGF-β, IL-1β) are released, causing vasodilation and increased permeability, to promote chemotaxis and cell migration into the wound bed
- Neutrophils respond first in 24-48 hours to the site to remove dead tissue by phagocytosis and clear infection
- Macrophages (most critical for wound healing) follow neutrophils in 48-72 hours, then by lymphocytes in 5-7 days post-injury, all playing a vital role in wound healing

II. **Proliferative phase** (days 4-21)

- Mainly encompasses epithelialization, angiogenesis, granulation tissue formation, and collagen deposition
- If basement membrane is intact in the wound, epithelial progenitor cells in skin appendages and deeper layers restore epidermis in 2 to 3 days
- If the basement membrane has been destroyed:
  - Epithelial proliferation and migration: epithelial cells located on the skin edge begin proliferating and sending out projections to re-establish a protective barrier
  - Neoangiogenesis: angiogenic factors activate endothelial cells, causing sprouting of capillaries and new vasculature formation in the scaffold
  - Granular tissue formation and collagen deposition
    - Fibroblasts migrate into the wound bed and proliferate
    - Fibroblast synthesis of immature type III collagen tissue, which rapidly gains tensile strength in the wound

III. **Remodeling phase** (3 weeks-1 year)

- Immature type III collagen is replaced by mature, organized, type I collagen and wound contraction occurs through the actions of myofibroblasts
- Extracellular matrix and subsequent scar is organized largely in response to mechanical tension, inflammation, and genetic phenotype
- Scar strength gradually increases over time
  - Strength is 3% of final strength at 1 week, 30% at 3 weeks, 80% at 3 months
- Scar maturation requires approximately 9-12 months in an adult, longer in children
- Scar revisions may be delayed a year or longer after injury to ensure remodeling is complete

FACTORS INFLUENCING WOUND HEALING

- Local factors
  - Fluid collection: hematoma or seroma
  - Premature wound closure
  - Blood supply
  - Temperature
  - Infection
  - Technique (gentle handling of tissues, orienting incisions or closures along optimal vectors to disperse mechanical tension) and ideal suture materials
  - Timing between injury to closure
  - Mechanical tension
  - Location on body
  - Presence of foreign body
  - History of radiation
- Systemic factors
  - Age
  - Nutrition
  - Nicotine use
  - Chronic illness (diabetes, hypothyroidism, vascular disease, neuropathy)
  - Genetic conditions predisposing to poor wound healing (e.g., collagen, vascular disorders)
  - Medications that interfere with wound healing (chemotherapy, steroids, etc.)

WOUND CLOSURE

Several surgical principles are important to keep in mind to expedite wound healing and reduce the incidence of hypertrophic or pathologic scarring. Approaches to wounds should always include adequate debridement (removal of any nonviable tissue and foreign bodies), bacteriologic control, and optimization of systemic factors governing wound healing.

- Healing by primary intention: wound closure by direct approximation, pedicled/free flap, or skin graft
    - Debride necrotic or nonviable tissue and irrigate copiously to expedite inflammatory phase
    - Dermis should be accurately approximated; wound edges should be aligned at the same depth to prevent overlapping or gapping
        - Skin glue may be used if the wound is limited to partial thickness depth
    - Scar may be red, raised, or pruritic at peak of collagen synthesis (approximately 6 weeks after closure)
- Healing by secondary intention: wound is left open to heal
    - Myofibroblasts promote contraction of wound edges
    - Epithelialization proceeds from wound margins towards center at 1 mm/day under ideal circumstances
    - Secondary healing is beneficial in heavily contaminated or "dirty" wounds (e.g., abscess drainage site), or wounds in areas that have excellent vascular supply (e.g., scalp)
    - Can often provide a more aesthetic or less obvious scar in the right setting
- Healing by tertiary intention: delayed wound closure after several days
    - Intentional interruption of healing started as secondary intention
    - May proceed any time after granulation tissue has formed in the wound
    - Delayed closure should be performed when the wound is not infected
        - In previously infected wounds, quantitative culture should demonstrate <100 CFU bacteria/gram of tissue
    - Skin grafting may be considered in larger wounds for definitive closure after adequate debridement with a well-vascularized wound bed

MANAGEMENT OF THE CLEAN WOUND

- Aim to obtain a closed wound as soon as possible to prevent infection, fibrosis, secondary deformity
- General principles:
    - Updated tetanus vaccine: administer if not within 10 years of booster for clean minor wounds or within 5 years for contaminated wounds
    - Local anesthesia:
        - Lidocaine with epinephrine preferred due to fast onset, longer anesthetic time, and improved hemostasis
        - Literature shows epinephrine is safe to use in digits, nose, penis, etc., unless area is already vascularly compromised
    - Tourniquets may help provide bloodless fields in digits/extremities
    - Surgical prep:
        - Aqueous-based:
            - Povidone-iodine: one of the few products that is widely effective and safe on nearly all skin and mucosal surfaces; must be diluted 1:1 with normal saline when used around the eyes; must be allowed to dry for full bactericidal effect
            - Chlorhexidine gluconate (CHG): more sustained antimicrobial activity and more resistant to neutralization by blood products than iodine
                - Contraindicated on genitalia, mucosal surfaces, and open wounds
            - Alcohol-based:
                - Ethyl and isopropyl alcohol: quick, sustained, durable, with broader spectrum antimicrobial activity
                - When used alone, fast and short acting, has broad-spectrum antimicrobial activity, and is inexpensive; can also be combined with iodine or CHG
                - Highly flammable
                - Contraindicated on genitalia, mucosal surfaces, and open wounds
    - Debridement and irrigation: remove clot, debris, foreign bodies, and necrotic tissue; copious irrigation to remove debris and decrease bacterial inoculum

- Closure: approximate dermis as atraumatically as possible, consider undermining of wound edges to relieve tension
- Dressing: must provide absorption, protection, immobilization, even compression, ideally without interfering with function

- Types of wounds and their treatment
  - Superficial abrasions: cleanse to remove foreign material and apply moist dressings or ointments to provide moist environment for re-establishment of epidermis
    - Remove gross debris buried in dermis within 24 hours of injury to prevent infection, prolonged inflammation, and traumatic tattoos
  - Contusion: evacuate soft tissue hematoma if a fluctuant, organized collection is present or if pressure of hematoma is compromising surrounding tissue (ears, nailbed, nasal septum, etc.)
    - Early: minimize by cooling with ice (24-48 hours)
    - Later: warm compresses helpful to speed reabsorption of blood
  - Laceration: revise and trim wound edges as necessary, debride, and reapproximate wound edges with sutures or surgical glue; may require multiple layers of closure depending on depth of wound and structures involved
  - Avulsion:
    - Partial: revise and suture the soft tissue flap if viable
    - Total: avulsed tissue may be irrigated, cleansed, defatted, and applied as a full thickness skin graft
  - Puncture wound: evaluate underlying damage, possibly explore wound for foreign body, and obtain X-ray if appropriate
    - If small, consider leaving open or partially open to promote egress of drainage
  - Bullet wounds: considered clean wounds that require local wound care and healing by secondary intention
  - Animal bites: debride, irrigate, and close primarily or leave open, depending upon anatomic location, time since bite, etc.
    - Augmentin is typically a mainstay of antibiotic prophylaxis
    - Consider rabies vaccine, if necessary
  - Wounds of face:
    - Largely develop as result of trauma
    - Important to first obtain a thorough trauma workup and rule out any intracranial injury, airway issues, or other intra-thoracic or abdominal injury
    - The face has reliable and excellent vascular supply, allowing for greater window of opportunity for delayed wound closure
    - Consider serial examination and delayed closure to evaluate extent of necrotic tissue burden before definitive debridement, particularly if “questionably viable” tissue is in the wound bed
    - Re-establishment of symmetry: carefully align anatomic landmarks such as vermilion border, ala, eyelid, eyebrow, helical rim
  - Special wounds:
    - Amputation of parts
      - Place amputated part in saline-soaked gauze in a plastic bag and place the bag on ice; avoid direct contact with ice to prevent thermal injury
      - Ischemia times for replantation are dictated by the amount of muscle in the amputated part
        - Digits: 12 hours of warm and 24 hours of cold ischemia
        - Upper/lower extremities: 6 hours of warm and 12 hours of cold ischemia
    - Cheek injury: may require exploration for parotid duct or facial nerve injury
    - Intraoral injuries: tongue, cheek, palate, and lip wounds require approximation with absorbable suture

        - Eyelids: align grey line and close in layers, keeping suture tails away from cornea and conjunctiva; consider temporary tarsorrhaphy
        - Ear injuries:
            - Auricular hematoma requires incision and drainage and well-molded dressing or sutured bolster to prevent cauliflower ear deformity
            - Through-and-through laceration requires 3-layer closure including cartilage
                - Tapered, non-cutting needles are indicated for cartilage repair to prevent fracturing or cheese-wiring of cartilage
            - Large composite defects must be approached in staged fashion

MANAGEMENT OF THE CONTAMINATED WOUND

- Guidelines for management of contaminated acute wounds:
    - Majority of traumatic wounds may be closed primarily after adequate sharp debridement and copious irrigation
    - Consider healing by secondary intention if:
        - Heavy bacterial inoculum
        - Long time lapse since initial injury
        - Crushed or ischemic tissue (i.e., severely contused or avulsion injury)
        - Prolonged steroid use
    - Antibiotics: systemic antibiotics are only useful if a therapeutic tissue level can be reached within four hours of injury or debridement
    - Wound closure
        - Buried deep dermal sutures should be used to keep wound edge tension to a minimum; limit the amount of foreign material in the wound as much as possible
        - Monofilament sutures are less prone to infection and are recommended in traumatic wounds
        - With regard to deep open abdominal wounds, loss of domain can occur when muscle, fascia, or skin necrose or retract, allowing extrusion of viscera
        - The goal of closure is to recreate lost domain and reestablish function of abdominal wall; may require multiple stages and coordination with general surgery team
- Guidelines for management of contaminated chronic wounds:
    - Debridement and irrigation, may require serial debridement to establish wound stability
    - Other forms of debridement:
        - Wet-to-dry dressings: involves applying moistened gauze to a wound bed, allowing the gauze to dry, and changing the dressings usually twice a day
            - Provides mechanical debridement as the gauze dries and is removed
        - Chemical debridement agents include collagenase, bromelain
    - Systemic antibiotics are of little use, unless patient demonstrates systemic signs of infection
    - Topical antimicrobials
        - Silver sulfadiazine and mafenide acetate ointments
        - Antimicrobial cleansers: acetic acid, hypochlorous acid
    - Biological dressings (allograft, xenograft, etc.)
        - Integra™ (Integra LifeSciences Corporation):
            - Bilayer wound matrix: superficial layer is a semi-permeable silicone membrane that mimics epidermis, deep layer is a collagen-GAG matrix that mimics dermis
            - The silicone layer is peeled off after incorporation of the deep layer
            - Useful for wound coverage over devascularized wound bed with limited immediate reconstructive options (e.g., exposed bone without periosteum)
    - Final closure
        - Often require a flap, skin graft, or delayed flap
        - Debridement helps convert a chronically contaminated wound to an acute clean wound by reducing biofilm

WOUND DRESSINGS

Dressings serve to protect the wound from trauma and to provide an ideal environment for healing. Some dressings provide protection as well as mechanical or chemical debridement.

- Antibacterial ointments
  - Bacitracin, Bacitracin/Neomycin/Polymyxin B, Mupirocin, and mafenide acetate
  - Provide a moist environment conducive to epithelialization
  - Beware of secondary inflammatory reactions that may mimic infection
  - Mupirocin effective against MRSA
  - Mafenide has better penetration of cartilage
  - Prolonged use of mafenide may promote fungal overgrowth
- Silver-based dressing
  - Silver ions disrupt bacterial cell walls and DNA synthesis, inactivate bacterial enzymes
  - Useful in burns
  - Antibacterial activity penetrates the eschar
- Medical grade honey
  - Low pH debrides necrotic tissue and high osmolarity help to reduce edema through osmosis
- Splinting and casting
  - Immobilization decreases shear forces on wounds and may help to promote wound healing
  - Splinting for extended periods of time can lead to stiffness
- Pressure dressings
  - May be useful to obliterate "dead space" or to prevent seroma/hematoma
  - Do not compress flaps too tightly, may compromise vascular supply

NEGATIVE PRESSURE WOUND THERAPY (NPWT)

- Beneficial tool for wounds not amenable to primary closure (large or contaminated wounds) and for allowing increased time between injury and time to closure (such as in wounds requiring coordination of two surgical teams, etc.)
- Technique includes application of foam sponge or gauze to the wound bed, covered with adhesive dressing, applied to a vacuum device that provides constant sub-atmospheric pressure (-50 to -175 mmHg)
  - Sponge should not be applied directly onto blood vessels or other fragile structures, grossly purulent or necrotic wounds, or on denuded bone
  - NPWT may be placed over bilayer matrices (e.g., Integra™, Integra LifeSciences Corporation) to promote ingrowth of granulation tissue and development of a vascularized wound bed
  - NPWT applied over a split thickness skin graft has been proven to increase take of the graft
  - Dressing should be changed every 48-72 hours to assess wound progress and viability of tissue
  - Veraflo™ (3M™, Solventum): NPWT that allows for instillation of solution into wound to help with irrigation and debridement
- Mechanism of action:
  - Maintains moist wound environment and reduces edema
  - Promotes local wound blood flow and angiogenesis, reduces presence of inflammatory mediators, and speeds overall collagen synthesis and rate of wound closure by offloading mechanical tension on wound
- Advantages: can be used as adjunct to serve as bolster for skin grafts, provides exudative management for draining wounds, and shortens time needed to create favorable wound bed
  - Wound care regimen is less frequent, making NPWT ideal for more cumbersome or extensive wounds that would otherwise require multiple daily dressing changes
- Disadvantages: cost of device, pain or discomfort with dressing changes and peri-wound irritation secondary to adhesive tape

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Chapter 6
Grafts and Flaps

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When a deformity cannot be closed primarily, and secondary healing would be unlikely, too slow, or suboptimal, grafts and flaps are employed to restore normal function and/or anatomy.

GRAFTS

Grafts are harvested from a donor site and transferred to the recipient site without carrying its own blood supply. It relies on new blood vessels from the recipient site bed to be generated (angiogenesis). A graft must have a wound bed of healthy tissue (granulation tissue, muscle, fascia, bone with intact periosteum, tendon with intact paratenon, or cartilage with intact perichondrium) because the graft is dependent on blood supply from the wound.

I. Skin grafts

- Thickness (Fig. 1)
    - Full-thickness skin grafts (FTSGs): consist of entire epidermis and dermis
    - Split-thickness skin grafts (STSGs): consist of epidermis and varying degrees of dermis; can be described as thin, intermediate, or thick (typical intermediate depth STSG is 12/1000 inch in depth)

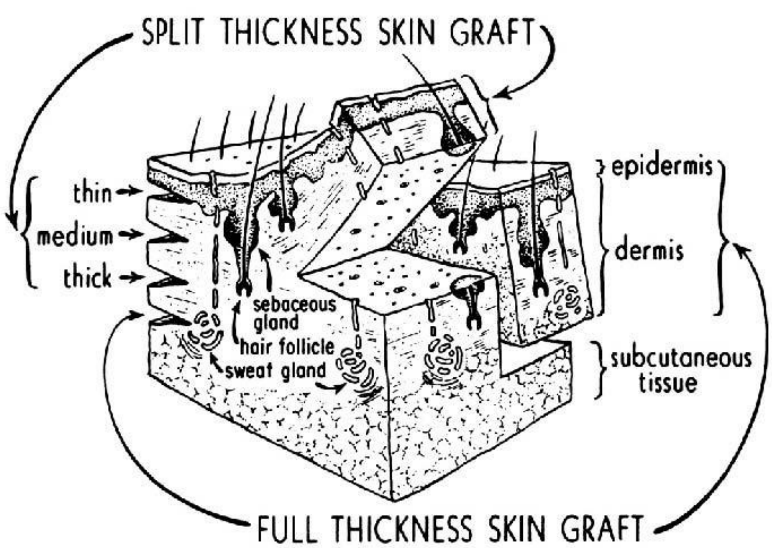

Figure 1. Components of FTSG versus STSG.

- Donor site
    - FTSG leaves behind no epidermal elements in the donor site from which resurfacing can take place
        - Donor site usually closed primarily
        - Must be taken from an area that has skin redundancy
        - Usually harvested with a scalpel between the dermis and the subcutaneous fat
        - After harvest, it can be defatted to thin it out prior to placing on a wound
    - STSG leaves behind adnexal remnants such as hair follicles and sweat glands, foci from which epidermal cells can repopulate and resurface the donor site

        - Typically harvested with a pneumatic or electric dermatome
        - The donor site is usually covered with an occlusive dressing and left to heal secondarily
- Recipient site
    - FTSGs usually used to resurface smaller defects because they are more limited in size
        - Commonly used to resurface defects of the face or hand
        - Provide better color consistency, texture, and undergo less secondary contraction
    - STSGs usually used to resurface larger defects
        - Undergo more secondary contraction as they heal compared to an FTSG
        - Typically darken in color compared to the area from which they were harvested
- Survival
    - FTSGs and STSGs survive by the same mechanism
        - Plasmatic imbibition (first 24-48 hours): initially, the skin graft passively absorbs nutrients from the wound bed by diffusion
        - Inosculation: by day 3, the cut ends of the vessels on the underside of the dermis line up with and begin to form connections to those of the wound bed
        - Angiogenesis: by day 5, new blood vessels grow into the graft and the graft becomes vascularized
    - Skin grafts fail by four main mechanisms:
        - Poor wound bed: because skin grafts rely on the underlying vascularity of the bed, wounds that are poorly vascularized with bare tendon, cartilage, or bone, or are damaged due to radiation or ischemia, will not support a skin graft
            - Synthetic materials cannot be covered by grafts for this reason
        - Shear: shear forces separate the graft from the bed and prevent the contact necessary for revascularization and subsequent “take,” which refers to the process of attachment and revascularization of a skin graft in the donor site
        - Hematoma/seroma: prevent contact of the graft to bed, inhibit revascularization
            - Must be drained by day 3 to ensure “take”
        - Infection: bacteria have proteolytic enzymes that lyse protein bonds needed for revascularization
            - Bacterial levels greater than 10^5 cells/gram of tissue in the wound will cause graft failure
- Skin substitutes: are used for temporary wound coverage, or as a bridge to another form of reconstruction, typically a skin graft
    - Allograft or acellular dermal matrices: cadaveric skin or dermis
    - Xenograft: skin from a different species, such as pigs; provides only temporary coverage
    - Synthetic: products like Integra™ (Integra LifeSciences Corporation), which is collagen/silicone bilayer designed to provide an occlusive environment as granulation forms through the tissue matrix; granulation will then support a skin graft after the silicone is removed

II. Other grafts

- Nerve: most common donor site is the sural nerve
- Fat: can be harvested as a structured graft or as lipoaspirate
- Tendon: common donor sites are the palmaris longus, plantaris, extensor digitorum longus
- Cartilage: common donor sites are the nasal septum, ear conchal bowl, rib
- Bone: common donor sites are the calvarium, iliac crest, tibial tuberosity, rib
- Muscle: typically small, can be harvested from any muscle
- Composite: a graft that has more than one component, i.e., cartilage and skin graft, or a dermal-fat graft

FLAPS

Flaps are tissues transferred with an intact vascular supply to the recipient site. They survive through this blood supply and are not dependent on the wound bed. Flaps can be used when the wound bed is unable to support a skin graft (such as to cover exposed hardware), or when a more complex, larger, or more aesthetic reconstruction is needed. They are the most versatile type of reconstruction used by plastic surgeons. Flap harvest always leaves a donor site that will need to be closed either primarily, with a graft, or with another flap.

I. Classification

- By composition (type of tissue transferred)
  - Single component
    - Skin flap: e.g., parascapular flap
    - Muscle flap: e.g., rectus abdominis muscle flap or latissimus dorsi muscle flap
    - Bone flap: e.g., fibula flap
    - Fascia flap: e.g., temporoparietal fascia
  - Multiple components:
    - Fasciocutaneous: e.g., radial forearm flap or anterolateral thigh flap
    - Myocutaneous: e.g., transverse rectus abdominis myocutaneous flap or latissimus myocutaneous flap
    - Osteocutaneous: e.g., fibula flap with a skin paddle or medial femoral condyle flap with skin paddle
    - Composite flap: comprised of multiple flap components that are directly attached to each other and harvested on single pedicle (e.g., latissimus osteomyocutaneous flap with muscle, skin, and bone)
    - Chimeric flap: multiple flap components that are harvested on their own vessel and freely mobile, with a single feeding vessel (Fig. 2)

Figure 2. Multi-segment fibula flap with fibula bone osteotomies, harvest of soleus muscle cuff based on muscle perforators, and independent skin paddle based on cutaneous perforators. *From Saint-Cyr M, et al. Free Tissue Transfers and Replantation. Plast Reconstr Surg 2012;130(6):858e-878e.*

- By location (proximity to the primary defect that needs to be reconstructed)
  - Local flaps
    - Raised from the tissue adjacent to the primary defect
    - Movement into the defect can be described as advancement, rotation, or transposition
    - Includes V-Y, rhomboid, and bilobed flaps

- Regional
  - Raised from tissue in the vicinity but not directly adjacent to the primary defect
  - Movement is described as transposition or interpolation
  - Such as the pedicled latissimus flap for breast reconstruction
- Distant
  - Raised from tissue at a distance from the primary defect
  - Usually requires re-anastomosis of the blood vessels to recipient blood vessels in the primary defect (see "free flaps" below)
  - There are a few examples of distant pedicled flaps, such as using a groin flap for hand reconstruction

- By vascular pattern
  - Random vs. axial
    - Random pattern flaps
      - Do not have a specific or named blood vessel as their blood supply
      - Designed based on the size of the flap base
      - Because of the random nature of the vascular pattern, these flaps are limited in dimensions, specifically in a length:base width ratio of 3:1
      - If designed longer than 3:1, a random blood supply often cannot support the flap (Fig. 3, 4).

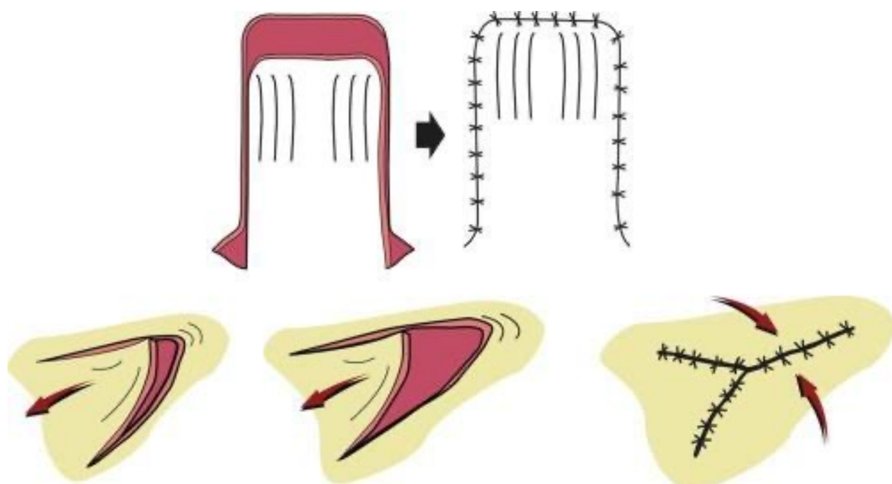

Figure 3. (Top) Advancement flap design. (Below) V-Y flap. Both are often designed as random flaps. *From Buchanan P, et al. Evidence-Based Medicine: Wound Closure. Plast Reconstr Surg 2016;138(3S):257S-270S.*

    - Axial pattern flaps
      - Designed with a specific named vascular system that enters the base and runs along its axis (Fig. 5)
      - Allows the flap to be designed as long and as wide as the territory the axial artery supplies (angiosome)
      - Blood supply requires artery and its accompanying vein
      - Greater length possible than with random flap
      - All free flaps are axial (see "free flaps" below)
    - Peninsular: skin and vessel intact in pedicle
    - Island: vessels intact, but no skin over pedicle
  - Pedicled vs. free
    - Pedicled flaps
      - Flap blood supply remains attached to its source
      - Transferred to the defect with its vascular pedicle acting as a leash

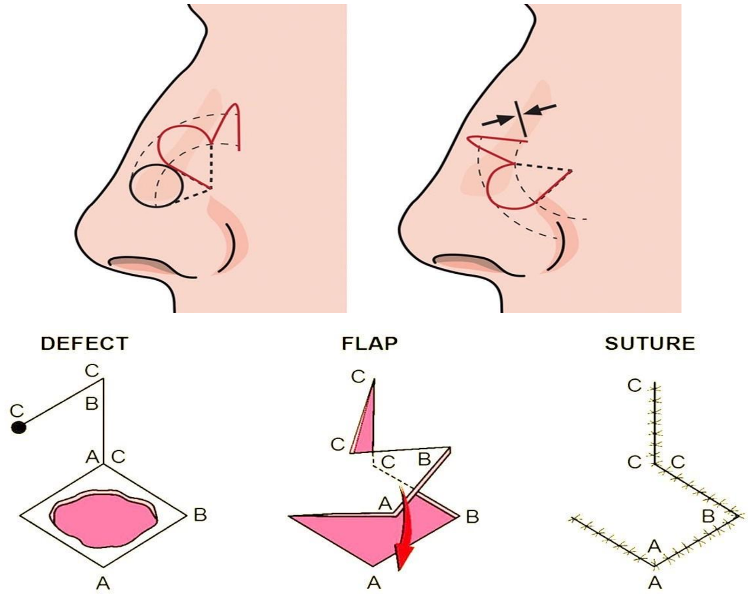

Figure 4. (Top) Bilobed flap. (Below) Rhomboid flap. Both may be designed as random flaps. *From Buchanan P, et al. Evidence-Based Medicine: Wound Closure. Plast Reconstr Surg 2016;138(3S):257S-270S.*

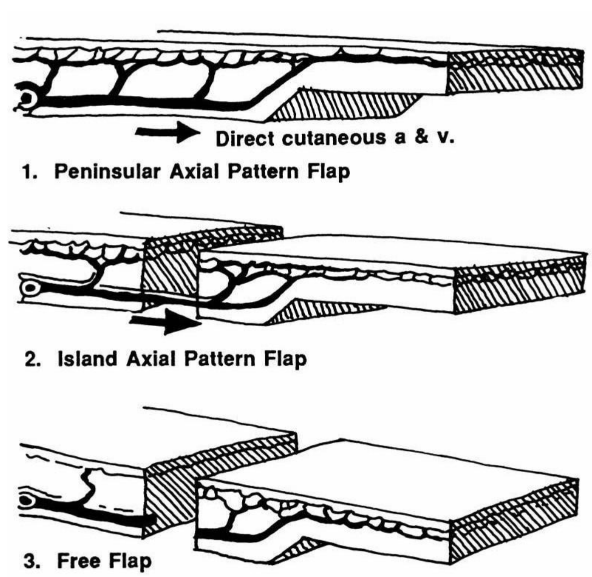

Figure 5. Axial/arterial pattern skin flaps.

- Free flaps
    - Detached at the vascular pedicle and transferred from the donor site to a recipient site
    - At the recipient site, the flap artery and vein are anastomosed to recipient vessels using microsurgical techniques
    - Allows more flexibility as tissues can be transferred nearly anywhere but requires microsurgical skill and increased operative time
- Perforator flaps
    - Supplied by smaller vessels that pass through or in between deep tissues
    - Typically harvested without the deep tissues in order to minimize donor site morbidity and to yield only the necessary amount of tissue for transfer

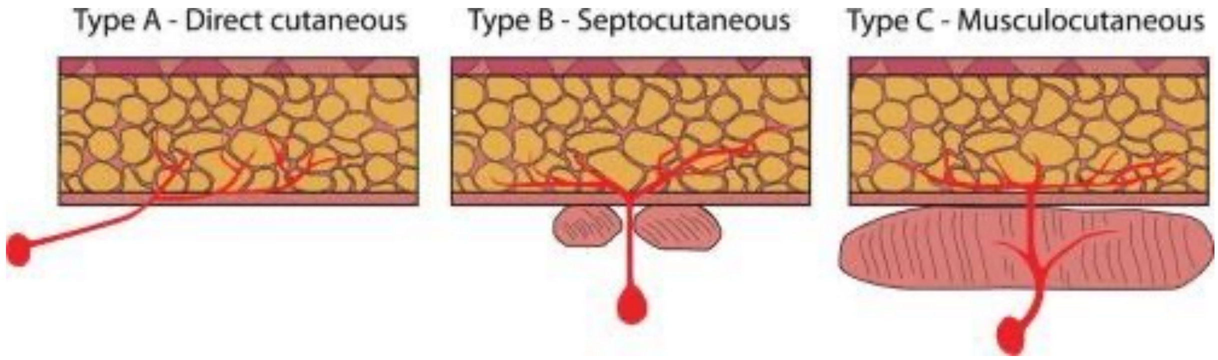

Figure 6. Mathes and Nahai classified fascial and fasciocutaneous flaps based on their vascular anatomy. Type A (left) are those flaps with a direct cutaneous pedicle to the fascia. Type B (center) are those flaps with a pedicle that has a septocutaneous perforator. Type C (right) are those with a musculocutaneous perforator. *From Buchanan PJ, Kung TA, Cederna PS. Evidence-Based Medicine: Wound Closure. Plast Reconstr Surg. 138(3S):257S-270S, September 2016.*

- Can be transferred either as a pedicled or free flap
- Perforators are described by their path from the main vessel to the skin (Fig. 6)
- Common perforator flaps:
    - Deep inferior epigastric perforator flap (DIEP): skin and fat of the lower abdomen supplied by the deep inferior epigastric artery and vein perforators without the rectus abdominis muscle
    - Anterolateral thigh perforator flap (ALT): skin and fat of the anterolateral thigh supplied by the descending branch of the lateral circumflex femoral vessel perforator(s)
    - Thoracodorsal artery perforator flap (TAP/TDAP flap): skin and fat of the lateral back supplied by the thoracodorsal artery and vein perforator without the latissimus dorsi muscle

II. Choosing the right flap

- The primary defect (recipient site considerations): "replace like with like"
    - Size
    - Location
    - Tissue type to be replaced: Muscle can eliminate more dead space, skin is better for resurfacing
    - Functional and aesthetic considerations
- The secondary defect (donor site considerations)
    - Location
    - Adhere to an angiosome, the territory that is supplied by a given vessel
    - What type of tissues are needed
    - Functional and aesthetic morbidity

III. Flap survival

- Success depends not only on survival, but also ability to achieve the goals of reconstruction
- Flap failure results ultimately from vascular compromise or the inability to achieve the goals of reconstruction.
    - Tension
    - Kinking of pedicle
    - Compression
    - Vascular thrombosis (typically more often a consideration in free flaps)
    - Infection

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Chapter 7
Microsurgery

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INTRODUCTION

- Microsurgery: type of surgery which uses precision instruments and a microscope to perform intricate surgery on small structures (arteries, veins, nerves, lymph vessels)
- Examples:
    - Free tissue transfer (aka "free flap" surgery), wherein living tissue is transplanted from one part of the body to another (Fig. 1)
    - Appendage replantation or reconstruction (Fig. 2)
    - Vascularized composite allotransplantation (VCA), wherein living tissue is transplanted from one individual to another (face and hand transplants)
- Potential tissues transferred: skin, muscle, tendons, bone, nerve, lymph nodes
- Transferred tissue is selected so it can survive based on a vascular pedicle
    - Tissue is transferred to another region of the body
    - Artery and vein are re-connected ("anastomosed") to blood vessels in the recipient site
    - Microvascular anastomosis restores blood supply to the transferred tissue

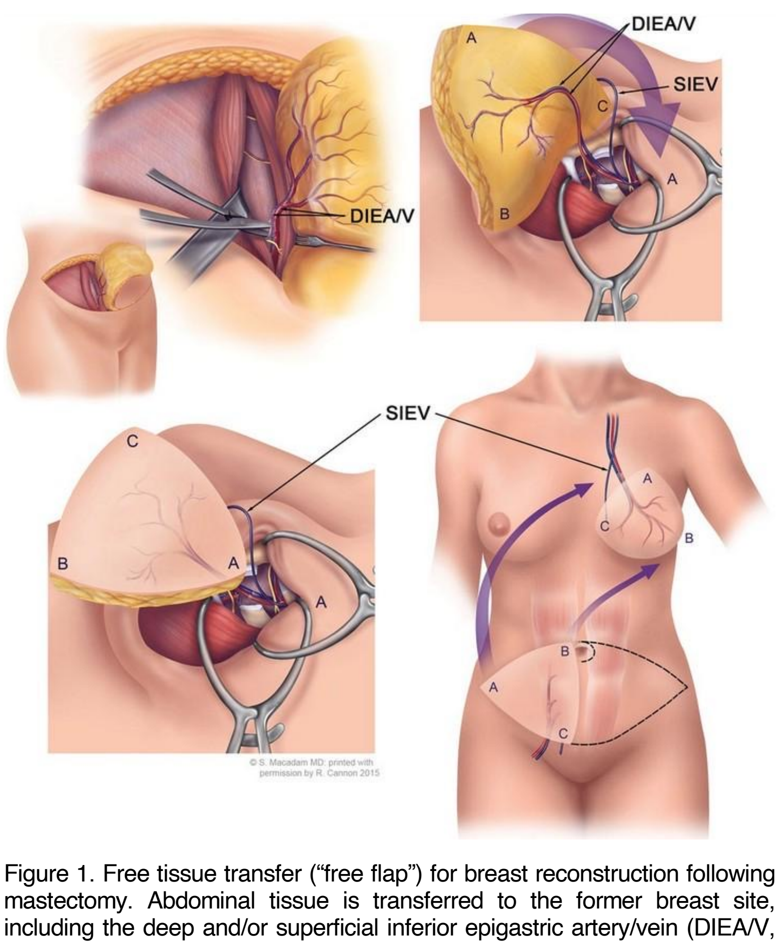

Figure 1. Free tissue transfer ("free flap") for breast reconstruction following mastectomy. Abdominal tissue is transferred to the former breast site, including the deep and/or superficial inferior epigastric artery/vein (DIEA/V, SIEA/V). *From Macadam S, et al. Evidence-Based Medicine: Autologous Breast Reconstruction. Plast Reconst Surg 2017;139(1):204e-29e.*

Figure 2. Vascularized free fibula flap for first metatarsophalangeal joint arthrodesis. *From Parikh RP, Sacks JM. Limb Salvage for Chronic Lower Extremity Wounds. Plastic Reconstr Surg. 2025;155(6):1056e-1070e.*

FREE FLAP TYPES

- Isolated tissue (pedicle)
    - Skin/subcutaneous Tissue
    - Deep inferior epigastric artery perforator (DIEP)
    - Superficial circumflex iliac artery perforator (SCIP)
- Muscle
    - Latissimus dorsi (thoracodorsal artery)
    - Rectus abdominis (deep inferior epigastric artery)
- Fasciocutaneous
    - Radial forearm free flap (RFFF; radial artery)
    - Anterolateral thigh (ALT; descending branch of lateral femoral circumflex artery)
- Bone
    - Fibula (peroneal artery)
    - Iliac crest (deep circumflex iliac artery)
- Nerve
    - Combined with other tissues as “innervated” flap
    - Innervated/free functional gracilis (+ obturator nerve)
    - Free toe transfer (+ digital nerves) (Figure 2)
- Lymph nodes (vascularized lymph node transplant, VLNT)
    - Groin (SCIP) and omentum are examples
    - Transferred with surrounding fat and supplying blood vessels
- Composite: combination of tissues taken as a single flap
    - Myocutaneous
    - Fasciocutaneous
    - Osteocutaneous
    - Innervated myocutaneous

- Appendage: finger, toe, penis (replant or reconstruction)
- Allogeneic composite tissue: face or hand transplant
- For details, see Grafts & Flaps (Chapter 6), Gender Affirmation Surgery (Chapter 25), Composite Tissue Allotransplantation (Chapter 26), and Lymphedema (Chapter 27)

SUPERMICROSURGERY

- Microneurovascular anastomosis for vessels of 0.3 to 0.8 mm and single nerve fascicles
- Requires high magnification operating room microscope and ultrafine microsurgical instruments as well as needles (11-0 to 13-0 microsutures)
- Applications in lymphedema surgery, digital replantation, pediatric microsurgery, neuroplastic surgery, and perforator to perforator reconstruction

SURGICAL INDICATIONS

- Adequate/acceptable result cannot be achieved by simpler method
- Severe tissue loss with exposed vital structures such as joint surfaces, bone without periosteum, vessels/nerves
- Large “dead space” requiring obliteration (filling)
- Restore form and/or function (i.e., breast reconstruction after mastectomy; Fig. 1)
- Loss of digits after blast injury to hand
- Congenital deformity: facial paralysis, severe thumb hypoplasia
- Gender affirmation surgery: female-to-male bottom surgery
- Lymphedema: cancer patients with lymph nodes removed for staging
    - Lymphovenous bypass: vessels anastomosed to local vein to redirect drainage around obstruction; lymph vessel diameter <0.8 mm
- Peripheral nerve reconstruction: nerve fascicle diameter ranges 0.1-1 mm
    - In situ nerve repair/coaptation/dissection needed

CONTRAINDICATIONS

- No absolute contraindications
- Age (young or old) less important than overall health
- Systemic disease: microsurgery contraindicated if patient cannot tolerate prolonged anesthesia, (e.g., surgery duration of 8-12 hours)
    - Cardiovascular and respiratory health
    - Renal insufficiency (high complication rate)
    - Hepatic function
    - Bleeding/clotting disorders (hypercoagulable state increases flap failure rate)
- Smoking:
    - Digital replantation contraindicated, ~80-90% failure
    - No increased failure risk for free flaps
    - Smokers have more wound healing complications; encourage quitting
- Previous radiation: not a contraindication

BASIC OPERATIVE TECHNIQUE

- Details may be finalized intraoperatively, based on:
    - Defect size/missing tissue after debridement or tumor resection
    - Caliber and appearance of available vessels
- Begin with dissection of tissue for transfer (+ vessels) and exposure of recipient vessels
- Team communication is critical (surgeons, anesthesia, nursing)
- Key portions of the surgery are beyond the limits of human eyesight
    - Tiny blood or lymphatic vessels: ~0.5-4 mm
    - Magnification is used during dissection, anastomosis (of artery, vein, and/or lymph vessels), and nerve coaptation

- Magnification tools:
  - Magnifying loupes (custom glasses with attached magnifying lenses, 2.5-6.5x)
  - Surgical microscope (4-40x)
- Anastomosis:
  - Blood flow temporarily obstructed with specialized atraumatic “Acland” clamps
  - Artery or lymph vessel: sewn together by hand (Fig. 3)
  - Interrupted suture technique common
  - End-to-end or end-to-side anastomoses are most common
  - Small caliber suture: 8-0 nylon (0.4 mm) to 12-0 nylon (0.01 mm)
  - Veins: vessel sizer used to estimate size of vein
    - Vessel coupler often used: vessel ends pulled through rings and edges everted onto sharp pins then opposing pins inter-digitate, sealing the vessels together (Fig. 4)
  - Clamps released to evaluate flow across anastomosis (Fig. 5)
  - Final steps are inset of transferred tissue and closure of donor site

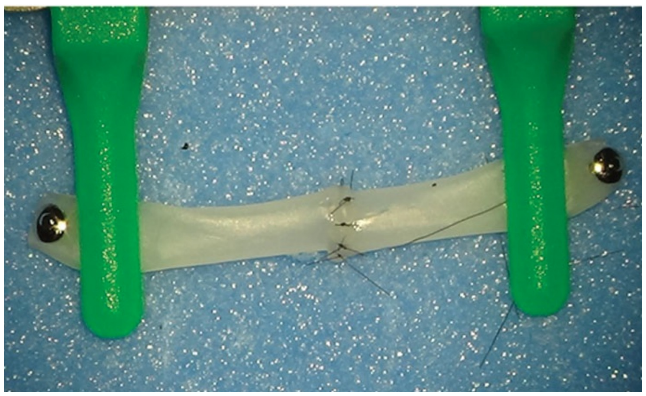

Figure 3. Arterial anastomosis of synthetic vessel under the microscope. A pair of green “Acland” clamps obstructs blood flow to enable visualization. *From van Mulken T et al. Preclinical Experience Using a New Robotic System Created for Microsurgery. Plast Reconstr Surg. 2018;142(5):1367-1376.*

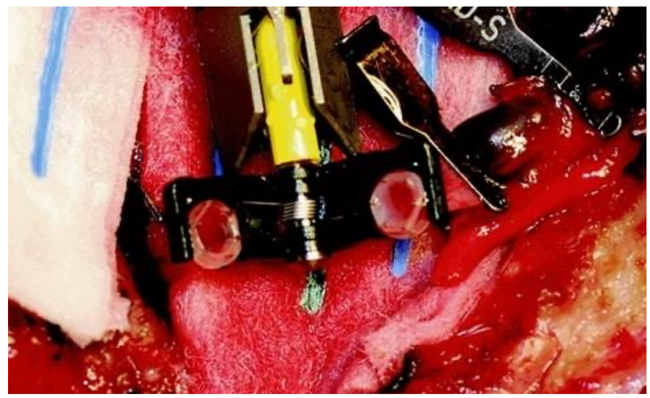

Figure 4. Vein anastomosis using a vessel coupler. The end of each vein has been pulled through the rings and everted onto the sharp pins. As the coupler is closed, opposing pins will interdigitate to seal the veins together. *From Jandali S, et al. 1000 Consecutive Venous Anastomoses Using the Microvascular Anastomotic Coupler in Breast Reconstruction. Plast Reconstr Surg 2010;125(3):792-8.*

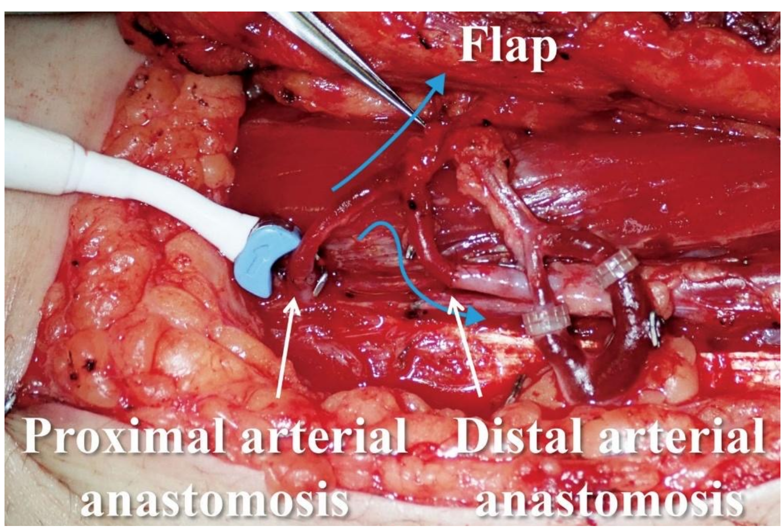

Figure 5. Clinical photograph of an end-to-end arterial anastomosis and venous anastomosis with a coupler device. *From Kagaya Y et al. A Quantitative Evaluation of the Flow-Increasing Effect of Flow-Through Arterial Anastomosis in the Vascular Pedicle of Free Flaps: A Prospective Clinical Before-and-After Study. Plast Reconstr Surg. 2021; 148(4):871-881.*

POST-OPERATIVE MONITORING AND COMPLICATIONS

- Gold standard: physical exam
    - Color
    - Temperature
    - Turgor
    - Capillary refill
    - Handheld doppler: signal checked at marked site on flap skin/surface
    - Pinprick to assess bleeding (slow, bright red blood is normal)
- Arterial compromise: pale, cool, flaccid, slow cap refill
- Venous congestion: purple/blue, tense, brisk cap refill (Fig. 6)
- Most vascular complications occur in the first 48 hours

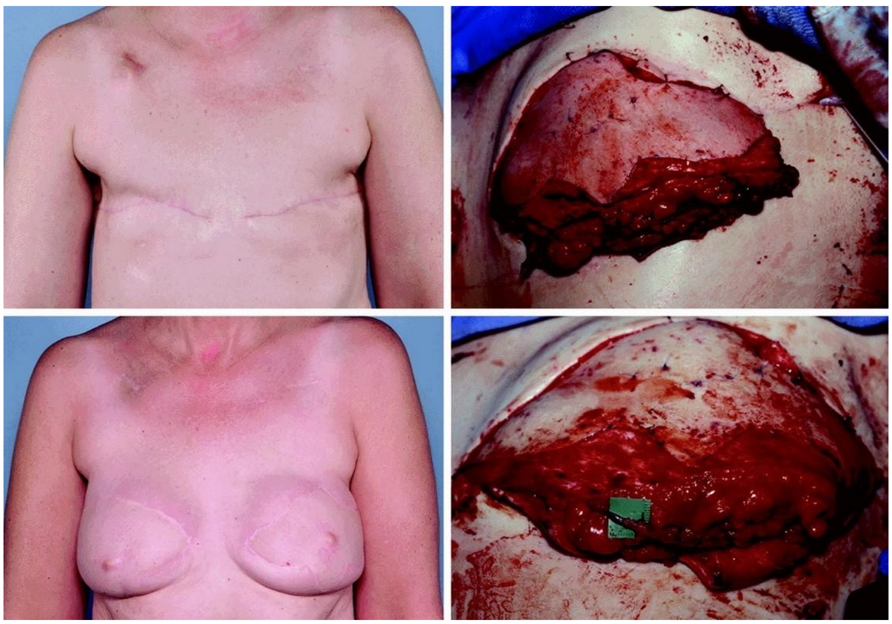

Figure 6. Breast reconstruction complicated by venous congestion of the left breast DIEP flap (upper right), while the right flap continued to have a good color (lower right). Congestion was addressed by anastomosis of an additional vein. Pre-operative image (upper left) and postoperative image at 28 months (lower left). *From Tran NV, et al. Microvascular Complications of DIEP Flaps. Plast and Reconst Surg 2007;119(5):1397-405.*

ADJUNCT MONITORING DEVICES

- Implantable doppler
    - Probe placed around artery or vein during surgery, connects to external flow monitor (Fig. 7)
- Laser Doppler
- Flow coupler: similar to implantable Doppler
- Transcutaneous tissue oximetry
    - Placed on flap skin paddle
    - Measures tissue oxygen saturation (StO2) (Fig. 8)
    - Early detection of vascular compromise
- Prompt return to operating room is critical
    - Evacuate any hematoma
    - Inspect vessels
    - Remove thrombus, revise anastomosis, and/or alleviate kinking, vein grafts
    - Consider leech therapy if vein patent but flap remains congested
        - Need antibiotics coverage while on leech therapy for coverage against Aeromonas hydrophila (can consider ciprofloxacin, Bactrim or ceftriaxone)

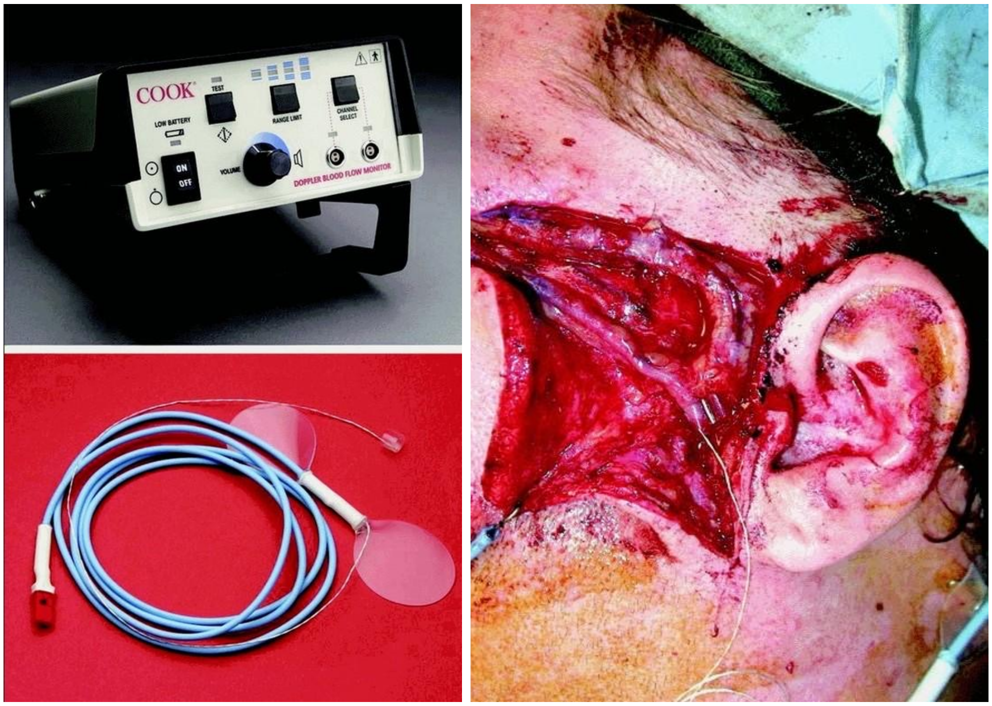

Figure 7. Implantable Doppler used to monitor a left cheek free flap reconstruction. A small silastic cuff probe (left lower) is placed around the vessel (right) and connected to an external flow monitor (upper left). *From Paydar K, et al. Implantable Venous Doppler Monitoring in Head and Neck Free Flap Reconstruction Increases the Salvage Rate. Plast Reconst Surg 2010; 125(4):1129-1134.*

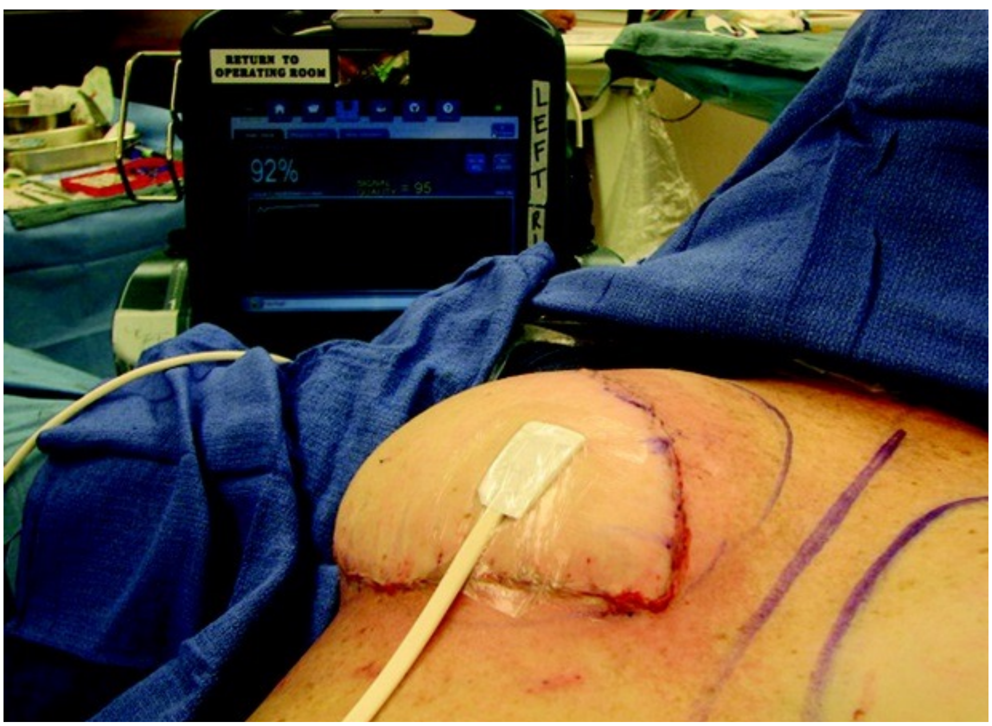

Figure 8. Transcutaneous tissue oxygen saturation value is projected on the device screen for each flap, which can also be monitored remotely. Typically, a drop of 20% or more in oxygen saturation is concerning for an ischemic event and warrants further flap perfusion investigation. *From Lin SJ, et al. Tissue Oximetry Monitoring in Microsurgical Breast Reconstruction Decreases Flap Loss and Improves Rate of Flap Salvage. Plast Reconstr Surg. 2011;127(3):1080-1085.*

MICROSURGERY TRAINING

- Specialized technical skills necessary
    - Use of magnifying loupes and/or microscope (Fig. 9)
    - Tissue and vessel handling
    - Anastomosis techniques
    - Suturing at microscopic scales
    - Often taught in a hands-on lab setting
- Animal-derived or synthetic vessel models
- May be incorporated into residency training or offered as a stand-alone course

Figure 9. Microsurgical working space with instruments and microscope. A digital camera enables optimal teaching. (Inset) Magnification of the visual field with a scale bar is shown. *From Pion E et al. New, Innovative, Three-Dimensional In Vivo Model for High-Level Microsurgical and Supermicrosurgical Training: A Replacement for Animal Models. Plastic and Reconstructive Surgery, Plast Reconstr Surg. 2022;150(2):432-436.*

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Chapter 8
Skin and Subcutaneous Lesions

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ANATOMY

I. Layers of the skin

- Epidermis: "Come, Let's Get Sun Burned"
    - Stratum corneum: keratinocytes compact, surrounded by lipid layer making skin waterproof
    - Stratum lucidum: only found in glabrous skin
    - Stratum granulosum: keratinocytes contain keratohyalin granules
    - Stratum spinosum: keratinocytes form intercellular connections via desmosomes
    - Stratum basale:
        - Basal cells: stem cells that differentiate into keratinocytes; origin of basal cell carcinoma
        - Melanocytes: origin of melanoma
        - Merkel cells
- Dermis
    - Papillary
    - Reticular

II. Sweat glands

- Apocrine:
    - Areola, axilla, labia majora/scrotum, periumbilical, perianal
    - Deposit sweat into hair follicles
    - Cause body odor + pheromones, start functioning at puberty
    - Hidradenitis suppurativa: malfunction of apocrine glands
        - Hurley classification:
            - Stage 1: abscess formation without sinus tracts
            - Stage 2: recurrent abscesses with sinus tracts, scarring
            - Stage 3: diffuse involvement with multiple interconnected sinus tracts and abscesses
        - Treatment: medical therapy first line
            - Mild: topical clindamycin
            - Moderate: oral antibiotics
            - Refractory: adalimumab (Humira): anti-TNF monoclonal antibody
            - Surgical excision is last resort
                - Radical resection of all hair-bearing skin with 1-2 cm of normal skin
                - Heal by secondary intention, primary closure, skin grafting, local flaps
- Eccrine:
    - Everywhere except vermillion border, nail plate, external auditory canal, nipple-areolar complex, labia, glans, clitoris
    - Highest amount in palms, soles
    - Functions:
        - Deposit sweat onto skin surface
            - Sweat is clear, colorless, odorless: contains water + electrolytes
        - Temperature homeostasis, secrete IgG, stem cells

        - Hyperhidrosis: overactive eccrine glands
    - Apoeccrine
        - Axilla, perianal areas
        - Secrete watery sweat in response to psychological/emotional stress

BENIGN SKIN LESIONS

- Acrochordon (skin tag):
    - Single or multiple small, skin-colored, pedunculated papules
    - Treatment (symptomatic lesions): cryotherapy, snip excision, or shave excision
- Epidermal inclusion cyst (sebaceous cyst, epidermoid cyst):
    - Caused by proliferation of epidermal cells in dermis, often arising after trauma
    - Skin-colored to yellow, firm, mobile nodules, often with an overlying central punctum
        - Well-circumscribed by cyst wall composed of stratified squamous epithelium
        - Communicate with surface via small opening, which may contain keratinaceous plug or blackhead
    - Typically asymptomatic, may become inflamed/infected
    - Treatment:
        - Acute infection: incision and drainage (avoid definitive excision as the tissue will be extremely inflamed)
        - Definitive treatment: surgical excision including cyst wall
- Pilar cyst (trichilemmal cyst):
    - Originates from outer root sheath of hair shaft
    - Lined by stratified squamous epithelium which undergoes keratinization
    - Firm, slow-growing subcutaneous nodules typically on the scalp
        - No overlying central punctum
    - Most common cutaneous cyst of the scalp
    - Definitive treatment: surgical excision including cyst wall
- Pilomatrixoma:
    - Caused by overgrowth of hair follicle matrix cells
    - Slow-growing, "rock-hard" subcutaneous masses with blue hue or ulcerative appearance
    - Bimodal distribution (first and sixth decades); more common in children
    - Mutation: CTNNB1 (dysregulates beta-catenin/LEF)
    - Treatment: surgical excision
- Dermoid cyst:
    - Congenital cysts located along lines of embryonic fusion in the head and neck region
    - Most commonly along the superolateral orbital ridge, midline of nose, and scalp
    - Skin-colored, non-tender, non-compressible, slow growing masses
        - Can arise in the dermis or subcutaneous tissue
        - May be fixed to underlying periosteum
        - Can cause underlying bone erosion
    - Midline dermoids require pre-operative US or MRI to rule out intracranial excision
        - Most common over anterior fontanelle, midline nose (40%)
    - Treatment: surgical excision (with neurosurgery assistance if intracranial)
- Seborrheic keratosis (verruca senilis, pigmented papilloma):
    - Hyperpigmented, waxy, verrucous papules with a characteristic "stuck-on" appearance
    - Appear in the fifth to seventh decades of life, usually on the head, neck, or trunk
    - Arise from the basal layer of the epidermis, are composed of well-differentiated basal cells
    - Treatment (cosmetic): cryotherapy, shave biopsy, dermabrasion
- Trichoepitheliomas:
    - Neoplasms of follicular origin
    - Multiple, yellowish-pink, translucent papules distributed symmetrically on the cheeks, eyelids, and nasolabial area

- More common in women
- Can be confused with basal cell carcinoma
- Treatment: excision to rule out basal cell carcinoma

- Eccrine poroma:
  - Solitary lesion (firm papule less than 2 cm in size) usually on the sole of the foot or the palm of the hand in persons older than 40 years
    - May also occur on the chest, the neck, or other locations
  - Can degenerate into malignant eccrine poroma or porocarcinoma
  - Treatment: surgical excision
- Verrucous nevus:
  - Closely set skin colored, brown, or gray-brown verrucous papules. May coalesce to form well-demarcated linear plaques along skin tension lines
  - Hyperkeratosis, acanthosis, and papillomatosis
  - Treatment: excision to deep dermis; consider laser, cryotherapy, or dermabrasion for more extensive lesions not amenable to excision
- Desmoid tumor:
  - Caused by overgrowth of musculoaponeurotic layer of the abdominal wall with unpredictable progression
  - Treatment: excision with 1 cm margins
- Cylindroma:
  - Adult-onset firm nodules of the face or scalp with smooth, flesh-colored, possibly telangiectatic surfaces
  - More common in women
  - Associated with Brooke-Spiegler syndrome (autosomal dominant, AD)
  - Treatment:
    - Solitary lesions: surgical excision, electrodessication
    - Grouped lesions: may need staged excision
- Pyogenic granuloma (Fig. 1):
  - Appears in early childhood, usually following minor trauma, as a rapidly growing, small (<1cm) red lesion
  - Friable and prone to bleeding
  - Treatment: silver nitrate vs. surgical excision
- Rhinophyma:
  - End-stage acne rosacea
  - Overgrowth of sebaceous glands of skin
  - Treatment:
    - Initial: isotretinoin, antibiotics
    - Refractory: tangential excision with healing by secondary intent
- Mucocele:
  - Cysts formed from mucin leakage of minor salivary glands
  - Located on lower lip
  - Treatment: surgical excision
- Pyoderma gangrenosum:
  - Dramatic deterioration of surgical wounds after 4 days to 6 weeks
    - Predominantly affects breasts, abdomen
  - Fever, chills, cellulitis, wound breakdown
    - Rapidly enlarging area of central skin ulceration plus violaceous skin with irregular borders
  - Risk factors: inflammatory bowel disease
  - Treatment: high-dose steroids, topical tacrolimus; avoid debridement

Figure 1. Pyogenic granuloma. These lesions occur most commonly on the face (above). (below) This lesion on the left supraclavicular fossa shows evidence of recent bleeding (arrowhead). *From Li W, et al. Cysts, pits, and tumors. Plast Reconstr Surg. 2009;124(1 Suppl):106e-16e.*

- Xanthelasma palpebrarum:
    - Asymptomatic yellow-orange papules and plaques, commonly on the medial eyelids
    - Associated with hyperlipidemia (lesions do not resolve with correction of hyperlipidemia)
    - Treatment (cosmetic): surgical excision
- Syringoma:
    - Asymptomatic, skin-colored or yellow papules and plaques of the eyelids or upper cheeks
    - Treatment (cosmetic): laser, cryotherapy, electrodessication, excision
- Nevus of Ota (nevus fuscoceruleus ophthalmomaxillaris or oculodermal melanocytosis):
    - Dermal melanocytic hamartoma with bluish hyperpigmentation
        - Occurs along ophthalmic and maxillary divisions of trigeminal nerve
    - Caused by failure of complete embryonic migration of melanocytes from the neural crest to the epidermis
        - Results in dermal nesting, resultant dermal melanin causes Tyndall effect
    - More prevalent in females, darker-pigmented individuals
    - Bimodal age incidence, peaks at 1 year of age and puberty
    - 10% associated with ipsilateral glaucoma
        - Recommend ophthalmologic referral
    - Malignant degeneration to melanoma occurs in approximately 4% of reported cases
    - Treatment: laser therapy – either Q-switched laser with ruby (694 nm), alexandrite (755 nm), or neodymium: yttrium-aluminum-garnet (1064 nm)
- Nevus of Ito:
    - Large blue-grey lesion that arising over areas innervated by the posterior supraclavicular and lateral cutaneous brachial nerves (shoulder)
    - Treatment: Q-switched laser
- Spitz nevus:
    - Well-circumscribed pink papule that rapidly increases in size
        - Pigmented variant (spindled cell nevus of Reed) is dark brown to black in color with pseudopods at the periphery, giving it a "starburst" appearance
        - May mimic melanoma
    - Most common in children (head and neck region)
    - Treatment: surgical excision
- Dermatofibroma (benign fibrous histiocytoma):
    - Solitary, firm, hyperpigmented macule or thin papule on the lower extremity
    - 4 times more common in women than in men
    - Treatment: surgical excision for painful or pruritic lesions
- Lipoma:
    - Soft, rubbery, non-tender, mobile subcutaneous nodules that are slow-growing
    - Mature adipocytes surrounded by thin fibrous capsule
    - Treatment: surgical excision
- Neurofibromas:
    - Associated with NF1; derived from Schwann cells
    - Types:
        - Plexiform: develop deep inside the body (involving nerves, blood vessels); presents with pain, numbness, weakness, disfigurement
            - Small risk of malignant degeneration
        - Dermal: small, nodule-like; no malignant potential
    - Treatment: excision, must sacrifice underlying nerve
- Schwannomas:
    - Peripheral nerve sheath tumors
    - Treatment: resection, can spare underlying nerve
- Glomus tumor:
    - Benign hamartomas originating from glomus body (vascular, neural elements responsible for thermoregulation)

    - Presents with pain, point tenderness, sensitivity to cold
    - Diagnosis: MRI (bright, discrete mass on T2-FLAIR)
    - Treatment: excision
- Nevus sebaceous (Jadassohn nevus):
    - Hairless, solitary, linear, well-demarcated patch or thin plaque on the scalp
        - Pink, yellow, orange or tan in color
    - Hormonal changes cause the lesion to thicken and become more verrucous and nodular in appearance during adolescence
    - RAS mutation
        - Associated with maternal HPV
        - <1% risk of degeneration into basal cell carcinoma
    - Treatment: serial monitoring vs. selective excision (less risk of carcinoma than previously thought)

PRE-MALIGNANT AND MALIGNANT SKIN LESIONS

I. Squamous cell carcinoma (SCC)

- SCC precursors:
    - Actinic keratoses:
        - Erythematous, rough, scaly lesions in sun-exposed areas
        - 5-10% risk of progression to squamous cell carcinoma
        - Risk factors: age, male, fair skin
        - Treatment:
            - <15 lesions: cryotherapy
            - >15 lesions: topical imiquimod (Aldara), topical 5-fluorouracil (pyrimidine synthetase inhibitor), retinoids, diclofenac gel, surgical excision
    - Cutaneous horn:
        - Hard, cone-shaped cutaneous projections typically caused by excessive epidermal growth and retention of keratin
        - 20% associated with premalignant lesions, 15% associated with SCC
        - Treatment: shave biopsy to exclude malignancy or definitive surgical excision
    - Keratoacanthoma (Fig. 2):
        - Solitary papule that grows rapidly in size with a crateriform center
        - Treatment: surgical excision recommended, cannot be reliably distinguished from SCC

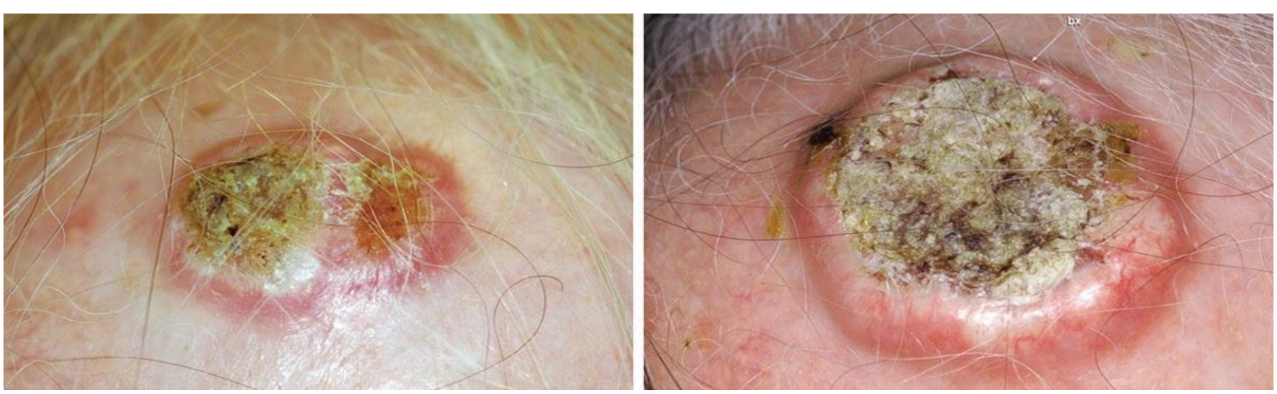

Figure 2. Keratoacanthoma demonstrating rapid growth over a 3-month period. *From Lee EH, et al. Benign and premalignant skin lesions. Plast Reconstr Surg 2010;125(5):188e-98e.*

    - Leukoplakia:
        - If on floor of mouth: 60% association with SCC in situ (SCCis) or invasive SCC
        - If on buccal mucosa: typically benign

- Bowen's disease:
  - Squamous cell carcinoma in situ (SCCis)
  - Full thickness epidermal atypia
  - Presents as a thin eczematous, erythematous plaque
- Erythroplasia of Queyrat: SCCis of the glans penis

- Arises from keratinocytes in stratum basale
- Erythematous, scaly or verrucous papule or plaque
- Risk factors: age, sun exposure, lighter skin
- High-risk lesions: poorly defined borders, recurrent lesion, immunosuppressed patient, rapid growth, neurologic symptoms, invasion to fat, size >2 cm, or size >6 mm in the central face, ears, scalp, genitalia, hands/feet
  - High risk subtypes: adenoid (acantholytic, adenosquamous, desmoplastic, metaplastic (carcinosarcomatous)
  - Marjolin's ulcer: SCC arising in chronic wound, area of previous radiation or chronic inflammation
- Margins:
  - Low-risk: 4 mm
  - High-risk: 6 mm or Mohs micrographic surgery
- May metastasize (most often with lesions on the ear or lip, lesions > 2 cm in size, and in the immunosuppressed population)

II. Basal cell carcinoma

- Most common skin cancer
- Arises from keratinocytes in stratum basale
- Pink, pearly papule with overlying telangiectasia and rolled borders; ulceration may be present, giving a characteristic "rodent bite" ulcer (Fig. 3)
- Risk factors: age, sun exposure, lighter skin
- High risk: poorly defined borders, recurrent lesion, immunosuppressed patient, site of previous radiation, peri-neural involvement, aggressive histology (morpheaform, sclerosing, mixed infiltrative, basosquamous, or micronodular), >2 cm in the trunk/extremities, or >1 cm in the head and neck

Figure 3. (above, left) Superficial basal cell carcinoma. (above, right) Nodular basal cell carcinoma. (below, left) Infiltrative basal cell carcinoma. (below, right) Pigmented basal cell carcinoma. *From Lee E, et al. Benign and premalignant skin lesions. Plast Reconstr Surg 2010;125(5):188e-98e.*

- Types:
  - Nodular (least aggressive with lowest risk of recurrence)
  - Infiltrating
  - Micronodular
  - Morpheaform
  - Sclerosing
  - Metatypical (basosquamous)
- Gorlin syndrome: autosomal dominant mutation in PTCH1
  - Multiple basal cell carcinomas, odontogenic cysts of mandible, facial dysmorphism, skeletal abnormalities of the vertebrae, skull and ribs
  - Treatment: surgical excision, Mohs, electrodessication, cryosurgery, Imiquimod (TLR7 agonist) for <2 cm BCCs of the trunk, extremities, or neck), photodynamic therapy, 5-FU, and radiation therapy
- Margins:
  - Low-risk: 4 mm
  - High-risk: 6-10 mm or Mohs
- Vismodegib and Sonidegib (a selective inhibitor of hedgehog pathway activation) are approved for the treatment of metastatic basal cell carcinoma and locally advanced basal cell carcinoma that has recurred after surgery, or in patients who are not surgical or radiation therapy candidates

III. Melanoma

- 3% of all skin cancers, but 65% of all skin cancer deaths
- Risk factors: lighter skin, age, sun exposure, family or personal history
- ABCDE signs of melanoma (Fig. 4):
  - Asymmetry
  - Border irregularity
  - Color variation
  - Diameter (>6 mm)
  - Enlarging or evolving

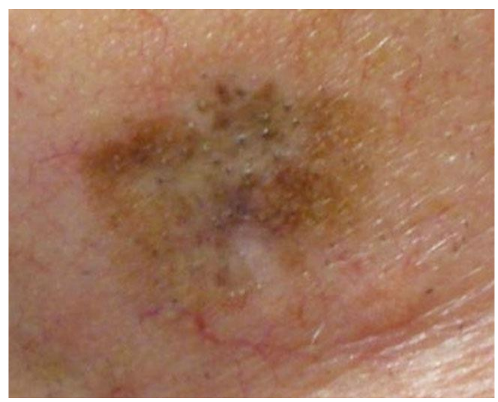

Figure 4. ABCDE signs of melanoma. A 75-year-old man with a left cheek lesion presenting with asymmetry, border irregularity, color variation, and diameter of 2.5 cm evolving over an 8-year period. *From Dzwierzynski W. Managing malignant melanoma. Plast Reconstr Surg 2013;132(3):446e-60e.*

- Predisposing conditions:
  - Dysplastic nevus: atypical melanocytes with potential for transformation
    - 6-10% risk melanoma
  - Atypical mole syndrome or familial atypical multiple mole melanoma (FAMMMS):
    - More than 100 melanocytic nevi
    - 1+ measures >8 mm
    - 1+ with clinically atypical features
    - 10% risk of melanoma
  - Giant congenital melanocytic nevi:
    - 2% risk of melanoma (similar to general population)
    - >20 cm nevus in adult or lesion with potential to exceed 20 cm in child
    - Lesions overlying spine have higher risk of occult spina bifida
    - Satellite lesions have higher risk of malignancy
    - Treatment: tissue expansion, serial excision
      - Excision does <u>not</u> reduce risk of melanoma
- Types of melanoma:
  - Superficial spreading: most common
    - Often arise in pre-existing nevi
    - Prolonged radial growth phase prior to invading dermis
    - Initially flat, but can become irregular or raised as the lesions grow

        - Nodular: second most common
            - Males more common than females
            - Arises de novo in normal skin
            - Dome-shaped, dark: may resemble blood blister
        - Lentigo maligna (Hutchinson's freckle): rare (only 4% melanomas)
            - Present as large, tan lesions with convoluted patterns and multiple amelanotic patches
            - May arise from pre-existing lentigo maligna lesions
            - Grow in a slow, radial fashion, before the vertical growth phase develops
            - Women more common than men
        - Acral lentiginous:
            - Rarest type in Caucasians, 30-60% of melanoma in dark-skinned individuals
            - Arises in palms, soles of feet, and nail beds
            - Risk factors: age 50 to 70, irregular border, change of lesion size, pigment in surrounding skin (Hutchinson sign), personal history of melanoma, single finger involvement
        - Amelanotic:
            - Lack pigment, often mistaken for other lesions
        - Desmoplastic:
            - Aggressive local growth, less frequent nodal metastases
            - Often confused with common nevi, blue nevi, Spitz nevi, pyogenic granulomas, or hemangiomas
    - Diagnosis:
        - Gold standard: excisional biopsy
        - Shave biopsy is often performed by other providers but can under-estimate depth
            - Has not been shown to affect prognosis/survival
    - Classification:
        - Breslow thickness: most important prognostic variable (followed by ulceration)
            - <1 mm, 1-2 mm, 2-4 mm, >4 mm
        - Clark level:
            - Level 1: confined to epidermis
            - Level 2: extends into upper papillary dermis
            - Level 3: extends down to reticular dermis
            - Level 4: extends to subcutaneous tissue
        - Immunohistochemistry: S100, HNB45, Mort1+
    - Treatment:
        - Surgical excision with margins determined by Breslow depth
            - Melanoma in-situ (MIS): 0.5 cm
            - < 1 mm: 1 cm
            - 1.01-2mm: 1-2 cm (generally 2 cm where allowable such as the trunk and extremities, and 1 cm in more aesthetically sensitive areas like the head and neck)
            - >2.01 mm: 2 cm
        - Sentinel lymph node biopsy (SLNB)
            - Indicated for intermediate thickness (1-4 mm) melanomas
            - May also be indicated for high-risk thin melanomas (0.75-1 mm thick with ulceration)
        - Completion lymph node dissection (CLND) if positive SLN or a clinically palpable node
        - Medical therapy for advanced (stage 3-4) disease
            - Immunomodulation + targeted molecular therapy toward mutations found in melanocytic lesions
            - Vemurafenib and dabrafenib: BRAF inhibitors, improved survival but develops rapid resistance with associated relapse

        - Interleukin-2: mmunomodulator that activates the host immune system to attack malignant cells, severe side effect profile
        - Ipilimumab: monoclonal antibody that suppresses CTLA-4, small but durable response, significant immunologic side effects
        - Nivolimumab: anti-PD-1 monoclonal antibody
        - Pembrolizumab: targets PDL1 receptor

IV. Merkel cell carcinoma

- Firm, painless nodule (up to 2 cm in diameter) or a mass (>2 cm in diameter), usually in the head and neck region
    - Red in color but may be flesh-colored, blue
    - Rapidly enlarges, aggressive with frequent nodal involvement
- Risk factors: AEIOU
    - Asymptomatic
    - Expanding rapidly (>3 mo)
    - Immunosuppressed
    - Over 50 years old
    - UV-exposed site
- Histology: CK20+, NSE+ small blue cells
- Treatment: surgical excision (1-2 cm margins down to investing fascia), SLNB, adjuvant radiation

V. Paget's disease

- Paget's disease of the breast: eczematous skin changes of the nipple areolar complex
    - Associated with ipsilateral breast cancer
- Extramammary Paget's disease: intraepithelial carcinoma involving the vulvar, perianal, perineal, scrotal, and penile regions
    - Presents as well-defined, moist, erythematous plaques associated with pruritis
    - 7 to 40% rate of associated malignancy
    - Treatment: wide local excision

VI. Dermatofibrosarcoma protuberans (DFSP)

- Malignant mesenchymal tumor, arises in the dermis and is characterized by latency in its initial detection, slow infiltrative growth, and local recurrence if not adequately treated
- Caused by chromosomal translocation t(17;22) fusing COL1A1 with PDGF-B
- Most common on the trunk followed by the proximal extremities
- Treatment: wide local excision with excision of deep fascia, margins up to 5 cm
    - Metastatic disease: chemotherapy (imatinib: PDGF receptor tyrosine kinase inhibitor)

VII. Angiosarcoma

- Appears as a purple plaque, commonly found in the face and scalp in older Caucasian men
- 50% in the head and neck
    - Also commonly found in the breast and extremities, particularly in patients with a history of lymphedema or radiation therapy
- Treatment: wide local excision
    - Frequently multifocal
    - Local recurrences common

VIII. Stewart-Treves syndrome

- Lymphangiosarcoma in post-mastectomy patients
- Diagnosis: incisional biopsy
- Treatment: WLE if possible with margins of at least 1 cm, or isolated limb perfusion with tumor necrosis factor and melphalan

INDICATIONS FOR MOHS EXCISION

- Sensitive anatomic locations
- Recurrent BCC or SCC
- Locations prone to recurrence: “H-zone” of the face- periorbital, periauricular, temple, upper lip, nose/ nasolabial fold
- Involvement of critical structures like eyelid, lip, nose
- Functionally important areas: genitals, perianal location, hands, feet
- Previously irradiated fields
- Large tumors >2 cm
- Lesions with ill-defined tumor margins
- Aggressive histiologic subtype
- Immunosuppressed patients

VASCULAR ANOMALIES

I. Congenital hemangiomas

- Present at birth
- No post-natal growth
- Red-violaceous discoloration with coarse telangiectasias, central pallor, and a peripheral pale halo
- More common in the extremities, equal sex distribution, and are solitary with an average diameter of 5 cm
- Two types:
    - Rapidly involuting congenital hemangioma (RICH):
        - Involutes rapidly after birth
        - 50% of lesions have completed regression by 7 months of age
            - Rthe remaining tumors are fully involuted by 14 months
        - Affects the head or neck (42%), limbs (52%) or trunk (6%)
        - Rarely requires treatment but may leave behind atrophic skin
    - Non-involuting congenital hemangioma (NICH):
        - Does not regress (remains unchanged with persistent fast-flow)
        - Involves the head or neck (43%), limbs (38%), or trunk (19%)
        - Staged excision can be considered if the scar will be less noticeable than lesion

II. Infantile hemangiomas

- Usually appear in the first two weeks of life, with 80% appearing in the first month of life
    - Proliferating phase: 0-9 months
        - Most of the growth achieved by 3 months
    - Involuting phase: 9 months to 12 years
        - Usually completed by age 4
- Involution leaves some scar or discoloration in 50% of patients
- Biopsy is rarely indicated, but are GLUT-1 positive on immunostaining
- Treatment:
    - Small (<2-3 cm) well-localized lesions: can use intralesional corticosteroid
    - Larger problematic lesions can be treated with oral prednisolone or propanolol
        - Propanolol: side effects of hypoglycemia
    - Surgery is indicated in the case of:
        - Failure or contraindication to pharmacotherapy
        - A well-localized tumor in an anatomically favorable area
        - If resection will be necessary in the future and the scar would be the same
        - Lesions (of any stage) that are compromising function (vision) or destroying vital structures

III. Kaposiform hemangioendothelioma

- Presents as a large (>5 cm), superficial, and diffuse lesion, with the overlying skin deep red-purple, tense, painful, and shiny
- Typically involves the trunk and extremities
- 50% present at birth (but can appear in childhood)
- Kasabach-Merritt phenomenon is common (thrombocytopenia <25,000, bruising, bleeding)
- Regression often seen after age 2, although long-term chronic pain and stiffness can persist
- Diagnosis: MRI
- First-line treatment is vincristine

IV. Capillary malformations

- Slow-flowing vascular malformation characterized by ectatic vessels located at various levels within the dermis
- Treatment: pulsed dye laser

V. Venous malformations

- Most common type of vascular malformation
- Present at birth, slowly increase in size as the child grows, change size with position, and are prone to thrombosis (phlebolith formation)
- Treatment: first line is sclerotherapy [sodium tetradecyl sulfate (STS), ethanol]
    - Aspirin helpful to prevent painful phleboliths

VI. Lymphatic malformations (cystic hygromas)

- Characterized as microcystic, macrocystic, or combined
- Most commonly occur in the cervicofacial region, axilla/chest, mediastinum, retroperitoneum, buttock, and perineum
- Diagnosis: MRI
- Treatment: reserved for symptomatic lesions that cause pain, significant deformity, or threaten vital structures
    - First line: sclerotherapy (doxycycline, STS, ethanol)
    - Can also use erbium laser or surgical excision

VII. Arteriovenous malformations

- High-flow vascular malformations characterized by warmth, pain, bony destruction, discoloration and sometimes ulceration of the overlying skin
- Treatment: embolization followed by excision 24-72 hrs later

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Chapter 9
Thermal, Electrical, and Chemical Injuries

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Thermal injuries are caused by exposure to extreme temperatures, chemicals, or electricity, and can result in destruction of the skin and underlying tissue causing local and systemic effects. The management of a major thermal injury requires an understanding of the pathophysiology, diagnosis, and treatment not only of the local skin injury, but also of the derangements that occur in hemodynamic, metabolic, nutritional, immunologic, and psychologic homeostatic mechanisms.

BURNS

- Pathophysiology: amount of tissue destruction is based on temperature (> 40° C) and time of exposure
- Diagnosis and prognosis:
  - Burn size: % of total body surface area (TBSA) burned
    - Rough estimates can be based on the rule of 9's (Fig. 1) or by the patient's palm size (the palm is approximately 1% TBSA)
    - The Lund-Browder chart is used to determine %TBSA
      - Note that different charts are required for adults and children due to head:chest size discrepancy and limb differentials for ages birth to seven years (Fig. 2, 3)

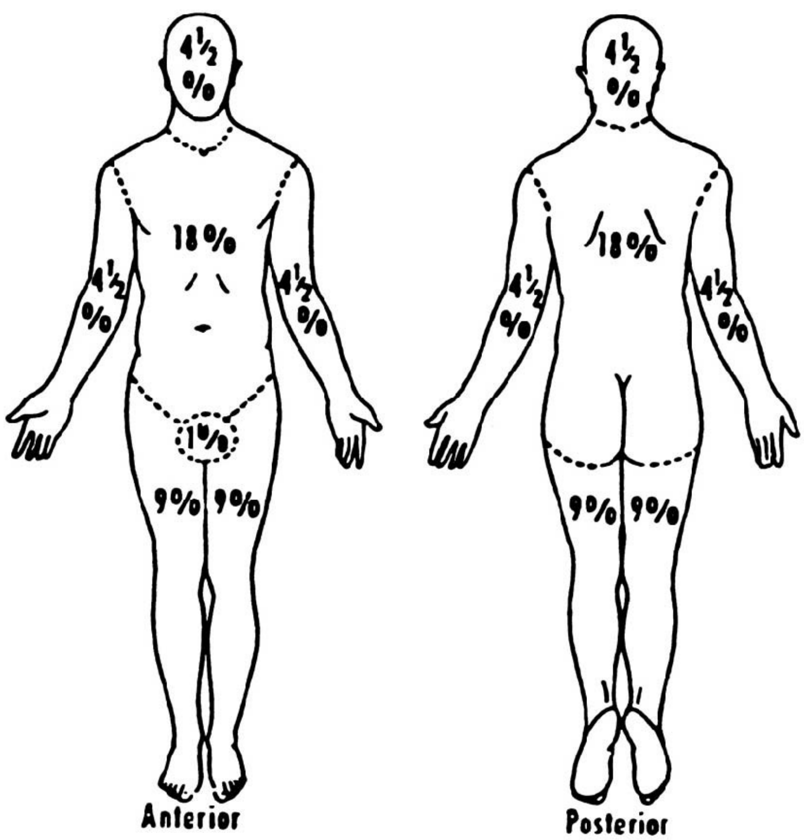
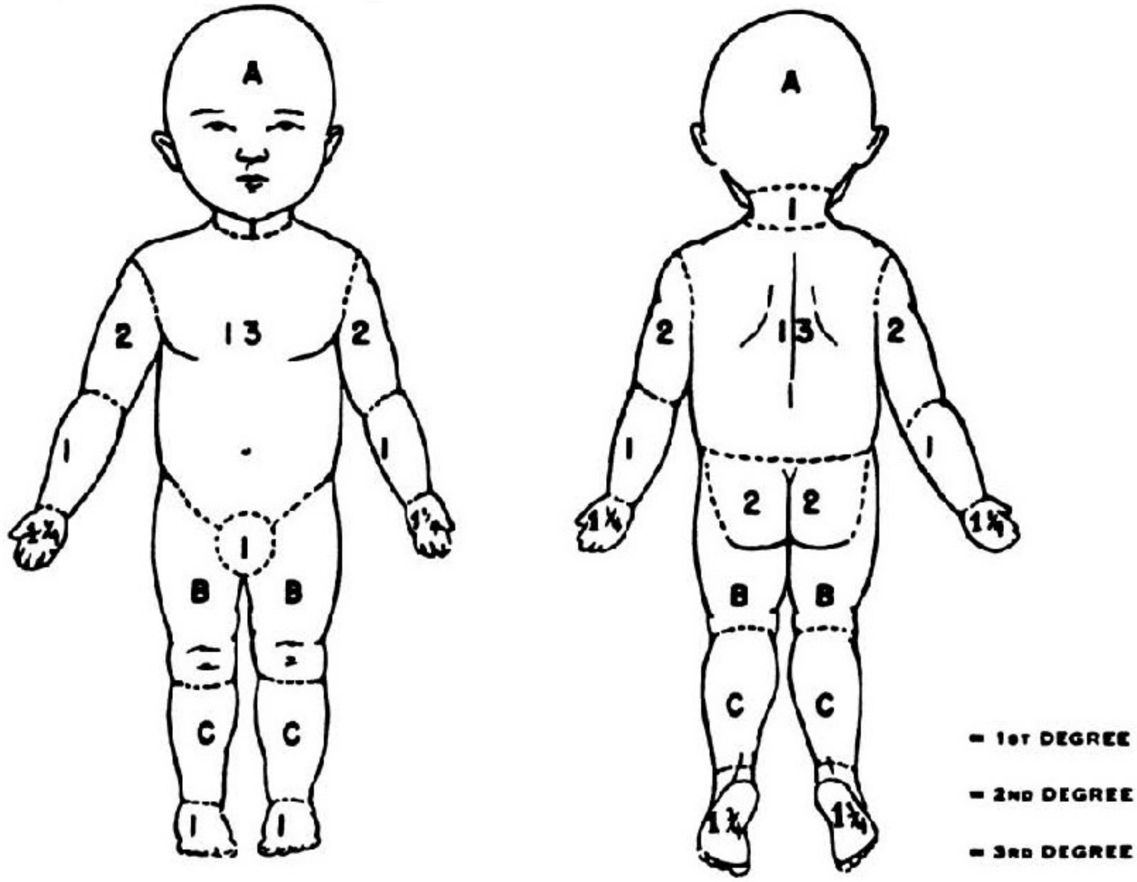


Figure 1. TBSA burn based on rule of 9's

BURN SHEET

NAME ______ AGE ______ NUMBER ______

BURN RECORD. AGES — BIRTH — 7 ½ DATE OF OBSERVATION ______



RELATIVE PERCENTAGES OF AREAS AFFECTED BY GROWTH

AREA		AGE 0	1	5
A	½ OF HEAD	9 ½	8 ½	6 ½
B	½ OF ONE THIGH	2 ¾	3 ¼	4
C	½ OF ONE LEG	2 ½	2 ½	2 ¾

% BURN BY AREAS

PROBABLE 3RD° BURN { HEAD ____ NECK ____ BODY ____ UP ARM ____ FOREARM ____ HANDS ____
GENITALS ____ BUTTOCKS ____ THIGHS ____ LEGS ____ FEET ____

TOTAL BURN { HEAD ____ NECK ____ BODY ____ UP. ARM ____ FOREARM ____ HANDS ____
GENITALS ____ BUTTOCKS ____ THIGHS ____ LEGS ____ FEET ____

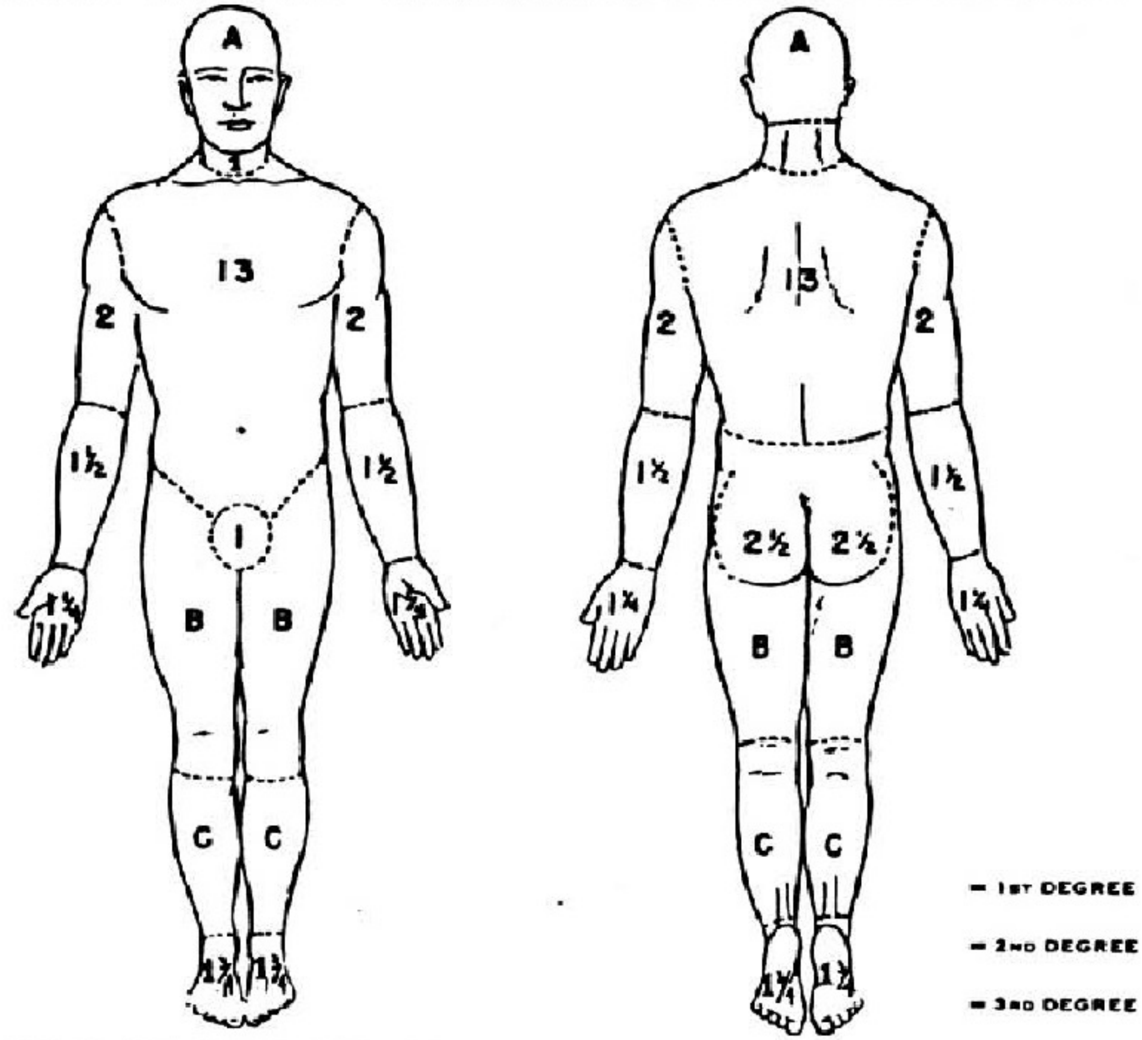
SUM OF ALL AREAS ______ PROBABLY 3RD° ______ TOTAL BURN ______

Figure 2. Lund-Browder chart for pediatric burns

BURN SHEET

NAME ______________________ AGE ________ NUMBER ______________

BURN RECORD. AGES 7 TO ADULT. DATE OF OBSERVATION ______________



RELATIVE PERCENTAGES OF AREAS AFFECTED BY GROWTH

AREA	AGE 10	15	ADULT
A ½ OF HEAD	5½	4½	3½
B ½ OF ONE THIGH	4¼	4½	4¾
C ½ OF ONE LEG	3	3¼	3½

% BURN BY AREAS

PROBABLE 3RD° BURN { HEAD ____ NECK ____ BODY ____ UP. ARM ____ FOREARM ____ HANDS ____
GENITALS ____ BUTTOCKS ____ THIGHS ____ LEGS ____ FEET ____

TOTAL BURN { HEAD ____ NECK ____ BODY ____ UP. ARM ____ FOREARM ____ HANDS ____
GENITALS ____ BUTTOCKS ____ THIGHS ____ LEGS ____ FEET ____

Figure 3. Lund-Browder chart for adult burns

- Age: burns at the extremes of age (very young or very old) carry a greater morbidity and mortality
- Depth: may be difficult to assess initially as injuries evolve and deepen over 24-72 hours
    - Varies based on type and temperature of etiologic agent, and time of exposure
    - Classification (Fig. 4 and Table 1)
        - First degree: superficial; erythema but no skin breaks; similar to a sunburn
        - Second degree: blisters present, red and painful, skin blanches
            - Superficial partial-thickness: involves epidermis and upper dermis
            - Deep partial-thickness: involves deeper dermis
        - Third degree: full-thickness; insensate, charred, or leathery in appearance; can appear bright cherry red but does not blanche
    - Fourth degree: deeper tissue such as muscle or bone affected

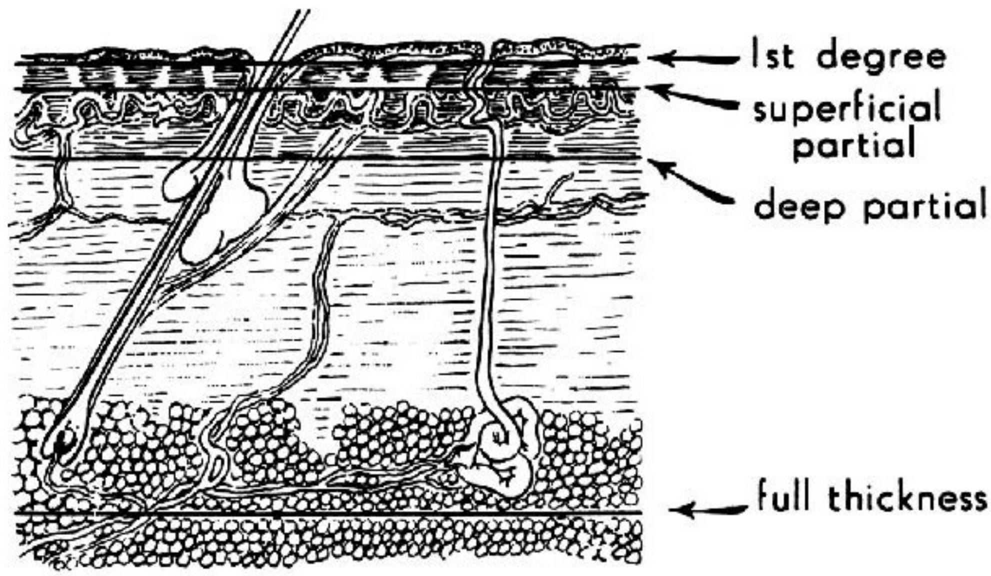


Figure 4. Classification of burns by depth

Table 1. Description and features of burns based on depth					
Degree	Depth	Layers involved	Features	Healing time	Management
First	Superficial	Epidermis only	Pink, red; brisk capillary refill, painful	<7 days	Symptomatic
Second	Superficial partial-thickness	Epidermis, papillary (upper) dermis	Pink, red; moist, edematous, brisk capillary refill, very painful	Variable, 10-28 days	Daily wound care, debride sloughed skin
	Deep partial-thickness	Epidermis, reticular (lower) dermis	White, pink, red; dry, no blanching, reduced sensation		Daily wound care, surgical excision and resurfacing
Third	Full-thickness	Epidermis, entire dermis	White, brown; dry, leathery, no blanching, insensate	>21 days	Surgical excision and resurfacing
Fourth	Full-thickness	Epidermis, entire dermis, fat, fascia, muscle, bone	Exposed deep tissue	N/A	Amputation, complex reconstruction

- Zones of injury:
    - Coagulation (central): tissues undergo necrosis and are irreparably damaged
    - Stasis (intermediate): vasoconstriction and ischemia (can improve or worsen, depending on treatment)
    - Hyperemia (peripheral): heals without scarring
- Location: face and neck, hands, feet, and perineum may cause specific functional issues and warrant careful attention; often necessitate hospitalization and/or transfer to a burn center (Table 2)
- Inhalation injury: beware of burns occurring in enclosed spaces
    - Signs include singed nasal/facial hair, carbon particles in pharynx, hoarseness, and conjunctivitis
    - Patients may not initially have any signs of airway compromise, so must have high index of suspicion
    - Inhalation injuries decrease the chance of survival and therefore require specific attention and treatment (Fig. 5)
- Consider associated injuries like fractures; depending on circumstances surrounding burn, patients may require full trauma workup
- Co-morbid factors (pre-existing cardiovascular, respiratory, renal and metabolic diseases; seizure disorders; alcoholism or drug abuse) should be considered and optimized during the acute and subacute treatment period to improve outcomes
- Prognosis: best determined by burn size (TBSA), age of patient, presence of inhalation injury (Fig. 5)
- Circumferential burns: can restrict blood flow to extremity or respiratory excursion of chest and may require emergent escharotomies
- Certain criteria are used to make the determination regarding whether transfer to a burn is necessary (Table 2)

- Treatment plan
  - History and physical exam
    - In pediatric burns, where the history does not correlate with the burn injury, consider the possibility of child abuse – contact social work and/or follow hospital-specific protocols
  - Relieve respiratory distress: escharotomies and/or intubation (see below)
  - Prevent and/or treat burn shock – fluid resuscitation with large bore IV x 2

Table 2. Burn center referral criteria (ABA Guidelines)
Partial-thickness burns >10% total body surface area (TBSA) in patients <10 yo or >50 yo
Partial-thickness burns >20% TBSA in all patients
Burns that involve the face, hands, feet, genitalia, perineum, or major joints
Third-degree burns in any age group
Electrical burns, including lightning injury
Chemical burns
Inhalational injury
Burn injury in patients with pre-existing medical disorders that could complicate management, prolong recovery, or affect mortality
Any patient with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or mortality
Burned children in hospitals without qualified personnel or equipment for the care of children
Burn injury in patients who will require special social, emotional, or rehabilitative intervention

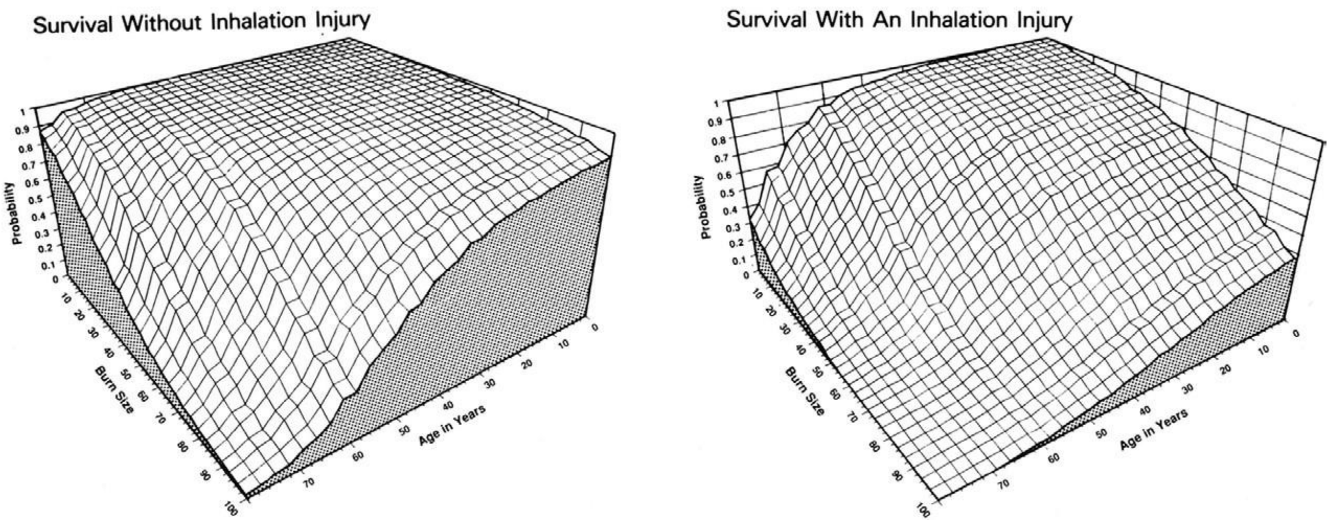


Figure 5. Survival from burns with and without inhalational injury

- - Monitor resuscitation with foley catheter and hourly urine output
  - Treat ileus and nausea: NG tube if > 20% TBSA burn or intubated
  - Tetanus prophylaxis
  - Thromboembolic prophylaxis
  - Baseline laboratory studies (i.e., CBC, CMP, UA, chest x-ray, EKG, cross-match, arterial blood gases, and carboxyhemoglobin)
  - Cleanse, debride, and treat the burn wounds
- Respiratory involvement:
  - Three major causes of respiratory distress in the burned patient
    1. Unyielding burn eschar encircling chest
       - Distress may be apparent immediately
       - Requires escharotomies (cutting into the eschar to relieve constriction)
    2. Carbon monoxide poisoning
       - May be present immediately or have a delayed presentation; high level of suspicion if patient exposed to smoke in an enclosed space
       - Diagnosed by carboxyhemoglobin levels measured in arterial blood gas
       - Important to remember that patients with a history of smoking may have baseline elevated carboxyhemoglobin
       - Initial treatment is displacement of CO by 100% O2 by facemask
       - Hyperbaric oxygen treatment may be of value, but is often not practical in many locations
    3. Smoke inhalation leading to pulmonary injury
       - Insidious in onset (18-36 hours)
       - Due to incomplete products of combustion, not heat (direct thermal injury to lungs occurs only secondary to steam burns)
       - Causes chemical injury to alveolar basement membrane and subsequent pulmonary edema
       - Initial treatment is humidified O2, but intubation and respiratory support may be required
       - Secondary bacterial infection of the initial chemical injury leads to progressive pulmonary insufficiency and infection – mucosal barrier of respiratory tract is damaged
       - Severe inhalation injury alone or in combination with thermal injury carries a grave prognosis

        - Three stages of presentation have been described:
            1. Acute pulmonary insufficiency (immediately postburn to 48 hours)
            2. Pulmonary edema (48-72 hours)
            3. Bronchopneumonia (25 days)
        - Monitor respiratory and mental status — be aware of hoarseness, wheezing, stridor. If any concerns about current or future airway involvement, best to intubate patient prior to excessive airway edema
- Burn shock
    - Massive amounts of fluid, electrolytes, and protein are lost from circulation almost immediately after burning (Table 3)

Table 3. Burn or associated condition dictating extra fluid administration
Underestimation of the %TBSA burn
Burns >80% TBSA
Associated traumatic injury
Electrical burn
Associated inhalational injury
Delayed start of resuscitation
Fourth degree burn
Administration of osmotic diuretics
Pediatric burns

    - Systemic inflammatory response occurs if > 20% TBSA burn in adults, >30% TBSA in children, and >15% TBSA in elderly — results in a hypermetabolic state and increased capillary permeability
    - Resuscitation requires replacement of sodium ions and water to restore plasma volume and cardiac output – initiate if adult burns >15-20% TBSA and pediatric burns >10% TBSA
        - Many formulas have been reported to achieve resuscitation, but these serve only as a guide for initial IVF; must also monitor UOP and hemodynamics to appropriately titrate rate
            - Parkland formula: 4 cc Ringer's lactate/kg/%TBSA burn over the first 24 hours
                - 1/2 of the 24-hour fluid requirement should be given in the first 8 hours postburn and the remaining 1/2 over the next 16 hours
            - Remember to factor in any fluid boluses patient may have received either in ED or at OSH when performing calculations
    - Administration of colloid during or after resuscitation can vary from burn center to burn center
    - Children should receive maintenance fluids (weight-based 5% dextrose in half-normal saline), as well as resuscitative fluids
- Monitoring resuscitation
    - Urine output 0.5-1cc/kg/hr in adults and 1cc/kg/hr in children <12 yo
    - A clear sensorium, pulse <140/min, BP >90/60 mmHg, HCO_3 >18meq/L, cardiac output >3.5 L/min/M^2 in adults
    - CVP in acute major burns is unreliable – use if myocardial disease, age >65 yo, inhalation injury, fluid requirements >150% of expected

- Metabolic considerations
    - Increased metabolic demands in patients with burn injury (hypermetabolic state)
    - High carbohydrate/high protein diet – dietician and tube feeds as needed
    - Early feeding (start at 12 hours) – prevents mucosal atrophy, ulceration, bacterial translocation in gut
    - Measure prealbumin to determine nutritional status (goal >20)
- Treatment of the burn wound
    - Primary treatment is early excision of full thickness burns as soon as possible
        - As soon as patient in stable, plan for multiple trips to the operating room
        - Surgeries performed in a warm room
        - Begin with largest areas first
        - Hand burns should be excised by 14 days post-injury
        - Face burns typically excised last
    - Necrotic tissues or any burned tissue not expected to heal within 2-3 weeks may be removed by any of several techniques
        - Formal excision
        - Tangential (layered) debridement
        - Enzymatic debridement
        - Hydrotherapy — a useful adjunct
    - Specific burn wound dressings differ from one burn center to another
        - The most common topical antibacterials are silver sulfadiazine (Silvadene®) and mafenide acetate (Sulfamylon®)
        - Dressing changes at least 1x/day with soap and water
        - Status of burn wound bacterial colonization and effectiveness of topical antibacterial treatment can be monitored by physical exam or biopsies of wound for quantitative and qualitative bacteriology
        - Systemic antibiotic therapy only used for sepsis, not prophylactically (breeds resistant organisms)
    - Wound closure by the patient's own skin (autograft) is the ultimate goal of treatment
        - Other options include:
            - Secondary intention healing
            - Allograft: will need to be replaced with autograft in a delayed fashion
            - Xenograft: will need to be replaced with autograft in a delayed fashion
        - Artificial skin: various dermal replacement products exist (Integra®, Restrata®, Matriderm®, Keresis®, BTM®, etc.)
        - Cultured epithelial cells: available only at certain centers, require time to grow them and $$$
    - Autografts should be applied to priority areas first, such as the hands, face and important joints, as well as the neck for possible tracheostomy placement
    - Once healed, pressure with elastic support/compression garments is usually necessary to reduce hypertrophic scarring
    - Physical therapy/occupational therapy - important adjunct in burn care, helps prevent contractures, especially for burns that cross joint surfaces
- Complications: can occur in every physiologic system or secondary to burn injury
    - Renal failure
        - From hypovolemia
        - Beware of nephrotoxic medications in the burn patient
        - Myoglobinuria associated with compartment syndrome
    - Gastrointestinal bleeding
        - Curling's ulcer: gastric ulcer that results from large TBSA burn due to decreased plasma volume that causes ischemia of gastric mucosa
            - More likely in burns over 40% TBSA
            - Usually remains subclinical

        - Antacids and H2 blockers
        - Increased risk with burn wound sepsis
- Burn wound sepsis (Table 4)
    - Monitored by physical exam, vitals, and tissue biopsy (qualitative and quantitative)
    - Must keep bacterial count <10^5 bacteria/gm of tissue
    - Clinically suspect global sepsis with:
        - Sudden onset of hyper- or hypothermia
        - Unexpected congestive heart failure or pulmonary edema
        - Development of the acute respiratory distress syndrome
        - Ileus occurring after 48 hours post-burn
        - Mental status change
        - Azotemia
        - Thrombocytopenia
        - Hypofibrinogenemia
        - Hyper- or hypoglycemia is especially suspect if burn > 40% TBSA
    - Blood cultures may be positive but in many cases are not

Table 4. Risk factors in burn wound infection
Patient factors
Extent of burn >30% TBSA
Depth of burn: full-thickness vs. partial-thickness
Age of patient (very young or very old at high risk)
Pre-existing disease
Wound dryness
Wound temperature
Secondary impairment of blood flow to wound
Acidosis
Microbial factors
Density >10^5 organisms per gram of tissue
Motility
Metabolic products: endotoxin, exotoxins, permeability of factors, other factors
Antimicrobial resistance

- Progressive pulmonary insufficiency
    - Can occur after:
        - Smoke inhalation
        - Pneumonia
        - Cardiac decompensation
        - Sepsis from any cause
    - Produces:
        - Hypoxemia
        - Hypocarbia
        - Pulmonary shunting
        - Acidosis
- Over-resuscitation
    - If IVF rate remains elevated despite adequate UOP, increased risk for:

- Over-resuscitation
  - If IVF rate remains elevated despite adequate UOP, increased risk for:
    - Abdominal compartment syndrome
    - Extremity compartment syndrome
    - Acute respiratory distress syndrome (ARDS)
- Wound contracture and hypertrophic scarring:
  - Largely preventable
  - Active range of motion of involved and adjacent joints is encouraged to prevent joint contractures from the outset
    - Splints and passive range of motion are used if active range of motion is unable to be performed, e.g., elbow and knee are kept in extension, fingers are kept in a position opposite to the burn injury to prevent contracture of reconstructed surfaces
    - Limb elevation and range of motion are useful for reducing edema and maintaining movement
  - Timely wound closure with adequate amounts of skin should largely eliminate these problems
  - Continued postoperative splinting and silicone-lined compression garments are of value in the remodeling of collagen with prevention of hypertrophic scars
  - Contractures may require future revision and reconstructive procedures months to years after original burn injury
    - Laser and steroid/5-FU injections can be helpful adjuncts to surgical procedures in tertiary burn reconstruction

CHEMICAL BURNS

- Pathophysiology
  - Tissue damage secondary to a chemical depends on:
  - Nature of agent
  - Concentration of the agent
  - Quantity of the agent
  - Length of time the agent is in contact with tissue
  - Degree of tissue penetration
  - Mechanism of action
- Diagnosis
  - Chemical burns are deeper than initially appear and may progress with time
    - Alkali burns may be more severe due to ability to deeply penetrate tissues
  - Fluid resuscitation needs often underestimated
  - Watch for renal/liver/pulmonary damage
- Treatment
  - Initial treatment is dilution of the chemical with tap water
    - Copious irrigation for 30 minutes
    - Exception: brush cement/concrete/powdered lye/other powders off dry
  - Special attention to eyes: after copious irrigation with saline, consult ophthalmologist
  - After 12 hours initial dilution, local care of the wound with debridement, topical antibacterials, and eventual wound closure is same as for thermal burn
- Of particular note are:
  - Gasoline
    - Excretion by lung
    - May cause large skin burn, if immersed
    - Watch for atelectasis, pulmonary infiltrates; surfactant is inhibited
  - Phenol
    - Dull, gray color to skin, may turn black

        - Urine may appear smoky in color
        - Spray water on burn surface
        - Wipe with polyethylene glycol
        - Direct renal toxicity
    - Hydrofluoric acid
        - Irrigate copiously with water
        - Subcutaneous injections of 10% calcium gluconate or intra-arterial infusion in affected extremities
        - Serial EKG and BMP monitoring of patients — may become hypocalcemic
        - Pulmonary edema may occur if subjected to fumes
    - Monitor effectiveness of treatment by frequent pain assessment — if treatment is working, pain should decrease
- White phosphorous burn
    - Do not allow to desiccate — may ignite
    - Each particle must be removed mechanically
    - Copper sulfate (2%) may counteract to make phosphorous more visible (turns black in color)
    - Watch for EKG changes (Q-T interval and S-T and T wave changes)
    - May cause hemoglobinemia and renal failure

ELECTRICAL BURNS

- Pathophysiology
    - Effects of passage of electric current through the body depend on:
        - Type of circuit
        - Voltage of circuit
        - Resistance offered by body
        - Amperage of current flowing through tissue
        - Pathway of current through the body
        - Duration of contact
    - Tissue resistance to electrical current increases from nerve (least resistant) to vessel to muscle to skin to tendon to fat to bone
- Diagnosis
    - Types of injury
        - Arc injury: localized injury caused by intense heat, current does not run through patient's body
        - Injury due to current
            - Due to heat generated as current flows through tissue
                - Injury more severe in tissue with high resistance (i.e., bones)
                - Vessels thrombose as current passes rapidly along them
                - Deeper structures are usually more profoundly affected (e.g., muscles of the deep volar forearm compartment more affected than superficial volar forearm compartment)
            - Effect of current may not be immediately seen
- Special effects of electrical injury
    - Cardiopulmonary
        - Anoxia and ventricular fibrillation may cause immediate death
        - Early and delayed rhythm abnormalities can occur
        - EKG changes may occur after burn in a delayed fashion; need serial EKG monitoring
    - Renal
        - High risk of renal failure due to hemoglobin and myoglobin deposits in renal tubules – important to see if myoglobinuria is present
            - Requires higher IVF/urine flow (75 cc/h in adults)
            - Must alkalinize urine to keep hemoglobin and myoglobin in more soluble state

        - Mannitol may be useful to clear heavy protein load
    - Musculoskeletal
        - Tetanic muscle contractions may be strong enough to fracture bones, especially spine
        - Although there may be minimal external damage, have a high suspicion for compartment syndrome in extremities — requires emergent fasciotomy
    - Spinal cord damage
        - Can occur secondary to fracture or demyelinating effecting of current
    - Abdominal effects
        - Intraperitoneal damage can occur to GI tract secondary to current
    - Vascular effects
        - Vessel thrombosis progresses with time
        - Delayed rupture of major vessels can occur
    - Cataract formation — late complication
    - Seizures
- Treatment
    - CPR if necessary
    - Fluids usually higher amounts than Parkland formula calculation
        - No formula is accurate because injury is more extensive than can be predicted by skin damage
        - Alkalinize with $NaHCO_3$, if myoglobinuria or hemoglobinuria present
    - Monitoring
        - CVP or pulmonary wedge pressure helpful since total capillary leak does not occur as it does in a in thermal burn
        - Maintain urine output at 75-100 cc/h until all myoglobin and/or hemoglobin disappears from urine
    - Wound management
        - Topical agent with good penetrating ability is needed [i.e., silver sulfadiazine (Silvadene®) or mafenide acetate (Sulfamylon®)]
        - Debride non-viable tissue early and repeat as necessary (every 48 h) to prevent sepsis
        - Major amputations frequently required
        - Technicium-99 stannous pyrophosphate scintigraphy may be useful to evaluate muscle damage
    - Treat associated injuries (e.g., fractures or compartment syndrome)

COLD INJURIES

The two conditions of thermal injury due to cold are local injury (frostbite) and systemic injury (hypothermia).

I. Frostbite

- Pathophysiology: formation of ice crystals in tissue fluid usually in areas that lose heat rapidly (e.g., extremities)
    - Anything which increases heat loss from the body (such as wind velocity) or decreases tissue perfusion (such as tight clothing) predisposes the patient to frostbite
    - Ability of various tissues to withstand cold injury is inversely proportional to their water content
- Treatment: key to successful treatment is rapid rewarming in a 40°C water bath
    - Admission to hospital usually required
    - Tetanus prophylaxis
    - Thrombolysis
        - If < 24 h since injury, consider systemic thrombolysis
        - NSAIDs, heparin, and aspirin therapy
    - Wound management: blister removal not required
    - Physical therapy: important to maintain range of motion; daily whirlpool and exercise

- Sympathectomy, anti-coagulants, and early amputation were of questionable value in controlled studies
- Usually wait until complete demarcation before proceeding with amputations. Non-viable portions of extremities will often autoamputate with good cosmetic and functional results, but takes a long time

II. Hypothermia

- Diagnosis
    - Core temperature < 34°C
    - Symptoms and signs mimic many other diseases
    - High level of suspicion necessary during cold injury season
- Treatment
    - Must be rapid to prevent death
    - Monitor EKG, CVP, and arterial blood gases and pH during warming and resuscitation, maintain urine output of 50 cc/h
    - Begin Ringer's lactate with 1 ampule $NaHCO_3$
    - Oral airway or endotracheal tube if necessary
    - Rapidly rewarm in 40°C hydrotherapy tank (requires 1-2 hours to maintain body temperature at 37°C)
    - Treat arrhythmias with IV lidocaine or amiodarone drip if necessary
    - Evaluate and treat any accompanying disease states

LIGHTNING INJURIES

- Cutaneous effects: lightning strikes may cause cutaneous burn wounds
    - Contact burns from clothing on fire or contact with hot metal (i.e., zippers, etc)
    - Entry and exit burns are usually small, may be partial or full-thickness
- Lightning burns are not the same as electrical burns; don't cause deep tissue injury
- May have temporary ischemic effects on extremity, such as pallor or neurologic deficits
    - Spontaneous recovery after a few hours is the expectation; probably due to local vasoconstriction
- Systemic effects can occur such as arrhythmias, cataracts, CNS symptoms (similar to electrical injuries)

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Chapter 10
Facial Fractures

Rachel Williams, MD
Yifan Guo, MD

Facial fractures are a common consequence of trauma and can significantly impact both function and aesthetic appearance. An understanding of the basic anatomy of the face, common fracture patterns, and principles of evaluation and management is essential for accurate diagnosis and effective treatment. This chapter introduces the foundational concepts of facial fractures, including their classification, clinical signs, indications for intervention, and surgical approaches.

INITIAL EVALUATION

- Obtain history: mechanism of injury, prior history of facial trauma, time of injury and subjective complaints, medical comorbidities, and past surgeries
- Physical exam
    - ABCs
    - Evaluate C-spine in patients with facial trauma
    - Inspect and palpate
    - Cranial nerve exam: sensation (CN V1, V2, V3) and motor (CN VII)
    - Eyes
        - Test pupillary light response
        - Test extraocular movements (EOM) to rule out entrapment
    - Assess for enophthalmos or proptosis
    - Ears
        - Assess for battle sign (bruising of mastoid), which can indicate skull base fracture
        - Assess for hemotympanum
    - Nose
        - Palpate nasal bones
        - Rule out septal hematoma
    - Midface
        - Assess for malar flattening
        - Assess for any increased mobility
    - Mandible
        - Assess occlusion (ask patient if their bite feels normal)
            - If patient unresponsive, examine wear of teeth
        - Any damaged or missing teeth
        - Palpate TMJ
        - Evaluate for dental injury, missing teeth
- Diagnostics
    - Maxillofacial CT is gold standard to evaluate facial fractures
        - Evaluate sagittal, coronal and axial views
        - 3D Reconstruction can be helpful for surgical planning

MANDIBLE FRACTURES

- Often more than one fracture site
- Teeth within line of fracture should be kept if root is not fractured
- Classified based on location of mandible (Fig. 1), simple vs. comminuted, open vs. closed, and intracapsular vs. extracapsular (condylar)

- Subtypes:
  - Symphyseal/parasymphyseal
  - Body
  - Angle
  - Coronoid
  - Condylar and subcondylar
  - Ramus
- Indications for open reduction and internal fixation (ORIF): displaced fracture with abnormal occlusion
  - Maxillomandibular fixation used to restore occlusion

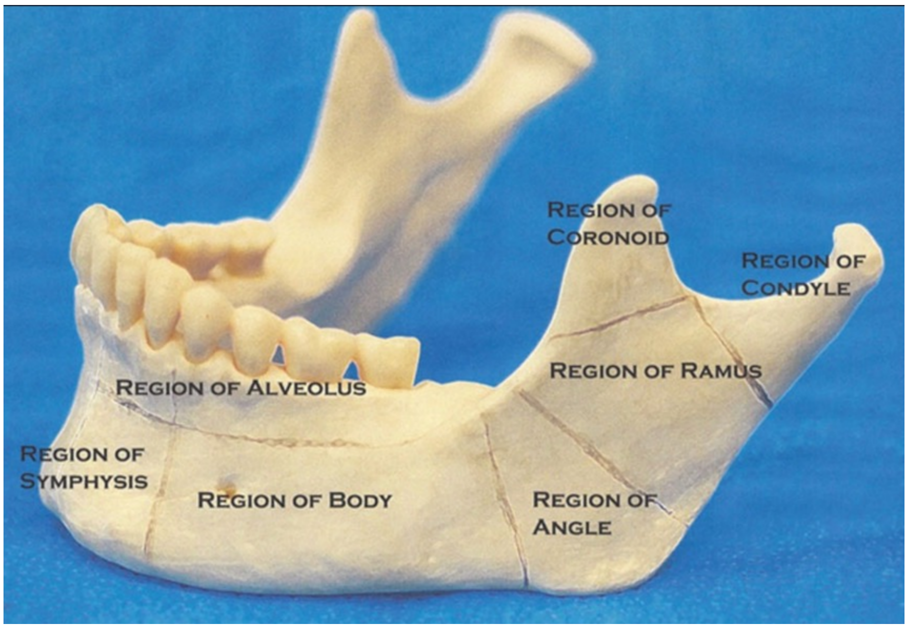

Figure 1. Anatomical regions of mandible. *From Morrow BT, et al. Evidence-based medicine: Mandible fractures. Plast Reconstr Surg . 2014 Dec;134(6):1381-1390.*

ZYGOMATICOMAXILLARY FRACTURES

- Zygoma articulates with maxilla, sphenoid, temporal and frontal bones
- Signs:
  - Flattened malar eminence
  - Trismus
  - Infraorbital nerve paresthesia
  - Diplopia, enopthalmos
- Zygomaticosphenoid articulation most important for reduction of fracture
- ORIF to restore facial width and malar projection
  - Approaches: eyelid (transconjunctival or subtarsal), intraoral, lateral brow or coronal (for arch)

ORBITAL FRACTURES

- Orbital floor and medial wall fractures most common
- Obtain ophthalmology consult to rule out ophthalmic emergencies: retrobulbar hematoma, hyphema, globe rupture, optic nerve injury, entrapment of extraocular muscles
- Signs:
  - Enophthalmos: fractures cause increase in intraorbital volume
  - Diplopia (especially with upward gaze)

- Hypoglobus
- Proptosis/exophthalmos: due to periorbital swelling

- Emergent intervention needed with entrapment of extraocular muscles
- Indications for ORIF: persistent diplopia, fracture >50% orbital floor, clinically significant enophthalmos
- ORIF through subtarsal and transconjunctival incisions

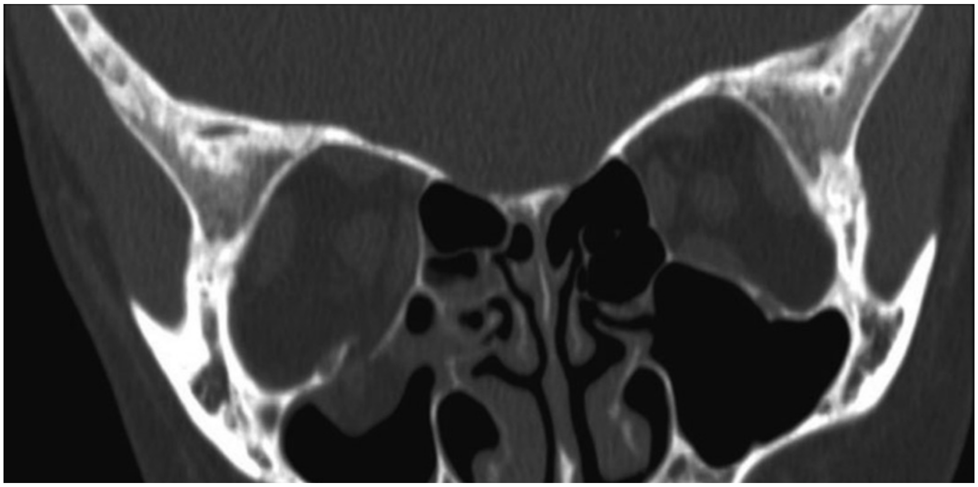

Figure 2. Coronal CT showing right orbital trapdoor fracture with displacement of inferior rectus muscle through fracture. Note the rounded shape of the muscle belly compared with the unaffected eye. *From Morrow BT, et al. Evidence-based medicine: Mandible fractures. Plast Reconstr Surg . 2014 Dec;134(6):1381-1390.*

NASAL FRACTURES

- Most common facial fracture
- Septal hematoma must be drained urgently
- Paired nasal bones compose upper one-third of nose
  - Lower two-thirds is paired cartilage
- Fractures typically treated within 2 weeks of injury
  - Closed reduction performed for simple nasal fractures
  - Open reduction if severe displacement or failed closed reduction

NASO-ORBITO-ETHMOID (NOE) FRACTURES

- Fracture of nasal bone, frontal maxilla, lacrimal bone and ethmoid bone
- Can involve medial canthal tendon
- Markowitz classification (Fig. 3):
  - 1: single non-comminuted fragment
  - 2: comminution, tendon attached to fragment
  - 3: comminution with tendon avulsion
- Signs:
  - Telecanthus
  - Shortened depressed nasal bone
  - Mobility of medial canthus on exam
- Rule out concurrent brain injury
- Early intervention to repair with canthal reattachment

FRONTAL BONE FRACTURES

- High force injury
- Anterior table fracture:

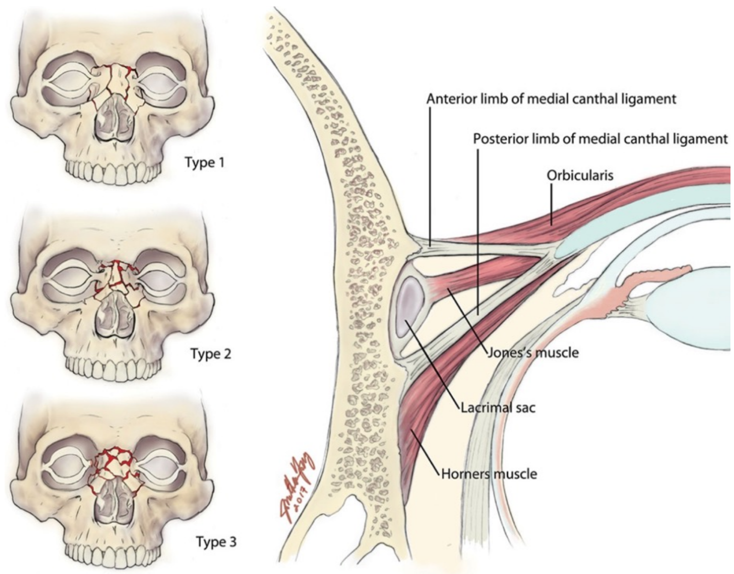

Figure 3. Markowitz classification of NOE fractures. *From Chaudry O, et al. Facial Fractures: Pearls and Perspectives. Plast Reconstr Surg . 2018 May;141(5):742e-758e.*

- Signs: forehead depression, step-off
- Treatment: observation or ORIF
- Posterior table fracture:
    - Risks: CSF leak, meningitis
    - Treatment (Fig. 4):
        - CSF leak present: Neurosurgical consultation, sinus obliteration or cranialization
        - No leak: observation or delayed repair
- Frontal outflow tract injury:
    - Requires sinus obliteration

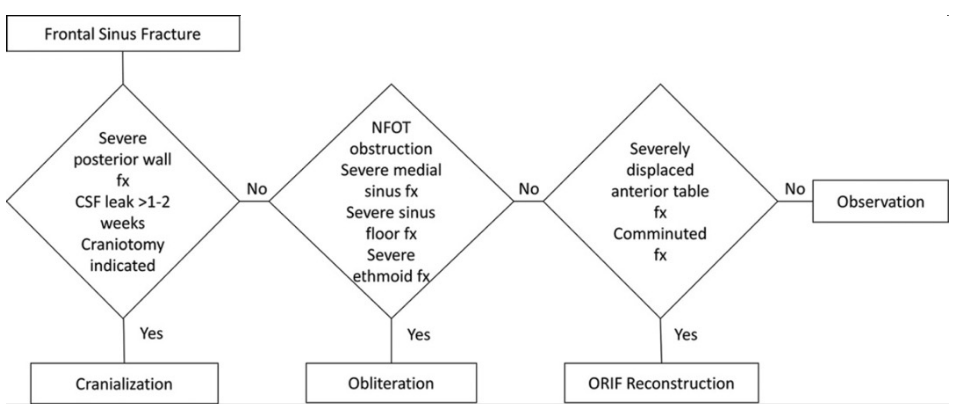

Figure 4. Decision tree for management of frontal sinus fractures. *From Chaudry O, et al. Facial Fractures: Pearls and Perspectives. Plast Reconstr Surg . 2018 May;141(5):742e-758e.*

MAXILLARY FRACTURES

- Frontal, zygomatic, palatine and alveolar processes
- Strength from three buttresses
    - Nasomaxillary
    - Zygomatic
    - Pterygomaxillary

- Le Fort classification (Fig. 5):
    - I: transverse fracture through maxilla above apices of teeth
        - Mobility of hard palate and teeth only
    - II: pyramidal fracture involves nasal bridge, maxilla, orbital floor and infraorbital rim
    - III: craniofacial disjunction involves zygomatic arch, orbital walls and nasal bridge
        - Fracture through pterygoid plates
        - Entire midface is mobile

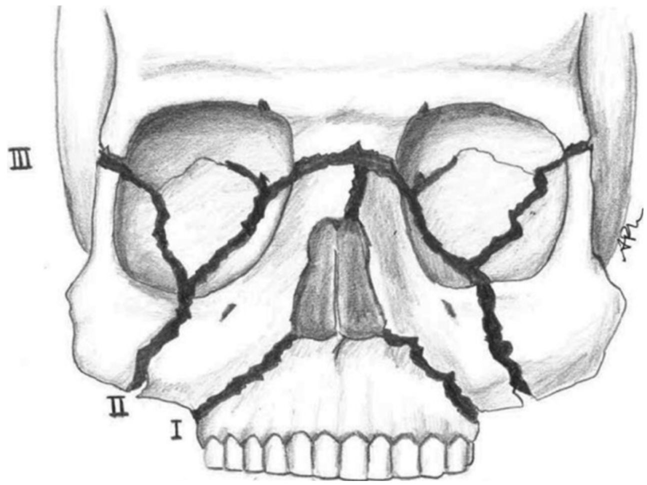

Figure 5. Le Fort classic description of midfacial fracture lines. Biomechanically these function as crumple zones and protect the neurocranium from frontal trauma. *From Chaudry O, et al. Facial Fractures: Pearls and Perspectives. Plast Reconstr Surg . 2018 May;141(5):742e-758e.*

- Treatment:
    - Alveolar fracture: arch bars and place segment in occlusion with IMF wires
    - Le Fort fractures: observation for minimally displaced fractures without occlusal changes; IMF with open reduction and internal fixation of nasomaxillary and zygomaxillary buttresses for displaced fractures

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Chapter 11
Head and Neck

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The head and neck region presents one of the most complex and functionally significant areas of reconstructive plastic surgery. Plastic surgeons frequently manage defects related to congenital anomalies, trauma, and oncologic resections in the head and neck area. The content of this chapter will focus on neoplasms of the head and neck, and their subsequent reconstruction. Essential functions including speech, swallowing, vision, and facial expression underpin the reconstructive efforts and a multi-disciplinary approach is critical for success. Strategies are guided by defect size and location, pathology, and regional priorities. This chapter will provide a comprehensive guide to tackle these challenging problems from the perspective of a plastic surgeon.

INFECTIONS

The head and neck are relatively resistant to infection due to their robust vascularity.

I. Routes of spread

- Upper aerodigestive infections may track into the mediastinum
- Scalp and orbital infections may spread intracranially via the dural sinuses and ophthalmic veins

II. Types

- Facial cellulitis: mostly due to staphylococcus or streptococcus
  - May use a cephalosporin
- Oral cavity infections: mostly due to anaerobic *Streptococcus* and *Bacteroides*
  - Use extended spectrum penicillin or other anaerobic coverage (Augmentin/Unasyn)
- Acute sialadenitis: fever, pain, swelling over the involved parotid gland
  - Seen with dehydration, debilitation, diabetics, poor oral hygiene
  - Treat with antibiotics, fluids
- Atypical mycobacteria: seen in enlarged lymph nodes
  - Drainage rarely required
  - Special cultures may be necessary

NEOPLASTIC *(exclusive of skin, see Chapter 8)*

Neoplastic processes are primarily managed by otolaryngologists, but provide major reconstructive challenges for plastic surgeons.

I. TNM staging

- The AJCC 8th edition introduced major changes to the TNM, or tumor-node-metastasis staging of head and neck neoplasms, most notably with the creation of a separate algorithm for HPV-associated oropharyngeal squamous cell carcinoma.
  - HPV status is determined by p16 immunohistochemistry as a surrogate
  - HPV DNA testing is recommended for prognostic accuracy
  - HPV-associated diseases have a better overall prognosis than other SCCs
- T: Tumor – denoted by the specific size of the major tumor mass
- N: Nodes – denoted by the number of affected nodes, and considers nodal chains on both the ipsilateral and contralateral neck as modifiers

- M: Metastasis – denotes the distant spread of this disease
    - Most common site is lungs, regardless of primary subsite or tissue type
    - HPV+ SCC has lower metastasis risk to non-HPV associated disease
    - American College of Radiology recommends comprehensive imaging (CT, MRI and FDG-PET/CT for accurate staging

II. Salivary gland tumors

- Classification of tumors by location
    - Parotid: most common (80%), most are benign (80%)
    - Submandibular: 55% incidence of malignancy
    - Minor salivary glands: least common, with highest incidence of malignancy (about 75%)
- Diagnosis
    - Primarily by physical examination
        - Any mass in the pre-auricular region or at the angle of the jaw is a parotid tumor until proven otherwise
    - Bimanual palpation: simultaneous intraoral and external palpation
    - Signs more commonly seen with malignancy:
        - Fixed or hard mass
        - Pain
        - Loss or disturbance of facial nerve function
        - Cervical lymphadenopathy (metastases)
- Treatment
    - For benign tumors:
        - Surgical removal of gland with sparing of adjacent nerves, e.g., facial nerve with parotid; lingual and hypoglossal nerves with submandibular
    - For malignant tumors:
        - Surgical removal of entire gland with sparing of nerve branches that are clearly not involved
        - Radiation therapy if tumor not completely removed
        - Cervical lymph node dissection with tumors prone to metastasize to nodes
- Pathology
    - Benign
        - Pleomorphic adenoma: (benign mixed) high recurrence rate with local excision
        - Papillary cystadenoma lymphomatosum (Warthin's tumor): may be bilateral, (10%) male, age 40-70
    - Malignant
        - Mucoepidermoid
        - Malignant mixed
        - Adenocarcinoma

III. Oral cavity tumors

- Classification
    - Anatomical: malignancies behave differently according to anatomic site and prognosis worsens from anterior to posterior
    - Histopathologic
        - Benign: fibroma, osteoma, lipoma, cyst, etc.
        - Malignant
            - Most are squamous cell carcinoma or variants (may be related to HPV, see above)
            - Palate carcinomas are often of minor salivary gland origin
            - Sarcomas in mandible, tongue, other sites are rare

- Diagnosis
  - Examination: including indirect laryngoscopy and nasopharyngeal endoscopy when indicated
  - "If tumor is the rumor, tissue is the issue" — biopsy of any lesion is essential for diagnosis
  - X-rays and scans as indicated
- Treatment
  - Surgical
    - Benign: simple excision
    - Malignant
      - Wide local excision with tumor-free margins with/without lymph node dissection
      - Palliative resection may be indicated for comfort and hygiene
      - Immediate reconstruction with vascularized flaps when indicated by size and location of defect *(see next section)*
  - Radiation therapy
    - Pre-operative
      - To increase chance for cure, especially with large lesions
      - May make an inoperable lesion operable by shrinking it and reducing involvement with unresectable structures
    - Post-operative
      - If tumor-free margin is questionable
      - For recurrence
      - Prophylactic — controversial
  - Chemotherapy: usually for advanced disease
  - Immunotherapy: increasing indications to downsize tumors or as primary treatment

RECONSTRUCTION

I. General principles

- Goals
  - Tension free closure of skin and soft tissue
  - Maintenance of motor and sensory function
  - Recreation of aesthetic contours
  - Restore speech and swallowing function
- Reconstructive ladder
  - Primary closure (often best option if possible)
  - Skin graft (full thickness for best color and quality match)
  - Local flaps (often require two stages)
  - Tissue expansion
  - Free tissue transfer
- Reconstructive elevator
  - More modern approach to head and neck reconstruction
  - Advocates for selecting the optimal technique based on defect complexity and patient needs, often bypassing intermediate steps for large, composite defects

II. Scalp

- Anatomy:
  - S (skin), C (Subcutaneous tissue), A (Aponeurosis/Galea), L (Loose areolar tissue), P (Pericranium)
- Goals:
  - Function: protection of intracranial structures from dessication, injury or infection
  - Aesthetic: maintaining appropriate hairline, limiting alopecia, scar patterns

        - Replace "like with like"
    - Primary closure often possible, can be assisted with galeal relaxation incisions (scoring), where an additional 3 cm can be gained
    - Rotation and/or advancement flap options
        - Should be roughly 4-to-6 times the size of the defect
        - O-to-Z flap
        - 3- or 4-flap Orticochea technique
    - Tissue expansion is an excellent option (can allow up to 50% reconstruction without obvious alopecia)
    - Free tissue transfer: typically reserved for large defects, defects previously radiated or planned to undergo radiation, or failed previous reconstructions
        - Latissimus dorsi flap ± posterior ribs and skin graft for composite defects
        - ALT free flap for vascularized fascia coverage

III. Eyelid

- Anatomy:
    - Eyelid is composed of 3 lamellae
        - Anterior lamella: skin and orbicularis oculi muscle
        - Middle lamella: orbital septum
        - Posterior lamella: tarsus and conjunctiva
    - Eyelid loss can be partial thickness (anterior ± septum) or full thickness (all 3 lamellae), which drives reconstructive options
- Main goal: tension-free coverage of the globe to prevent exposure keratopathy and ectropion (chronic eyelid irritation)
- Defect size and thickness determines reconstruction options
    - ≤30% can be closed primarily; performing lateral canthotomy and cantholysis can allow closure of defects up to 50%
    - >50% requires local flap rearrangements, which often requiring two or more stages
        - Upper eyelid
            - Cutler-Beard flap: staged pedicled flap from lower eyelid
        - Lower eyelid
            - Hughes flap: staged pedicled flap from upper eyelid
            - Tenzel semicircular flap
            - Mustarde cheek advancement flap
            - Unipedicled (Fricke) flap
            - Bipedicled (Tripier) lid switch flap
    - Skin grafting is an option for anterior lamellar defects that cannot be closed primarily

IV. Nose

- Anatomy:
    - Nine subunits: single dorsum, tip, columella, and paired sidewalls, soft triangles, and alar lobules (Fig. 1)
- Main goal: create aesthetic piriform aperture coverage and maintain airway patency and nasal lining
- Often complicated by need for cartilaginous support
- Numerous local flap options:
    - Bilobed flap: for defects up to 1.5 cm; Y-shaped tissue pivoted to fill defect and one donor site, with the other donor closed primarily
    - Nasolabial flap: tissue from along the cheek-nose junction swung into defect on the nasal ala or sidewall
    - Forehead flap: workhorse two- or three-staged technique where tissue from the central forehead is swung down to reconstruct part or all of the nose

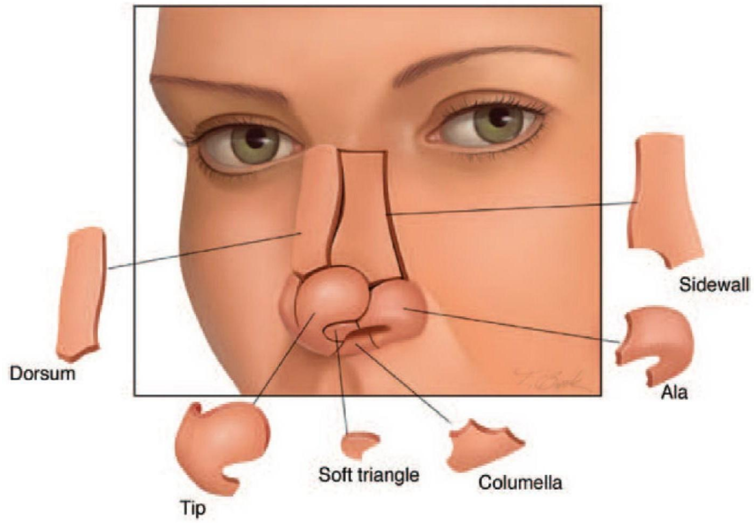

Figure 1. Nasal subunits

- Free tissue transfer is often reserved for subtotal/total reconstruction, or when local tissue isn't available or sufficient
  - Radial forearm flaps: thin, pliable coverage that can also be used for lining or composite defects where palatal reconstruction is also desired
  - Auricular helical rim flap can be used to reconstruct alar defects due to its contour and cartilage support

V. Ear

- Anatomy:
  - The ear is made up of distinct subunits that have characteristic contour, cartilage support and skin characteristics
  - Optimal functional and aesthetic outcomes depend on defect size, cartilage loss and remnant structures available for reconstruction
  - Ear subunits include the helix, antihelix, scaphoid fossa, concha, tragus, antitragus and lobule
- Main goals: primarily aesthetic reconstruction (symmetry important)
- Options by size:
  - <15-20 mm or ¼ of auricular height: wedge excision and primary closure
  - >20mm but less than 40 mm (¼ to ¾ of auricular height):
    - Antia-Buch chondrocutaneous advancement flap: advancement of the helical rim and adjacent tissue to reconstruct marginal auricular defects in a single stage
    - Staged postauricular chondrocutaneous advancement flaps
- Total reconstruction: fabrication of an autologous cartilage construct (typically rib cartilage) or alloplastic (Medpor) implant covered local tissue
  - Temporoparietal fascia flap provides excellent vascularized coverage of construct
  - Tissue expansion of parietal scalp and postauricular tissue is an acceptable option
  - Free tissue transfer is rarely used in this population
  - Congenital microtia
    - Commonly associated with craniofacial microsomia (hemifacial microsomia/Goldenhar syndrome), oculo-auriculo-vertebral spectrum (OAVS), Treacher Collins syndrome, and 22q11.2 deletion syndrome
    - Typically classified by the Nagata system (lobule type, small concha type, concha type and anotia)
    - Reconstruction with autologous cartilage (Brent, Nagata and Firmin techniques, which are stratified by surgical stages required to complete reconstruction)

        - Autologous rib cartilage should not be harvested before age 8-10, when sufficient rib cartilage exists for reconstruction and sufficient adult ear growth has occurred
    - Alloplastic reconstruction can be used with no donor site morbidity, but there are high rates of infection, reoperation and implant extrusion
- One of the few facial structures where a prosthesis is a good option

VI. Lip

- Anatomy:
    - Anatomic subunits of the lip include the cutaneous (white) lip, the vermillion (red) lip, the vermillion border, oral mucosa and commissures
    - Critical associations include the philtral columns, cupid's bow and the continuity of the orbicularis oris muscle, and the modiolus
- Main goal: recreate oral competence and speech with a sensate aesthetic construct
- Perfect alignment of incisions key, or otherwise can be very noticeable
- Defects are characterized by location (central, lateral), depth (partial vs. full-thickness), and size (measured as a percentage of the lip)
- Rule of thirds for defects
    - ≤1/3: primary closure
    - ≤2/3: local flaps
        - Abbé lip switch flap: two-stage, section of lip swung to fill defect in opposite lip
        - Estlander flap: lateral end of lip swung up to end of opposite lip
    - ≥2/3:
        - Karapandzic flap: circumoral incision to mobilize lip and cheek, may narrow oral opening (microstomia) (Fig. 2)
    - Complex defects may require total lip reconstruction, where the radial forearm, ALT and gracilis are workhorse free flaps

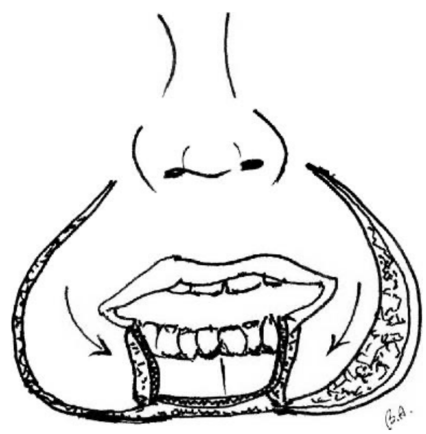

Figure 2. Karapandzic flap illustrating circumoral incision to mobilize lip and cheek

VII. Cheek

- Oncologic resection of skin cancers, oropharyngeal cancers or parotid tumors can leave defects on the face and cheek
- Anatomy: skin, subcutaneous tissue, mimetic facial muscles, buccal fat pad, and oral cavity
- Options for reconstruction:
    - Primary closure
        - Indications: small cheek defects where there is sufficient surrounding tissue laxity to allow tension-free closure without distortion of adjacent anatomic landmarks such as the eyelid, oral commissure, or alar base

- Local rotational or advancement flaps
  - Indications: moderate-sized defects that cannot be closed primarily without causing distortion, but where local tissue is available and a good color and texture match is desired
  - Nasolabial flap:
    - Indications: small to moderate defects of the medial cheek, perinasal, and perioral regions; especially useful for defects near the nasolabial fold, alar base, and upper lip
    - Flap design: along the nasolabial fold, with the superior border at the alar base and the inferior border at the oral commissure; typically raised in the subcutaneous plane, preserving the underlying facial artery when possible
  - Cervicofacial flap (Fig. 3):
    - Indications: large cheek defects, especially those involving the lower and lateral cheek, infraorbital, and preauricular regions; preferred when a large area of skin and subcutaneous tissue is required, and when a good color and texture match is critical
    - Flap design: superior border of the flap raised at the zygomatic arch, lateral border at the preauricular crease, and inferior border extending into the cervical region; can be raised in either the subcutaneous plane or the deep plane (superficial musculoaponeurotic system, SMAS), with both approaches showing low complication rates

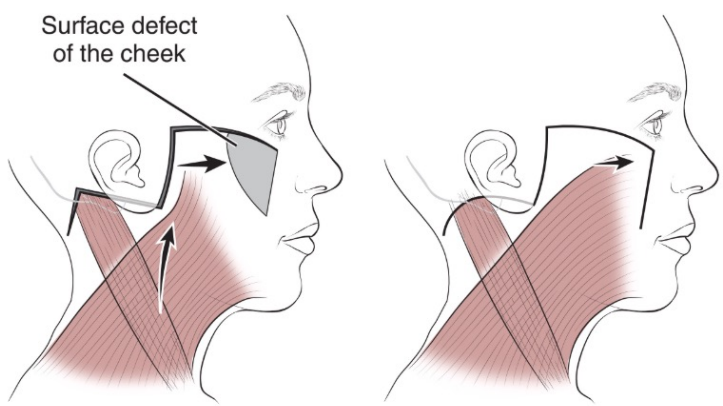

Figure 3. Cervicofacial flap

  - Submental island flap:
    - Indications: moderate to large defects of the lower and midface, particularly in the lower cheek, submandibular, and perioral regions; especially useful when free tissue transfer is not feasible or when a hair-bearing flap is desired in male patients
    - Flap design: based on the submental artery and vein, with the skin paddle designed in the submental region, typically between the mandibular border and the hyoid bone; dissection is performed in the subplatysmal plane, taking care to preserve the vascular pedicle
- Free tissue transfer
  - Indicated for large defects with a paucity of local tissue for coverage
  - Workhorse flaps include fasciocutaneous flaps, including the radial forearm free flap (RFFF), medial sural artery perforator (MSAP) flap, and the anterolateral thigh flap (ALT)
  - Can obtain composite flaps (osteocutaneous, or neurotized ALT/RFFF) depending on defects after resection

VIII. Mandible

- Main goal: restore speech and mastication
- Most common pathologies:
  - Squamous cell carcinoma (SCC)
    - Histology: invasive nests/cords of atypical squamous cells, keratin pearls, intercellular bridges
    - Imaging: ill-defined lytic lesion, cortical destruction, soft tissue mass
    - Physical: ulcerated mucosal lesion, induration, possible trismus
    - Treatment: marginal resection if no medullary invasion; segmental mandibulectomy if medullary or extensive cortical invasion; the American Head & Neck Society recommends segmental resection for medullary invasion
    - Success: 5-year survival ~60% for both marginal and segmental resection; segmental resection may improve local control in medullary invasion
  - Ameloblastoma
    - Histology: islands of odontogenic epithelium with peripheral palisading and reverse polarization; follicular and plexiform patterns
    - Imaging: multilocular “soap-bubble” or “honeycomb” radiolucency, often in posterior mandible
    - Physical: painless jaw swelling, facial asymmetry
    - Treatment: segmental resection is standard for solid/multicystic types; marsupialization plus curettage for unicystic types
    - Success: ~4.5% recurrence for marsupialization plus curettage for cystic types; <5% recurrence for segmental resection with free flap reconstruction
  - Odontogenic keratocyst (keratocystic odontogenic tumor)
    - Histology: parakeratinized stratified squamous epithelium, palisaded basal layer, corrugated surface
    - Imaging: well-defined unilocular or multilocular radiolucency, often in posterior body/ramus
    - Physical: asymptomatic swelling, sometimes incidental
    - Treatment: enucleation with peripheral ostectomy or marsupialization for large lesions
    - Success: recurrence rates 10-30% with enucleation, lower with adjunctive therapy
  - Ossifying fibroma
    - Histology: well-circumscribed fibro-osseous lesion with fibrous stroma and mineralized material (bone/cementum)
    - Imaging: well-demarcated, mixed radiolucent-radiopaque lesion, often in premolar-molar region
    - Physical: slow-growing, painless swelling
    - Treatment: enucleation or curettage for small lesions; resection for large/recurrent lesions
    - Success: recurrence is rare after complete excision
- Gold standard is bony reconstruction, but soft tissue reconstruction may be indicated for posterior defects
  - Non-vascularized bone grafts: only for small lateral defects (<6 cm) and if no radiation is planned, per the American Head & Neck Society
  - Vascularized bone graft (free flap)
    - Fibula osteocutaneous flap: workhorse, can be shaped into an entire mandible and can also provide skin and soft tissue for floor of mouth or tongue reconstruction
    - Can also use scapular flap, iliac crest flap

- Vascularized soft tissue-only free flap
  - Mandibular defects posterior to angle involving non-tooth bearing mandible can be reconstructed with soft tissue free flap only
- Titanium reconstruction plates are an option for patients who cannot tolerate a free flap operation but extrusion through the tissue is a common problem

IX. Maxillary reconstruction

- Main goal is to restore three-dimensional anatomy of the midface
  - Separate the oral and nasal cavities
  - Provide bony support for midface structures
  - Enable functional outcomes such as intelligible speech, effective swallowing, mastication, with acceptable facial aesthetics
- Classified by the Brown classification system for maxillary defects (Fig. 4)
  - Stratifies defects vertically and horizontally
    - Vertical
      - Class I: Limited maxillectomy not involving oroantral fistula
      - Class II: Maxillectomy with oroantral or oronasal fistula, orbit spared
      - Class III: Maxillectomy with orbital involvement, globe spared
      - Class IV: Maxillectomy with orbital exenteration
    - Horizontal
      - Class 1: Defect in central palate
      - Class a: Defect in hemipalate (one side only)
      - Class b: Defect extends to contralateral palate
      - Class c: Total hard palate defect

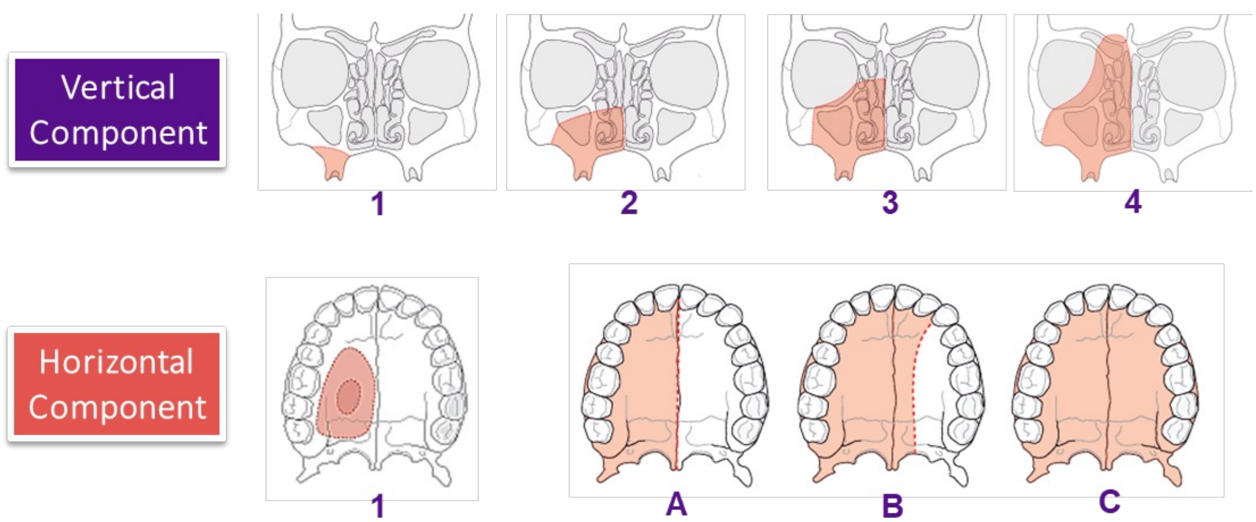

Figure 4. Brown classification for maxillary defects

- Gold standard for treatment is vascularized osteocutaneous free flaps
  - Fibula free flap provides bony support and the opportunity for dental rehabilitation, specifically in cases where the alveolus and dental arch require reconstruction
    - Preferred for Brown class II through IV defects
    - Long segment of bone (up to 25 cm)
    - Capacity for multiple osteotomies to recreate the facial buttresses
    - Accepts dental implants
    - Adaptations:
      - Two- or three-piece depending on need for midface projection
      - Double-barreled (stacked, biaxial) to improve bony height

            - Prelaminated osteomucosal flap for central maxillary defects with need for buccal mucosa
    - Deep circumflex iliac artery osteocutaneous flap (DCIA)
        - Preferred for Brown class IIB/C defects
        - Robust bone stock (iliac crest), but limited length
    - Scapular free flaps
        - An option for patients with contraindications to fibula flaps
        - Preferred for Brown class II defects, and select III and IV defects
        - Useful for reconstructions with extensive soft tissue defects but limited bony involvement
            - Lowest donor site morbidity
            - Allows for chimeric designs – incorporating tissue based off the subscapular system (latissimus dorsi, parascapular skin) and has long pedicle
            - Can be more technically challenging, difficult to work with a 2-team approach in head and neck reconstruction
    - RFFF: option for resurfacing of palatal defects that need palatal or alveolar reconstruction and desire dental rehabilitation

X. Oral cavity reconstruction

- Main goals: restore swallowing and speech, prevent fistula formation
- Can use skin grafts for small posterior pharyngeal defects
- Partial tongue resection can be closed primarily
- Free flaps:
    - Free radial forearm utilized for thin, pliable reconstruction (i.e., partial tongue, buccal mucosa, pharyngeal defects)
    - Anterolateral thigh (ALT) provides more significant bulk (i.e., for subtotal/total glossectomies)

XI. Hypopharyngeal/esophageal reconstruction

- Main goals: Restore alimentary continuity, facilitate speech rehabilitation (usually through tracheoesophageal puncture)
- Free tissue transfer remains the gold standard for reconstruction
    - Tubed ALT flap
        - Provides excellent speech and swallow rates, with low rates of stricture formation
        - Minimal donor site complications and low fistula formation rates
    - Free jejunal flap
        - Provides excellent swallow rates and the lowest rates of stricture formation
        - Higher rates of fistula formation, and the poorest speech outcomes
    - RFFF
        - Less commonly used due to higher fistula and stricture rates, and worse speech and swallow outcomes
        - Most ideal for high BMI patients in whom ALT flap is too thick

MISCELLANEOUS

I. Orthognathic surgery

- Deformities of the mandible
    - Classification:
        - Retrognathia: mandibular retrusion with respect to maxilla
        - Prognathia: mandibular protrusion with respect to maxilla
        - Micrognathia: underdeveloped, retruded mandible
        - Open bite: teeth cannot be brought into opposition

            - Crossbite: lower teeth lateral to upper teeth
            - Micro- and microgenia: under or overdevelopment of chin
            - Teeth numbers
                - Pediatric teeth are lettered A through T (A-J for maxilla; K-T for mandible)
                - Adult teeth are numbered 1-32 (1-16 for maxilla; 17-32 for mandible)
                    - 1, 16, 17, 32 are considered "thirds," which are your third molars, or "wisdom teeth"
            - Dental position and surfaces of the teeth
                - Mesial: moving toward the midline
                - Distal: moving away from the midline
                - Lingual: surface facing toward the tongue
                - Facial (labial or buccal): surface facing the cheek or lips
                - Incisal: biting surface of anterior tooth
                - Occlusal: biting surface of posterior tooth
                - Overjet: position of maxillary teeth relative to the mandibular teeth in sagittal plane; can be positive or negative
                - Overbite: position of maxillary teeth relative to mandibular teeth in the coronal plane
            - Angle class of occlusion
                - Class I: normal occlusion; mesiobuccal cusp of maxillary first molar fits into the buccal groove of the mandibular first molar
                - Class II: retrognathia; mesiobuccal cusp of maxillary first molar is mesial to the buccal groove of the mandibular first molar
                - Class III: prognathia or pseudoprognathia (cleft pathology, maxillary deficiency); mesiobuccal cusp of maxillary first molar is **distal** to the buccal groove of the mandibular first molar
        - Treatment
            - Establishment of normal or near normal occlusion of primary importance
            - Use of osteotomies with repositioning of bone segments, bone grafts as needed, with or without orthodontic corrective measures as needed
            - Mandibular distraction for severe discrepancies often seen in Pierre Robin Sequence (microretrognathia, glossoptosis, and upper airway obstruction)
    - Deformities of the maxilla
        - Most commonly, retrusions or underdevelopment, "dish-face"
        - Must also examine the vertical height of the midface (vertical maxillary excess, VME versus vertical maxillary deficiency, VMD)
    - Temporomandibular joint disorder
        - Etiology: previous trauma, arthritis, bone overgrowth, bruxism, tumors
        - Symptoms: pain, crepitus, joint noises, limited opening, occlusion change
        - Diagnosis
            - Consider patient history
            - Examination: auscultation, opening, occlusion
            - Imaging: tomograms, arthrogram/arthroscopy is gold standard, MRI
        - Treatment
            - Conservative: joint rest, analgesics, bite plate, etc.
            - Surgery: seldom indicated

II. Virtual Surgical Planning (VSP)

- Standard adjunct to head and neck reconstruction and has growing applications in trauma
- Leverages high resolution CT imaging to create a 3D model of the patient's anatomy prior to surgery, allowing for pre-operative simulation of osteotomies, pre-bending of plates and planned hardware placement (Fig. 5)

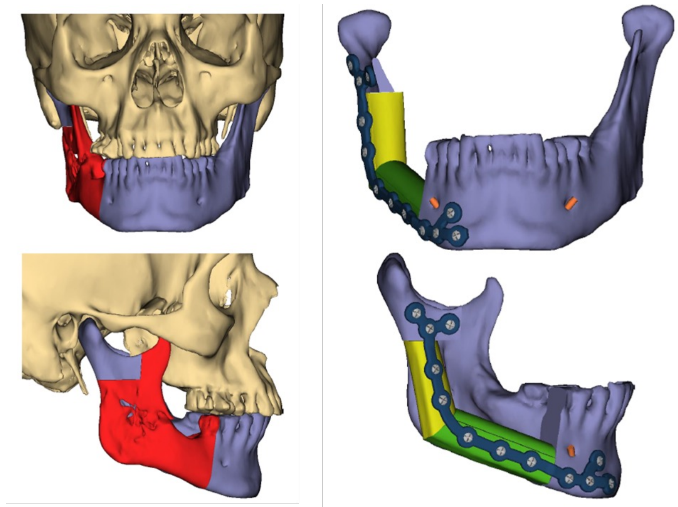

Figure 5. VSP with resection noted in red, with two-piece fibula free flap reconstruction (yellow, green) and custom plate

- Advantages:
  - Improved operative efficiency by reducing operative times
  - Improved precision, improving aesthetic and functional outcomes
  - Immediate dental restoration in certain reconstructions
- Limitations:
  - High upfront cost and potential delays due to manufacturing; this has delayed its widespread adoption in the trauma setting
  - Limited flexibility intraoperatively if complications encountered

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Chapter 12
Pediatric Plastic Surgery

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The field of pediatric plastic surgery encompasses unique conditions, treatment principles, and complication profiles. The most common pediatric plastic surgery problems include congenital craniofacial anomalies, acquired craniofacial problems (such as facial fractures), brachial plexus injuries, hand anomalies, congenital nevi, and vascular malformations. Cleft lip and palate are discussed in a separate chapter.

CONGENITAL CRANIOFACIAL ANOMALIES

I. Craniofacial embryology and development

- Facial embryology:
  - Facial development occurs between 3-8 weeks of gestation
  - Face originates from 5 prominences that appear during 4th week (Fig. 1)
    - Central frontonasal prominence, arising from mesenchyme ventral to forebrain
    - Paired maxillary prominences
    - Paired mandibular prominences
  - Paired maxillary and mandibular prominences both arise from neural crest cells migrating from 1st branchial arch
    - These prominences surround the primitive mouth (stomodeum)
  - Prominences give rise to:
    - Frontonasal prominence, which divides into:
      - Medial nasal process: nasal tip, columella, philtrum and premaxilla
      - Lateral nasal process: nasal alae
    - Maxillary prominences: upper jaw, upper lip (lateral to philtrum), orbital floor, inferior portion of lateral nasal wall
    - Mandibular prominence: lower jaw
  - Between 5-6 weeks nasal processes enlarge, migrate and coalesce in the midline to unite with maxillary processes and form upper lip

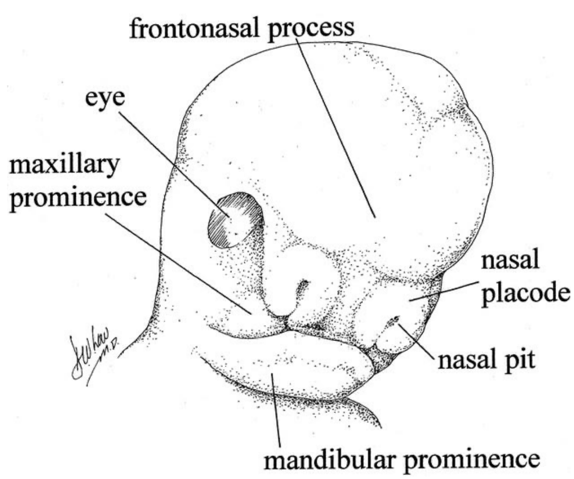

Figure 1. Craniofacial embryology. The five facial prominences. *From Losee, JE, Kirschner, RE, Whitaker, LA, Bartlett, SP. Congenital nasal anomalies: a classification scheme. Plast Reconstr Surg 2004;113:676-689.*

- Cranial development:
  - Cranium divided into:
    - Neurocranium: structures that surround the brain
    - Viscerocranium: structures that surround oral cavity, pharynx, upper respiratory system and face
  - Ossification
    - Cranial base (occipital, sphenoid and temporal bones): endochondral ossification
    - Cranial vault: intramembranous ossification
  - Cranial growth responds to increased brain volume
    - Brain size triples by 1 year
    - Brain size quadruples by 2 years
    - Cranial vault is 90% of adult size by age 5
    - Brain has reached 95% of adult size by age 8-10
  - Normal cranial growth occurs through
    - Suture growth: perpendicular to suture
    - Appositional growth: bone resorption of the inner surface and bone deposition on the outer surface

II. Craniosynostosis (CS)

- Definition: premature fusion of one or more cranial vault sutures
  - Calvarium grows parallel to fused suture
- Incidence: 1:2,500 live births
- Normal suture and fontanelle closure
  - Suture fusion:
    - Metopic: 6-8 months
    - Sagittal: 22 years
    - Coronal: 24 years
    - Lambdoid: 26 years
    - Squamosal: 35 years
  - Fontanelle closure:
    - Posterior: 3-6 months
    - Anterior: 9-12 months
- Characteristic head shape according to suture affected (Fig. 2)
  - Sagittal: scaphocephaly (Greek, *scapho*, meaning boat-shaped) or dolichocephaly
  - Metopic: trigonocephaly (Greek, *trigono*, meaning triangular or keel-shaped)
    - Metopic ridge: can be normal variant that develops as suture is closing during first year of life, observe asymptomatic ridge in child <1 year
  - Coronal, bilateral: brachycephaly (Greek, *brachy*, meaning short in AP direction)
  - Coronal, unilateral: plagiocephaly (Greek, *plagios*, meaning oblique or slanted)
    - Associated with Harlequin deformity
    - Must distinguish from positional plagiocephaly, where suture is normal
      - Head deformity is similar, but there is a parallelogram configuration of the head (if seen from above) with anterior displacement of the ipsilateral ear, frontal bossing, and occipital flattening
      - Unicoronal craniosynostosis looks like a trapezoid from above
- Categorized into non-syndromic and syndromic types
  - Non-syndromic CS (most common, 67-80%)
    - Order of frequency according to suture type:
      - Sagittal (40-50%)
      - Metopic (25%)
      - Coronal (5-10% bilateral; 15-20% unilateral)
      - Lambdoid (<3%)

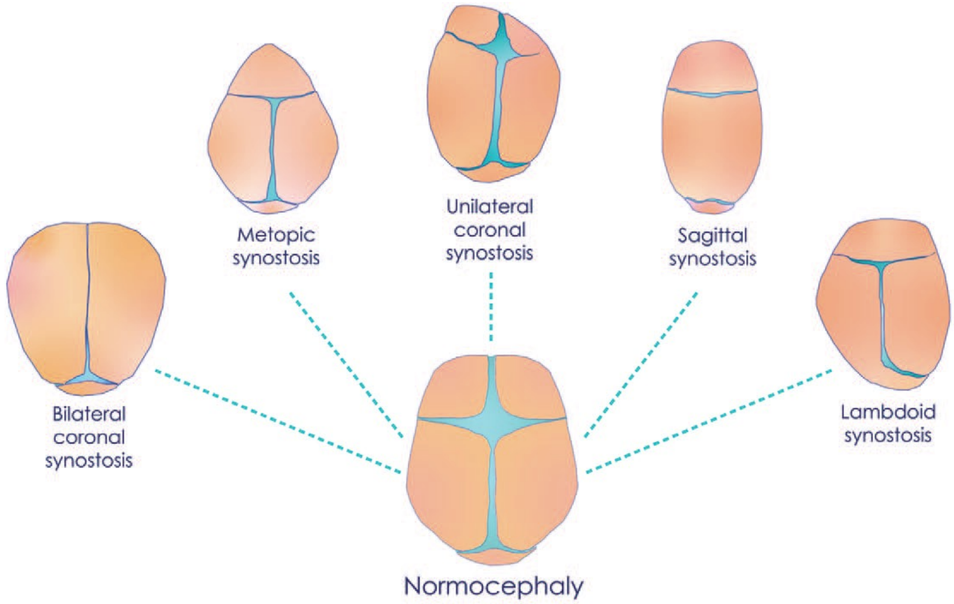

Figure 2. Skull deformities related to nonsyndromic craniosynostoses. *From Tahiri Y, Bartlett SP, Gilardino MS. Evidence-based medicine: Nonsyndromic craniosynostosis. Plast Reconstr Surg. 2017 Jul;140(1):177e-191e.*

- Longstanding debate as to whether non-syndromic patients have increased incidence of developmental delay. New evidence shows some degree of executive dysfunction in up to 50% of these children
- Treatment indications:
    - Prevent increased intracranial pressure (ICP)
    - Correct the cranial deformity and normalize appearance
- Treatment:
    - Varies depending on suture affected and severity
    - Usually performed within first year of life to take advantage of molding capacity of skull
    - Minimally invasive procedures: extended strip suturectomy/craniectomy (<4-6 months, age limit varies by institution and surgeon) ± springs ± postoperative helmet therapy
    - Anterior vault reshaping [fronto-orbital advancement (FOA)/reshaping], for bicoronal, unicoronal, and metopic
    - Total vault reshaping for sagittal
    - Posterior vault reshaping for sagittal – proponents of this operation believe that frontal dysmorphology normalizes over time after addressing the posterior vault

- Syndromic CS:
    - Higher incidence of elevated ICP than non-syndromic
    - Major associated syndromes:
        - Apert: bicoronal CS, exorbitism, severe midfacial retrusion, complex syndactyly of digits of the hands/feet, developmental delay; autosomal dominant (AD) mutation in FGFR2
        - Crouzon: bicoronal CS, shallow orbits (proptosis, exorbitism), midfacial retrusion, conductive hearing loss, parrot-beak nose, high crowded dental arch; normal intelligence; FGFR2 mutation
        - Pfeiffer: bicoronal CS, exorbitism, midfacial retrusion, broad thumbs and toes, can have developmental delay; FGFR1/2 mutation
        - Muenke: bicoronal CS, midface hypoplasia, carpal/ tarsal fusions, hearing loss, developmental delay; AD mutation FGFR3

        - Carpenter: multi-suture CS, developmental delay, cardiac defects, flat nose, high palate, pre-axial polydactyly, symbrachydactyly; autosomal recessive (AR) mutation RAB23
        - Saethre-Chotzen: bicoronal CS, eyelid ptosis, low frontal hairline, ear anomalies, partial syndactyly; TWIST mutation
        - Antley-Bixer: bicoronal CS, choanal atresia, radio-humeral synostosis; AR mutation FGFR2
    - Characteristic head shape involves turribrachycephaly (Greek, turri, tower)
        - Pfeiffer associated with cloverleaf skull (Kleeblattschadel)
            - Fusion of coronal, lambdoid, sagittal sutures; squamosal spared
    - Goals of surgery:
        - Expand intracranial volume
        - Normalize head shape and appearance
        - Correct profound exorbitism to prevent corneal exposure/blindness
        - Correct malocclusion (operations targeting occlusion are done later in childhood/adolescence)
    - General timeline of surgical interventions: may vary
        - Suturectomy for decompression of elevated ICP, if present (<3 months)
        - Posterior cranial vault distraction (6-12 months) – this is becoming the first line treatment in many syndromic patients, as it creates more volume per mm of advancement compared with FOA, and its use decreases the number of intracranial procedures required
        - Anterior/total vault reshaping/fronto-orbital advancement (FOA) (4-12 months)
        - Midface procedures: Le Fort III or monobloc advancement (4-12 years).
        - Orthognathic surgery: skeletal maturity
        - In general, craniofacial distraction leads to greater advancement, less relapse than conventional procedures
        - Autologous bone preferred in pediatric population
            - Diploic space is narrow but still available in infants
            - Can also use cortical bone scrapings

III. Craniofacial clefts

- Lack of fusion of facial processes resulting in abnormal separation of skeletal and soft tissue structures of the face and cranium (alternative theory of lack of mesodermal penetration)
- Rare, estimated 1.4-5.1 per 100,000 births
- Classified by Paul Tessier, father of modern craniofacial surgery
- Tessier classification system relates soft tissue to skeletal landmarks (Fig. 3)
    - Any combination of clefts is possible
    - 0: midline cleft lip
    - 0-7: lower half of face
    - 8-14: upper half of face
- Cleft lip: failure of fusion of maxillary and medial nasal processes
- Tessier 2, 3, and 4: failure of fusion of frontonasal/ maxillary prominences
- Proboscis lateralis: failure of fusion of lateral and maxillary nasal prominences
- Facial dysostoses are associated with certain clefts:
    - Craniofacial/hemifacial microsomia: #7 cleft (most common facial cleft)
    - Treacher Collins: clefts # 6, 7, 8
    - CHARGE syndrome:
        - Deletion of CHD7
        - Coloboma, heart defects, atresia of nasal choanae, retardation of growth, GI issues, ear deafness
        - Orofacial clefts

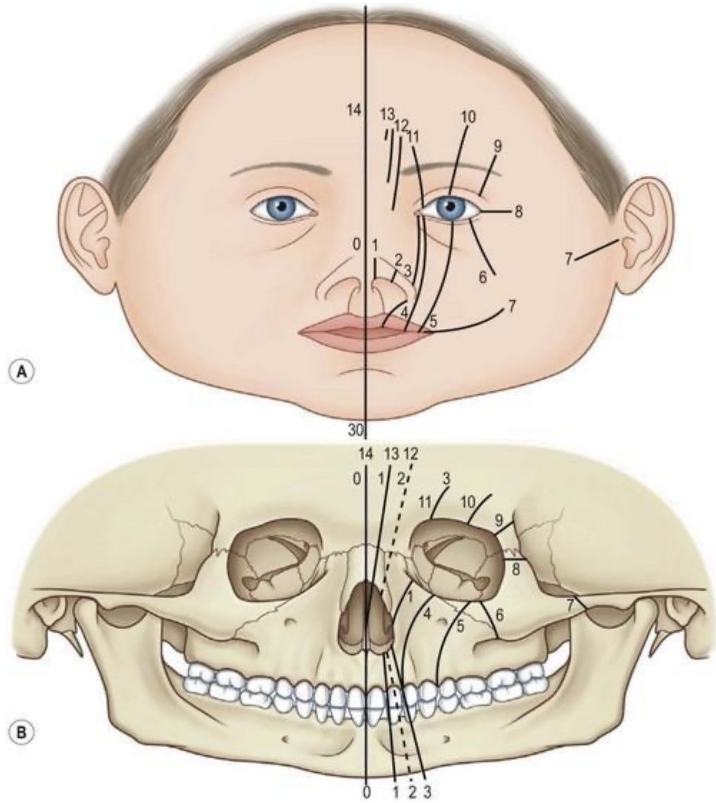

Figure 3. Tessier classification of orofacial clefts. (A) soft tissue clefts and (B) bony clefts.

IV. Facial dysostoses

- Treacher Collins syndrome (mandibulofacial dysostosis):
  - Rare, autosomal dominant, variable penetrance disorder
  - Associated with TCOF1 mutations on chromosome 5q
  - 1st branchial arch, groove and pouch affected
  - Defined by the bilateral presence of three Tessier Clefts #6, 7, 8, which result in all the phenotypic manifestations
  - Clinical manifestations:
    - Hypoplasia/aplasia of the zygomatic arch
      - Lateral orbit deficiency
      - Midface retrusion
      - Micrognathia
      - Lateral canthus hypoplasia/downward slanting palpebral fissures
    - Hypoplasia of temporalis muscle
    - Coloboma and retraction of lower lid
    - Variable ear malformations (microtia/anotia) and deafness
    - Mandibular hypoplasia with microretrognathia
      - Airway compromise due to narrow pharyngeal diameter
      - May require tracheostomy and/or mandibular distraction
    - Parrot-beak nose ± choanal atresia
    - Normal intelligence
  - Treatment:
    - Maxillary or mandibular hypoplasia: airway management including mandibular distraction, counterclockwise craniofacial distraction
    - Absent mandibular condyles: autologous bone grafts (calvaria, rib, iliac crest) and autologous fat/tissue transfer

- Craniofacial microsomia (hemifacial microsomia):
    - Spectrum of morphogenetic abnormalities affecting the craniofacial skeleton, soft tissues and neuromuscular structures derived from the 1st and 2nd branchial arches
    - Proposed cause: thrombosis of stapedial artery
    - Second most common craniofacial malformation (following cleft lip and palate)
    - 3:2 male:female
    - 1:3,500-5,600 live births affected
    - Usually unilateral (therefore the more common name hemifacial microsomia)
    - Manifestations:
        - Hypoplasia of mandibular ramus (uni or bilateral)
            - ± hypoplasia of the maxilla, zygoma and temporal bone
            - Deviated chin
            - Tilted occlusal plane (cant) → malocclusion
        - Microtia ± hearing loss
        - Paresis of CN V or CN VII common
    - Associated with Tessier #7 facial cleft
    - Pruzansky classification:
        I. Small ramus with identifiable anatomy
        II. A functioning TMJ but with abnormal shape and glenoid fossa
            a. Glenoid fossa is in acceptable functional position
            b. TMJ is abnormally placed
        III. Absent ramus and non-existent glenoid fossa
    - Treatment:
        - Augment deficient areas
            - Skeletal: autologous bone (calvarium, rib, iliac crest)
            - Soft tissue: free flap and/or fat grafting
        - Mandibular correction depends upon severity of hypoplasia
            - Distraction may be necessary to achieve correction of malocclusion versus conventional orthognathic procedures to correct jaw discrepancies at skeletal maturity
    - Bone-anchored hearing aids
- Goldenhar syndrome (oculo-auriculo-vertebral spectrum):
    - Variant of craniofacial/hemifacial microsomia with additional manifestations
    - Cause: faulty neural crest cell migration, associated with intrauterine occlusion of stapedial artery
    - Only 5% of hemifacial microsomia cases have these features
    - Sporadic occurrence
    - Manifestations:
        - Prominent frontal bossing, low hairline
        - Low-set ears
        - Anterior accessory auricular appendages
        - Colobomas of upper eyelid
        - Epibulbar dermoids
        - Hemifacial microsomia
        - Vertebral spine abnormalities
        - Abnormalities of heart, kidneys, lungs
- Pierre Robin sequence:
    - 1:8,500-20,000 live births
    - Triad of:
        1. Micrognathia
        2. Glossoptosis (tongue retruded back into the pharynx)
        3. Upper airway obstruction
    - Sequence, not a syndrome, but can co-occur with a syndrome

        - Intrinsic/extrinsic disturbance of mandible development (leads to micrognathia)
        - Arrest of rotation/descent of tongue from between palatal shelves
        - Lack of palatal fusion or high, U-shaped palate
        - Tongue remains pressed against posterior pharynx = airway obstruction and feeding issues
        - May or may not have cleft palate
    - May be isolated or associated with certain craniofacial syndromes
        - Stickler syndrome (hereditary arthro-ophthalmopathy): AD or AR mutations in COL2A1, COL11A1, COL11A2
            - Cleft palate, midface hypoplasia, retinal detachment, sensorineural hearing loss, joint abnormalities
        - Nager syndrome: AR mutation chromosome 9
            - Radial hand deformities, mandibular/ maxillary hypoplasia, high nasal bridge, long philtrum, cleft palate with VPI, class II malocclusion, short stature
        - Treacher Collins (see above)
    - Treatment:
        - Immediate treatment goals in the neonate are establishing a patent airway and improving feeding; four treatment modalities available
            - Conservative treatment: if newborn demonstrates adequate feeding and weight gain; mild airway obstruction relieved by change in positioning
            - Tongue-lip adhesion: temporary suturing of tongue to lower lip to address glossoptosis, higher risk of needing gastrostomy tube
            - Tracheostomy: immediate airway control in emergent scenario, but significant morbidity; currently used as last resort
            - Mandibular distraction: preferred by most centers where available for significant upper airway obstruction; addresses mandibular hypoplasia
                - Tongue moves anteriorly and relieves airway obstruction
                - Lower risk of requiring gastrostomy for feeding compared with tongue-lip adhesion.
        - Requirements:
            - Continuous pulse oximetry and airway monitoring
            - Multidisciplinary evaluation by genetics, ophthalmology, PRS, feeding specialist
            - Laryngoscopy/bronchoscopy: other airway anomalies are relative contraindication to distraction
            - Polysomnogram (sleep apnea)
- Van der Woude:
    - AD mutation IRF6
    - Cleft lip and palate, lower lip pits, facial clefting, syndactyly
        - Most common cause of inherited cleft palate
- Popliteal pterygium:
    - AD mutation IRF6
    - Cleft lip and palate, popliteal webbing, toe webs, lip pits, webbing of mouth and eyelids
- DiGeorge (velocardiofacial syndrome):
    - AD, 22q11 deletion
    - Diagnosis: FISH
    - Hypocalcemia, coloboma, heart defects (aberrant medialized carotid arteries), choanal atresia, growth retardation, GU anomalies, ear anomalies, deafness
    - Consult immunology, cardiology
- Moebius syndrome:
    - Defect in 1st and 2nd branchial arches

        - Bilateral congenital abducens and facial nerve palsy, club feet/ syndactyly, rudimentary fingers + toes, cardiac defects, clefts, microgenia
- Parry-Romberg (coup de sabre, linear scleroderma):
    - Slow progressive hemifacial atrophy following ipsilateral branches of trigeminal (V) nerve
        - Starts age 5-15 years, lasts 2-10 years
        - Involves skin, eyes, soft, tissue, muscle, and bone in trigeminal nerve distribution; does <u>not</u> affect sensation
    - Associated with epilepsy, presents with cutaneous vertical furrow
    - Treatment:
        - Mild-moderate: fat transfer
        - Moderate-severe: free flap surgery once disease process is stable
        - Methotrexate, steroids
        - Ophthalmology consult for eye involvement
- Beckwith-Wiedemann:
    - Mutation on chromosome 11
    - Macrosomia, macroglossia, omphalocele, ear folds
- Other embryologic defects:
    - Branchial cyst, sinus, or fistula
        - Epithelial-lined tract frequently in the lateral neck presenting along the anterior border of the sternocleidomastoid muscle.
        - May present as a cyst or as a sinus connected with either the skin or oropharynx, or as a fistula between both skin and oropharynx openings
        - Treatment: excision
    - Thyroglossal duct cyst or sinus:
        - Cyst in the mid-anterior neck over or just below the hyoid bone, with or without a sinus tract to the base of the tongue (foramen cecum); moves with swallowing
        - Treatment: Sistrunk procedure (removal of cyst, sinus tract, and portion of hyoid)

V. Ear deformities

- Embryology: 4-10 weeks gestation
    - 6 mesenchymal hillocks form from 1st pharyngeal cleft + 1st-2nd pharyngeal arch
    - Hillocks 1-3: tragus, root of helix, and superior helix
    - Hillocks 4-6: posterior helix, antihelix, antitragus, lobule
    - Antihelix: 2nd branchial arch
    - Meckel's cartilage: 1st branchial arch
    - Middle ear: 1st pharyngeal pouch
- Congenital:
    - Anotia: complete absence; very rare
    - Microtia: vestigial remnants or absence of part of ear
        - May present with other mandibular deformities, such as hemifacial microsomia, Goldenhar or Treacher Collins
        - Treatment:
            - Nagata (2-stage) vs. Brent (4-stage) techniques (several modifications exist): construction of sculpted ear framework from autologous rib cartilage graft that is buried under scalp skin
                - Usually requires 2-4 operations starting at age 6-8, when rib cartilage is big enough
                - Nagata method usually requires child to be age 10 or older
            - Synthetic implant (Medpor) covered by vascularized temporoparietal fascial flap
                - Risk of extrusion from minor trauma, loss 2/2 infection
            - Bone anchored hearing aids: place behind mastoid after ear reconstruction

        - Prominent ears: creation of an antihelical fold and/or re-positioning/reduction of concha
            - Mustarde sutures: horizontal mattress sutures from scapha to concha, recreating antihelical fold
            - Furnas sutures: concho-mastoid sutures
            - Stenstrom's technique: scoring of anterior surface of antihelical cartilage
                - Gibson principle: cartilage will warp away from scored surface
            - Luckett's technique: excision of crescent-shaped portion of skin away from posterior antihelix
        - Stahl ear: normal ear with third crus, can be accompanied by prominence
            - Third crus "unfurls" the helical rim and makes ear appear pointed
        - Cryptotia ("pocket ear" or "hidden ear")
            - Superior helical rim buried behind skin of scalp
            - Caused by anomaly of intrinsic transverse + oblique auricular muscles
            - On exam: able to recreate normal ear appearance with digital manipulation
            - Treatment: ear molding in infancy vs. superior incision to release cartilage, resurface posterior defect with skin graft or local flap (V-Y, Z-plasty)
        - Constricted ear:
            - Hooding of scapha, helix + flattening of antihelix, hypoplasia of superior third of auricle, Tanzer classification is useful for describing severity
            - Mild "lop ear" vs. severe "cup ear"
            - Treatment:
                - Infancy: ear molding (start by 2 weeks of age d/t presence of maternal estrogen making ear pliable)
                - Adult: redundant cartilage excision, flag flap transfer (Banner flap)
                - More severe constricted ear requires autologous reconstruction (treated similarly to microtia)
        - Darwin's tubercle: pointed thickening at junction of upper- and middle-third of helix
    - Trauma:
        - Loss of part or all of ear: treated similarly to microtia/anotia
            - Can attempt microvascular reimplantation in acute setting
        - Auricular hematoma: requires evacuation with bolster dressing
            - Failure to drain → cauliflower ear
        - Use of a prosthetic ear may be indicated in some patients

PEDIATRIC FACIAL FRACTURES

- Epidemiology: uncommon; less than 15% of all facial fractures
    - Frequency increases with age
- Unique characteristics in children:
    - At birth, ratio of cranial:facial volume is 8:1; by completion of growth, it becomes 2.5:1; This changing ratio produces variation in fracture site frequency with age
    - Protective anatomical factors
        - Larger fat pads
        - Decreased pneumatization of sinuses
        - Skeletal flexibility
        - Compliant sutures
    - Fractures that entrap orbital contents (trap-door fractures) are more common secondary to greater bony elasticity
    - Up to 75% can have associated serious trauma (especially cervical spine, neurological, ophthalmologic and abdominal)
- Causes:
    - Most common overall (per National Trauma Databank): motor vehicle crashes (MVC), violence, and falls

- Some variation by age:
    - 0-5 years: falls
    - 6-11: MVC, sports
    - 12-18 years: sports, assault
- Fracture sites:
    - Vary with age
    - Most common overall are orbital and mandible
    - Skull fractures more common in younger children
    - Facial fractures more common as children grow, following midface growth (maxilla, zygomaticomaxillary complex, nasal, mandible)
- General treatment principles (see Chapter 10):
    - Growing skeleton possesses inherent plasticity that may render operative intervention unnecessary for a given injury
    - Usually more conservative treatment preferred in this patient population due to fear of altering growing facial skeleton and developing dentition

BRACHIAL PLEXUS BIRTH PALSY

- Anatomy:
    - Spinal roots: C5-T1
    - Trunks: upper, middle and lower
    - Divisions: anterior and posterior from each trunk
    - Cords: lateral, posterior and medial
    - Terminal branches: major peripheral nerves of upper extremity: musculocutaneous, axillary, radial, ulnar, median
- Incidence: 1.5 per 100 full-term births
- Risk factors:
    - Shoulder dystocia
    - Forceps delivery
    - Gestational diabetes (macrosomia)
    - Breech delivery
- Upper-root cervical injury in 73% or Erb-Duchenne palsy
    - Caused by injury in Erb's point (convergence of C5-C6 roots as they form upper trunk)
    - "Waiter's tip" appearance: lack of deltoid, supraspinatus and biceps functions
- Evaluation:
    - Passive and active ROM
        - Evaluate with reflexes, such as Moro
    - Imaging usually not helpful
- Treatment:
    - Physical therapy to preserve ROM
    - Indications for surgical exploration:
        - Absent biceps or deltoid function by 3-6 months
        - Absent elbow flexion, wrist, thumb or finger extension by 9 months
        - Flail limb with Horner's syndrome
    - Follow patients longitudinally
        - Partial recoveries or no recoveries may need tendon transfers or nerve grafting
        - 90% will have spontaneous resolution within 2 months
            - If biceps function recovered by 6 months, near-normal function can be expected

CONGENITAL HAND ANOMALIES

- Limb grows by proliferation of mesenchyme
- Limb bud appears at 4 weeks, finger buds at 6 weeks, finger apoptosis 6-8 weeks, ossification at 8-12 weeks

- HOX genes:
    - Proximal-distal limb growth: epical ectodermal ridge (AER)
        - Regulated by fibroblast growth factor (FGF)
        - Loss of AER → arrested limb development
    - Anterior-posterior limb growth (radial-ulnar axis): zone of polarizing activity (ZPA)
        - Responsible for AP axis differentiation
            - Involves sonic hedgehog (SHH), Hoxb8
        - Duplication of ZPA → mirror hand/foot
    - Dorsal/ventral:
        - Dorsal: Wnt7a induces transcription factor LMx-1b
        - Ventral: engrailed-1
- Swanson types of embryonic failure:
    - Failure of formation
        - Cleft hand (ectrodactyly)
            - AD partial or total absence of central fingers (typically 3rd ray)
        - Radial longitudinal deficiency (RLD): hypoplasia/ dysplasia of distal radius +/- thumb
            - Classification:
                1. Short distal radius
                2. Hypoplastic radius
                3. Partial absence of radius
                4. Total absence of radius
            - Associated with various syndromes
                - TAR: thrombocytopenia; AR absent radius syndrome
                    - Absent radius, normal thumb
                    - Manifests in infancy, can be fatal
                - Holt-Oram: AD RLD + cardiac defects (ASD, VSD)
                - Fanconi anemia: AR RLD + pancytopenia
                    - Presents at age 3 with pancytopenia, aplastic anemia: CBC won't show aplastic anemia until >3 years, so diagnosis made with chromosomal breakage test at earlier age
                    - Treatment: bone marrow transplant
                - Nager syndrome
                - VACTERL: vertebral anomalies, anal atresia, cardiac issues, tracheo-esophageal fistula, renal agenesis, limb deformities
    - Failure of differentiation (separation)
        - Syndactyly
            - Failure of apoptosis (BMP mutation)
            - 1:200 live births
            - 10:1 whites > blacks
            - 2:1 males > females
            - Bilateral = unilateral
            - Long + ring finger most common (57%); thumb + index finger most rare (3%)
            - May be familial (15-40% cases), sporadic simple, or associated with a syndrome (Apert, Poland syndromes)
            - Types:
                - Simple: skin fusion only
                    - Ligaments usually normal; duplicated tendons, nerves, sheaths
                - Complex: bony fusion
                    - Various fusion levels with fingernail synechia, abnormal tendons
                - Complicated: involves vascular tissues, tendons or nerves
                    - Also various fusion levels with fingernail synechia, abnormal tendons
                - Incomplete: partial fusion
                - Complete: total fusion including nailbed

        - Evaluation: careful physical examination and X-rays (critical)
        - Treatment: surgical; dozens of techniques exist
            - Usually reassurance and waiting until hand is larger (6-12 months)
            - Release border digits earlier to prevent abnormal growth of the longer digit, complete release by 24 months to ensure pincer grasp development
            - Simple: reconstruct webspace with dorsal rectangular flap
                - Digital arteries are limit of dissection
    - Symbrachydactyly
        - Poland syndrome
    - Camptodactyly: painless, progressive nontraumatic contracture of PIP joint
        - 1% population
        - Treatment: static splinting, surgery is last resort
    - Clinodactyly: delta phalanx (bracketed epiphysis/triangular shaped growth plate) causes excessive radial vs. ulnar deviation of a digit
    - Kirner deformity: progressive palmar + radial curvature of little finger distal phalanx
        - Occurs in pre-adolescents
- Duplication
    - Mirror hand
    - Polydactyly
        - Pre-axial/radial (thumb duplication)
            - Wassel classification:
                I. Bifid distal phalanx (3%)
                II. Duplicated distal phalanx (15%)
                III. Bifid proximal phalanx
                IV. Duplicated proximal phalanx (43%)
                V. Bifid metacarpal
                VI. Duplicated metacarpal
                VII. Triphalangism
            - Treatment:
                - Typically preserving ulnar digit no matter what classification
                - Type II: excise radial portion, reconstruct radial collateral ligament
                    - Can also try Bilhaut-Cloquet: excise central portion of both distal phalanges, fuse together
                - Type IV: excise radial portion, reconstruct RCL, maintain UCL (maintains thumb stability at MCP), reposition eccentric flexors/ extensors, find + reattach APB/use to reconstruct RCL
        - Post-axial: extra ulnar digit
            - More common
            - Affects African-Americans disproportionately (1:43 live births)
            - Classification:
                A. Fully formed duplicate digit
                    - Treatment: surgical excision
                B. Nubbin
                    - Treatment: suture ligation of skin bridge, surgical excision of neurovascular bundle
- Overgrowth
    - Macrodactyly
        - Cause: lipomatous hamartoma within digital nerves, cause overgrowth of hands + fingers in tumor distribution
        - Treatment :
            - Debulking
            - Epiphysiodesis (premature closure of growth plates) at MCP, PIP, DIP to slow disease

- Undergrowth
    - Brachydactyly
    - Hypoplastic thumb:
        - Blauth classification:
            1. Small thumb with full neurovascular compliment
                - Non-operative
            2. All bones present but hypoplastic, UCL insufficient, thenar hypoplasia, MCP instability
                - Treatment: opponensplasty, deepening of 1st webspace
            3. Hypoplastic, further separated based on CMC stability
                A. Intact CMC
                    - Treatment: opponensplasty, deepening of 1st webspace

                B. Deficient CMC, absent trapezium, absent MCP + IP joint motion
                    - Treatment: index pollicization
                        - Index EDC → APL
                        - Index EIP → EPL
                        - Dorsal interosseous → APB (abductor pollicis brevis)
                        - Palmar interosseous → adductor pollicis
                        - Shortened index finger metacarpal head → articular surface of CMC
                        - Joints:
                            - Index MP → thumb CMC
                            - Index PIP → thumb MCP
                            - Index DIP →thumb IP

                C. Remnant metacarpal head
            4. Pouce flottant (floating thumb)
                - No musculoskeletal attachments between thumb + hand
                - Treatment: index pollicization
            5. Aplastic thumb
                - Treatment: index pollicization
        - Must intervene between 3 mo-3 years of age, as child learns pinch at 3 years
    - Constriction band syndrome:
        - 12% all congenital limb deformities
        - Affects multiple extremities asymmetrically (on avg. 3 extremities involved)
        - Varies from skin dimpling to digital amputation, constriction rings, lymphedema distal to ring, acrosyndactyly (pathognomonic)
        - No genetic cause: associated with prematurity, low birth weight, young and multigravida mothers, oligohydramnios
        - Can cause compartment syndrome
        - Causes:
            - Intrinsic defect theory: genetic defect causes mesenchymal hypoplasia and scarring, low amniotic fluid causes constriction rings
            - Extrinsic defect theory: amniotic tissue entangles fetal parts, leading to constriction
        - Treatment:
            - Stage 1: excise 50% band
            - Stage 2: excise remaining 50% in 3-6 months (unless compartment syndrome present, then excise all at once)
- Generalized skeletal deformities:
    - Dystrophic dwarfism
- Congenital trigger finger:
    - More common in ulnar digits
    - Associated with malformations of superficial and deep flexors

    - Treatment: A1 pulley release, tenoplasty of chiasm with partial A2 pulley release
- Congenital trigger thumb:
    - Flexion of IP joint of thumb, sporadic locking
    - Treatment:
        - Observe at 1 year
        - Treat after 3 years
    - Associated with Notta's node (enlargement of flexor tendon proximal to A1 pulley)
        - Do not excise this
- Salter-Harris fractures: pediatric fractures across growth plate
    - SALTER
        1. Straight across growth plate
        2. Above (most common)
        3. Below
        4. Through everything
        5. "Erasing" of growth plate or crush

VASCULAR ANOMALIES

- Tumors: endothelial cell proliferation, malignant or benign (e.g., hemangiomas)
    - Infantile hemangioma: most common benign tumor of infancy; incidence 4-10% by 1 year
        - 3:1 female > male; 60% in head and neck, 25% in trunk
        - Appears in first weeks of life as a telangiectasia or clustered pinhead red lesions
        - Associated with GLUT1 mutations
        - Phases:
            - Proliferative: rapid evolution until 0-12 months, 80% of tumor size by 5 months
            - Involuting phase: lasts 1 to 10 years; tumor shrinks, color fades, lesion flattens
            - Involuted phase: involution complete at age >10 years, but can occur earlier; half of cases will have residual atrophy and contour deformity
        - Treatment:
            - Conservative: total involution occurs in 50% by 5 years, 70% by 7, and 90% by 9
            - Propranolol: induction of apoptosis and fat development, serves to limit proliferative phase; side effect of hypoglycemia
            - Intralesional steroids: in growth phase, they can arrest growth but will not regress; oral steroids are option when lesion too large
            - Laser: pulsed light and Nd:YAG lasers, mainly for ulcerated hemangiomas and for residual color
            - Surgery: typically delayed until school age otherwise to give time for involution
                - Urgent if hemangioma threatens important structures or function (i.e., visual, nasolaryngeal or auditory obstruction)
        - Complications:
            - Bleeding
            - Ulceration (often painful)
            - Infection
            - Kasabach-Merrit: profound thrombocytopenia with kaposiform hemangioendothelioma
            - High output heart failure if large visceral hemangiomas
            - Emotional distress
    - Congenital hemangioma:
        - Present at birth
        - Two forms:
            - Rapidly involuting congenital hemangioma (RICH): disappears by first year
            - Non-involuting congenital hemangioma (NICH): does not respond to pharmacotherapy

- Vascular malformations: congenital malformation of vessels (venous, capillary, lymphatic, arteriovenous)
  - Structural and morphologic anomalies resulting from faulty embryologic development
  - Present at birth, grow proportionately, and do <u>not</u> regress, unlike hemangiomas
  - Capillary malformations or port-wine stains:
    - 0.3% newborns; 3:1 female > male
    - Face in 80%, usually affect distribution of V1-V2
    - Treatment: photocoagulation with laser ± imiquimod (anti-angiogenesis)
    - Associated with:
      - Sturge-Weber syndrome: may be associated with ocular and CNS anomalies
      - Klippel-Trenauney: in extremity, overlying deeper venous malformation and skeletal hypertrophy
      - Parkes-Weber syndrome: similar to previous, but with associated AV fistula
  - Venous malformations: bluish/purple lesions with spongy texture that swell with dependency and deflate with elevation
    - Incidence 1-4%
    - Treatment: sclerotherapy, compression garments for symptoms, Nd:YAG or argon lasers, surgical resection (if morbidity of resection is reasonably low)
  - Lymphatic malformations (previously called cystic hygroma); macrocystic or microcystic
    - Soft and compressible, can cause bony overgrowth
    - Combined venous-lymphatic are common
    - Frequently infected; aggressive antibiotics crucial
    - Treatment: sclerosing agents, laser ablation, surgery, compression; antibiotics for infectious episodes
  - Arteriovenous malformations: pulsatile high-flow lesions
    - Anatomy and hemodynamics defined by angiography
    - Varying clinical states
      - Quiescent: appearing as only a pink stain
      - Expansive: with thrill and dilated venous network
      - Destructive: with cutaneous ulcers, necrosis, bleeding
      - Decompensated: causing cardiac compromise
    - Treatment: embolization prior to surgical resection within very short time frame; wide local excision (high recurrence), ischemic suture techniques
    - Complications:
      - Consumptive coagulopathy
      - Heart failure
      - Local destruction of anatomy
      - Bleeding

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Chapter 13
Cleft Lip and Palate

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Cleft lip and palate deformities are common congenital craniofacial defects with significant implications for function, appearance, and psychosocial well-being. These anomalies arise from disruptions in embryologic fusion of facial processes, leading to a spectrum of defects involving the lip, alveolus, and palate, that may occur in isolation in combination. Cleft lip (CL) and/or cleft palate (CP, CL/P) requires a lifelong, staged, multidisciplinary approach — from surgical repair and speech therapy to psychosocial support and dental/orthodontic rehabilitation. Modern cleft care remains a global health priority, with over 75% of cases occurring in low- and middle-income countries.

EMBRYOLOGY

- Upper face is assembled through the coordinated fusion of five key prominences (Fig. 1) between 6 and 8 weeks of gestation; fusion is essential for the development of a normal anatomic lip and palate (Fig. 2)
    - Unpaired, midline frontonasal prominence: forehead, nasal midline and septum, as well as primary palate and midline lip (philtrum)
    - Paired lateral nasal prominences: nasal alae
    - Paired maxillary prominences: maxilla and zygoma, alveolus, secondary palate and lateral portion of upper lip
- Failure of fusion leads to a wide spectrum of orofacial clefting
    - Bilateral failure of maxillary and frontonasal prominence fusion leads to a protrusive primary palate often referred to as the “premaxilla”
    - Unilateral failure leads to a spectrum of clefts ranging from mini-microform cleft (notching) to complete cleft lip and palatal defects
        - Anterior fusion failure leads to cleft lip
        - Failure of the lateral nasal prominence and the maxillary prominences lead to oblique facial clefts
    - Failure of fusion between the mandibular and maxillary prominences leads to transverse facial clefts, as commonly seen in Treacher Collins Syndrome

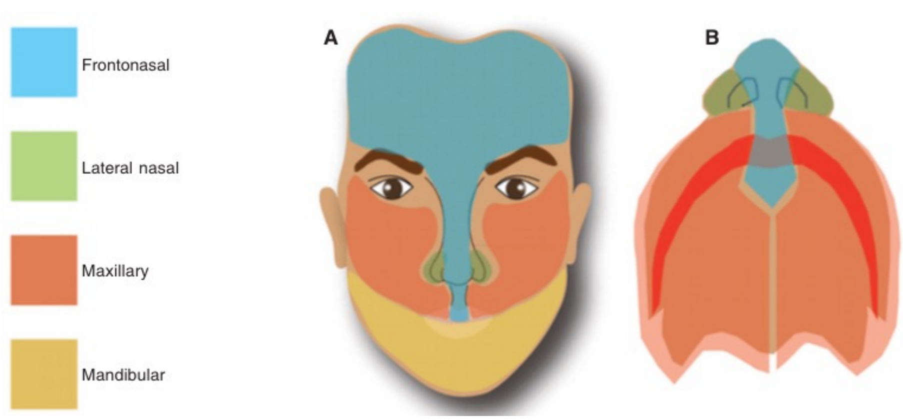

Figure 1. Facial prominences (A, coronal; B, axial). The frontonasal prominence (blue) gives rise to the forehead, midline of nose, septum, philtrum, middle portion of upper lip and primary palate. The lateral nasal prominences (green) form the nasal alae. The maxillary prominence (red) contains the palatal shelves which fuse with the frontonasal prominence in the midline. Failure of this fusion leads to orofacial clefting. *Reprinted with permission, Comprehensive Cleft Care, 2nd Ed. Losee and Kirschner, ed.*

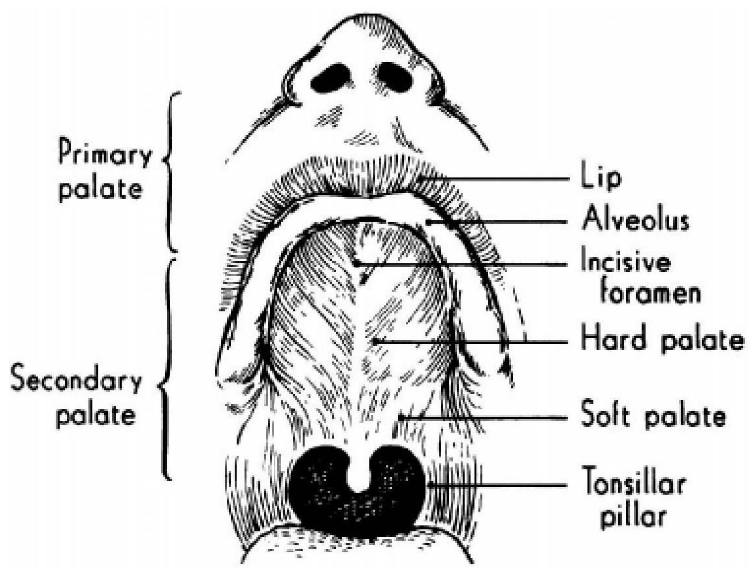

Figure 2. Basic anatomy of the lip and palate

DIAGNOSIS

- Second-trimester ultrasound (anatomy scan) can reliably detect cleft lip using coronal and axial facial views; detection with three-dimensional ultrasound, and when indicated, fetal MRI shows high rates of success and can identify associated abnormalities
- Isolated cleft palate is challenging to diagnose prenatally
- Initial priorities after postnatal diagnosis include:
    - Prompt referral to multidisciplinary team (see below)
    - Airway and feeding assessment to ascertain the need for intervention by otolaryngologists and speech language pathologists while inpatient
    - Early referral associated with improved outcomes and timely surgical intervention

EPIDEMIOLOGY

- Terminology
    - Orofacial clefting typically considers cleft lip with or without palate (CL, CL/P) and cleft palate (CP) as similar entities, but these are distinct pathologies
- Prevalence
    - Globally
        - CL/P: 1.0 to 1.7 per 1,000 births
        - CP: 0.3 to 0.8 per 1,000 birthers
    - By ethnicity
        - Native American ~ Asian > Hispanic > Caucasian > Black
    - By sex
        - CL/P more common in males (2:1 ratio)
        - CP more common in females (2:1 ratio)
    - By family history (Table 1)
        - Strongest risk factor for both CL/P and CP
    - Environmental risks
        - Lack of maternal folic acid supplementation
        - Advanced maternal age (>35 years)
        - Maternal smoking
        - Anticonvulsant or retinoic acid exposure (highest risk)
        - High maternal fever during early pregnancy (>39°C)
        - Consanguinity

Family History	CL/P (% Risk)	CP (% Risk)
No FHx	0.1-0.2	0.04-1
One parent affected	2-5	2-7
Two parents affected	15-20	15-20
One sibling affected	3-5	2-7
≥ Two siblings affected	10-15	10-15
Bilateral CL/P in family	Higher than unilateral	
Unilateral CL/P in family	Baseline recurrence	

Table 1. CL/P or CP risk stratified by family history

- High maternal fever during early pregnancy (>39°C)
- Consanguinity
- Syndromic associations
    - CL/P: trisomy 21, Pierre Robin Sequence, Van der Woude (lower lip pits with IRF6 genetic association)
    - CP: DiGeorge Syndrome (most common) or Stickler syndrome

CLASSIFICATION

I. Cleft lip

- CL divided into unilateral/bilateral and incomplete/complete (Fig. 3)

Figure 3. Cleft lip classification

- Anatomic associations with unilateral cleft lip
    - Competence of the orbicularis oris muscle is disrupted by the cleft; normally these fibers will dessicate at the midline and insert into the dermis of opposing philtral columns
    - Caudal (anterior) nasal septum *deviates away* from cleft side
    - Cranial (posterior) nasal septum *deviates toward* the cleft side
    - Nasal ala
        - Cleft nasal ala (lower lateral cartilage, LLC) is collapsed, retruded and inferiorly displaced
        - Non-cleft nasal ala is laterally and superiorly displaced
        - Orbicularis oris on cleft side inserts on the alar base or piriform rim, contributing to vertical deficiency of the lateral lip element
    - Lateral lip element (cleft side) is shortened and vertically deficient
    - Medial lip element (non cleft side) is often hypoplastic
        - Columella is *shortened* on and *deviates away* from the cleft side

- Functional deficits
    - Cleft lip
        - Cannot form fluid/air seal in eating/speech
        - Malocclusion of teeth
    - Cleft palate
        - Cannot separate nose from mouth so air escapes during speech (velopharyngeal insufficiency)
        - Cannot suck on breast/bottle well due to poor seal for intraoral negative pressure
        - Middle ear disease/infections, often chronic

II. Cleft palate

- Veau classification (Fig. 4)
    - Type 1: clefts of the soft palate posterior to the hard palate
    - Type 2: complete cleft of the secondary palate up to the incisive foramen
    - Type 3: complete unilateral cleft lip, alveolus and palate
    - Type 4: bilateral complete cleft lip, alveolus and palate
- LAHSHAL classification (Fig. 5)
    - Derivation of the Kernahan and Stark "Striped Y" classification which assigns a letter (L for Lip, A for alveolus, H for hard palate and S for soft palate) to each part of the orofacial anatomy to delineate location of cleft

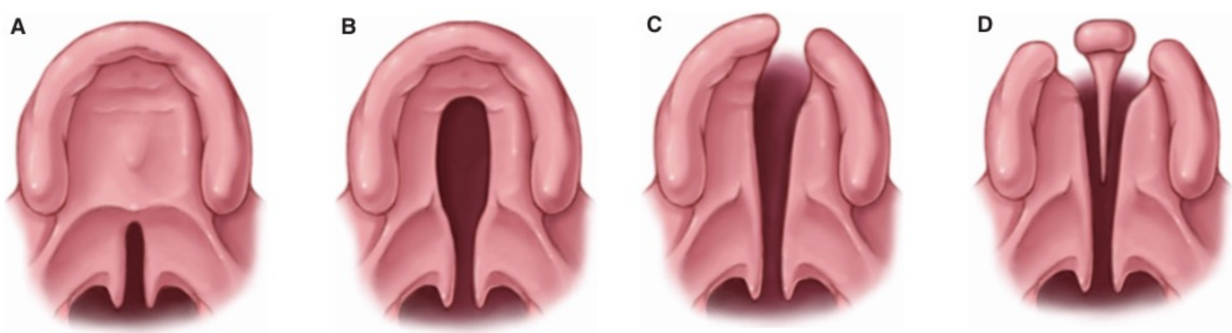

Figure 4. Veau Classification. A) Type 1; B) Type 2; C) Type 3; and D) Type 4. *Reprinted with permission, Comprehensive Cleft Care, 2nd Ed. Losee and Kirschner, ed.*

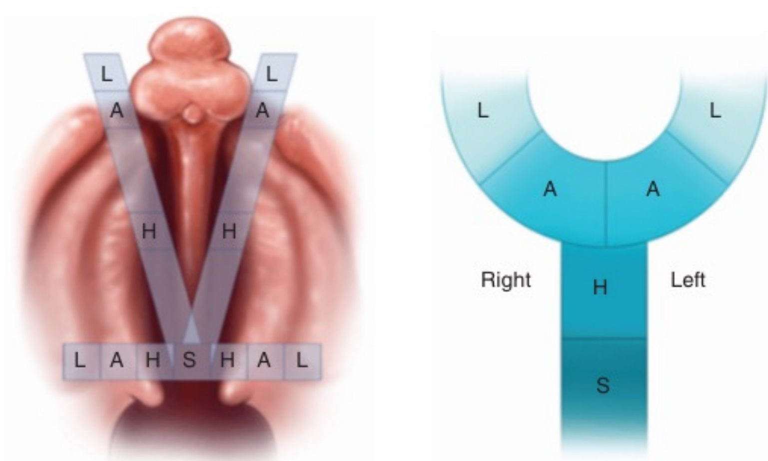

Figure 5. LAHSHAL Classification. Each element (Lip, Alveolus, Hard Palate and Soft Palate) is given a letter to denote area of clefting. *Reprinted with permission, Comprehensive Cleft Care, 2nd Ed. Losee and Kirschner, ed.*

II. Submucous cleft

- Submucous cleft palate is a distinct entity with an abnormal attachment of the palatal muscles with an intact oral and nasal mucosa
- Cardinal signs
  - Bifid uvula
  - V-shaped notch at hard palate
  - "Zona pellucida" or translucent area in the midline of the soft palate

MANAGEMENT

- Multidisciplinary Care
  - American Cleft Palate-Craniofacial Association (ACPA) has updated guidelines to emphasize standardized, interdisciplinary and longitudinal care
  - ACPA-approved teams must include core specialists who meet patients annually to review care
    - Plastic surgeon: provides primary surgical repair, revisions and care planning
    - Otolaryngologist (ENT): ear tube placement and hearing plan
    - Audiologist: hearing assessment
    - Speech-language pathologist (SLP): early feeding counseling, speech development patterns, velopharyngeal function
    - Pediatric dentist: early dentition assessment, regular cleaning as patients have high risk of carious disease
    - Orthodontist: arch/palatal expansion, assessment and preparation for alveolar bone grafting
    - Geneticist or genetic counselor: assess syndromic/recurrence risk for family
    - Psychologist or social worker: coping, family support, school support
    - Nurse/team coordinator: central point of communication
- Presurgical orthopedics and early management strategies for wide clefts
  - Goals:
    - Reduce the alveolar gap between cleft
    - Improve nasolabial symmetry, alar base collapse and lip malposition
    - Facilitate more successful surgical repair
  - Techniques:
    - Lip taping: easy to perform, cheap, less time-intensive way to narrow arch dimensions
      - Can be initiated in the first week of life and has been shown to improve pre-operative lip symmetry
      - Can be done with commercial products (DynaCleft tape) or Steri-Strips
    - Nasoalveolar molding (NAM): passive molding device that has been shown to narrow arch width, improve nasal form and create a more favorable configuration for surgical repair
      - Can be costly and require frequent dental visits for revision of the device over the first several weeks of life
    - Lip adhesion surgery: first stage surgery indicated in children with wide unilateral or bilateral clefts, where presurgical orthopedics were unsuccessful
      - Similarly, in patients with severe tissue deficiency, this will reduce tension until the time of definitive cheiloplasty and palatal repair
- Longitudinal cleft care: key interventions
  - 0-2 weeks: initial team referral, feeding support, genetic evaluation
  - 1-3 months: presurgical orthopedics, CL planning and repair
  - 3-6 months: lip adhesion or CL repair
  - 6-12 months: CP repair, SL/P assessment begins
  - 2-5 years: speech therapy, nasal/lip revisions as needed
  - 6-9 years: orthodontic care, alveolar bone grafting timed with canine eruption

        - 10-14 years: orthodontic care, psychosocial monitoring, VPI surgery if indicated
        - 14-18 years: orthognathic surgery planning, definitive cleft rhinoplasty
- Surgical intervention
    - Simultaneous nasal correction (primary cleft rhinoplasty) at the time of lip surgery has been shown to improve nasal aesthetics, obviate the need for future nasal surgery in 44-83% of patients and increase patient-reported outcome metrics after repair
        - Drawbacks include increasing scar burden and thereby enhancing maxillary restriction, leading to potential need for orthognathic surgery in some patients
    - Unilateral cleft lip repair
        - Goals:
            - Establishment of normal oral competence
            - Removal of anatomic deformity with minimal scar burden
            - Correction of nasal deformity
        - Key anatomic landmarks for markings:
            - Nordhoff's point: intended Cupid's bow peak, cleft side
                - Position is on the lateral lip element where the vermillion height is greatest
                - Determine height by isolating the Cupid's bow peak on the non-cleft side (reference height)
                - Use calipers to transpose to the cleft side for symmetry
            - Philtral height (non-cleft side) is compared to the cleft philtral height; the difference of these two lengths determines need for interposition flaps/triangles
            - Alar base
            - Columellar base
        - Fisher's anatomic subunit repair: emphasizes aligning the incision along the natural borders of the lip's aesthetic units
            - Markings recreate the philtral ridge/column and white roll
            - Repair is "hidden" within the junction of anatomic subunits
            - Utilizes "Fisher's triangles" to address height discrepancy between cleft and non-cleft sides
            - This approach is less dependent on cleft severity for achieving symmetry
        - Rotation-advancement repair (Millard and its modifications): uses a curvilinear incision on the medial lip element (rotation) and an advancement flap from the lateral lip element
            - A flap: primary rotation flap from medial lip element rotated downward to bring the cleft-side Cupid's bow peak into alignment with the noncleft side
            - B flap: primary advancement flap from the lateral lip element advanced medially to fill the defect created by the rotation of the A flap
            - C flap: small triangular back cut from the superior aspect of the medial lip element to provide additional length to the medial lip
            - M flap: small triangular mucosal flap created at the vermilion border of the lateral lip element
                - Primary role is to augment the central vermilion, thereby improving the fullness and continuity of the red lip and minimizing notching at the vermilion border
            - L flap: lateral mucosal flap, typically designed from the lateral lip element, and is used to reconstruct the nasal floor and the oral vestibule
                - Inset into the defect created after rotation and advancement of the main lip elements, helping to restore the continuity of the nasal sill and the mucosal lining of the upper lip
    - Bilateral cleft lip repair
        - Key anatomic landmarks for markings:
            - Peaks of Cupid's bow (crista philtra right and left)
            - Midline of Cupid's bow (labiale superius)

        - Oral commissures (cheilion)
        - Alar base
        - Vermillion-mucosal junction
    - Mulliken bilateral lip repair: prolabial skin and mucosa are preserved to form the philtrum and the central vermillion, while the muscle is discarded
        - Lateral lip elements (muscle, mucosa and vermillion) are advanced medially to reconstruct the oral sling and augment the central tubercle
- Cleft palate repair
    - Goals:
        - Address the aberrant insertion of the levator veli palatini (LVP) on the hard palate to restore posterior, coronal continuity
        - Reduce nasal efflux of fluid with feeding, improve suck
        - Competent velum to allow for normal speech development
        - Minimize adverse effects on craniofacial growth
            - Early repair (before 9 months): improved speech outcomes at the cost of increased maxillary hypoplasia
            - Late repair (after 1 year): worse speech outcomes with reduced risk of maxillary hypoplasia
    - Hard palate repair
        - Von Langenbeck: straight line closure with lateral relaxing incisions
        - V-Y pushback: adds length with V-Y pushback sending flaps posteriorly
        - Two flap palatoplasty (Bardach): hard palate mucoperiosteal flaps based on the greater palatine artery; does not lengthen palate so must be paired with a soft palate repair to achieve length
    - Soft palate repair
        - Furlow double-opposing z-plasty: three-layer tension-free closure with opposing myonasal and myomucosal flaps that bring the sagittally positioned LVP posterior
            - Poor success in wide clefts
            - Palatal length at the expense of width
            - Lower rates of velopharyngel insufficiency compared to IVVP
        - Intravelar veloplasty (IVVP) (Sommerlad technique): meticulous dissection of the levator muscle and straight-line repositioning; leaves a large soft-tissue defect between the hard palate and the newly-posteriorly positioned soft palate
            - Lower rates of middle ear pathology (otitis media)
            - Similar speech outcomes
            - Less effect on maxillary growth compared to Furlow
        - Adjuncts to address oronasal fistula
            - Buccal myomucosal flap: myomucosal flap (buccinator muscle) inferior to the Stenson's duct and rotated into the hard-soft palate junction; decreases rates of VPI with decreased risk of maxillary restriction for wide clefts (Veau III/IV)
            - Buccal fat pad flap: placed within lateral relaxing incisions for wide clefts (will mucosalize); isolate with a mucosal incision superior to Stenson's and obtain fat deep to buccinator, anterior to masseter and inferior to the zygomatic arch
    - Alveolar cleft bone grafting (ACBG)
        - Autologous bone grafting (typically from iliac crest) within the cleft alveolus to restore bony continuity and provide periodontal support to teeth adjacent to and erupting into the cleft margin
        - Typically performed at ages 6-8 (when the canine root is 1/2 to 2/3 formed)
        - Early grafting is associated with improved success, as erupted canines bring bone into the graft during eruption, providing stability

        - Pre-operative maxillary expansion and alignment of the alveolar segments is critical to success, reducing tension and improving bony fill
        - Adjuncts
            - Recombinant Human Bone Morphogenic Protein-2 (rhBMP-2): osteoinductive protein that stimulates bone formation and can be used as an alternative or an adjunct
                - Major complication with rhBMP-2 is increased risk of facial swelling, which can be significant
            - Collagen membranes have been utilized to provide barrier function to grafts to protect the nasal layer and improve infectious complication rates
    - Orthognathic surgery
        - Risk of maxillary hypoplasia with cleft lip and palate repair is common, with conservative estimates saying 1 in 4 will require orthognathic surgery to address malocclusion
        - Typically, cleft patients have angle class III malocclusion, and can present with anterior crossbite, negative overjet, midface retrusion or pseudoprognathism
        - Comprehensive presurgical orthodontic care prior to treatment is essential for preventing relapse. If velopharyngeal insufficiency or fistulae exist in the palatal, these will worsen with orthognathic surgery
        - Treatment options:
            - Le Fort I maxillary advancement: standard treatment for class III
            - Distraction osteogenesis, with Le Fort I osteotomy: reserved for large advancements (typically >1 cm) or when soft-tissue tension and relapse risk is high)

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Chapter 14
Facial Paralysis

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The facial nerve (CN VII) innervates 17 paired muscles, along with the unpaired orbicularis oris muscle. Most of these muscles are involved in facial expression. They play a central role in nonverbal communication and are also essential for key functions such as eye closure, nasal breathing, speech articulation, and maintaining oral competence. Because of this, facial paralysis can have profound physical and psychosocial effects on patients. Although a wide range of surgical options exist for facial reanimation, no current technique can fully replicate the complex and coordinated movements of the native mimetic musculature.

FACIAL NERVE ANATOMY (CN VII)

- Embryology:
    - Second branchial (pharyngeal) arch
- Course:
    - Exits skull base from the stylomastoid foramen
    - Travels within the parotid gland and divides into five motor branches
- Landmarks for identification:
    - Tympanomastoid suture: medial to the suture line
    - Tragal pointer: 1 cm inferior and deep
    - Posterior belly of the digastric muscle: found midway between muscle and styloid process
- Functional components:
    - Motor: innervates muscles of facial expression (17 pairs + 1 unpaired orbicularis oris muscle)
    - Sensory:
        - External auditory canal
        - Auricular concha
        - Tympanic membrane (minor contribution)
    - Special sensory (taste): anterior 2/3rds of the tongue
    - Parasympathetic innervation
        - Lacrimal glands
        - Submandibular glands
        - Sublingual glands
    - Five motor branches that control facial mimetic muscles (Table 1; Fig. 1, 2)

MIMETIC MUSCLES

The mimetic muscles are responsible for facial expression and can be broadly grouped based on their functional roles in controlling facial apertures, such as the eyes and mouth. The muscles act by either constricting (sphincter-like function) or expanding (opening and elevating) facial features. This balance allows for the expressions for nonverbal communication and facial function.

- Functional groupings:
    - Constriction of facial apertures (sphincter function):
        - Orbicularis oculi: closes the eyelids
        - Orbicularis oris: closes the lips
        - Buccinator: compresses the cheek against the teeth; assists with oral competence
    - Expansion of facial apertures (antagonists to sphincters): widen the eyes or mouth by elevating or depressing the surrounding soft tissues

Table 1. Five motor branches of CN VII		
Branch	Function(s)	Anatomical Notes
Temporal (frontal)	Brow elevation/depression	Runs in temporoparietal fascia Pitanguy’s line: ~0.5cm below tragus to ~1.5cm above lateral brow (superficial course)
Zygomatic	Eyelid closure, oral commissure elevation	5 to 8 branches that lie deep near the parotid-masseteric fascia in the same plane as the parotid duct
Buccal	Oral commissure elevation, upper lip elevation, nasal compression/flaring, cheek compression	Multiple branches course medially across masseter, often form a plexus with zygomatic branches; superficial to buccinator muscle
Marginal mandibular	Oral commissure depression, chin elevation/dimpling	1 to 3 branches that cross superficial to facial artery/vein; superior to mandibular border anterior to facial vessels
Cervical	Oral commissure depression	1 branch that innervates the platysma at a point of entry 2 or 3 cm caudal to the vascular pedicle of the platysma

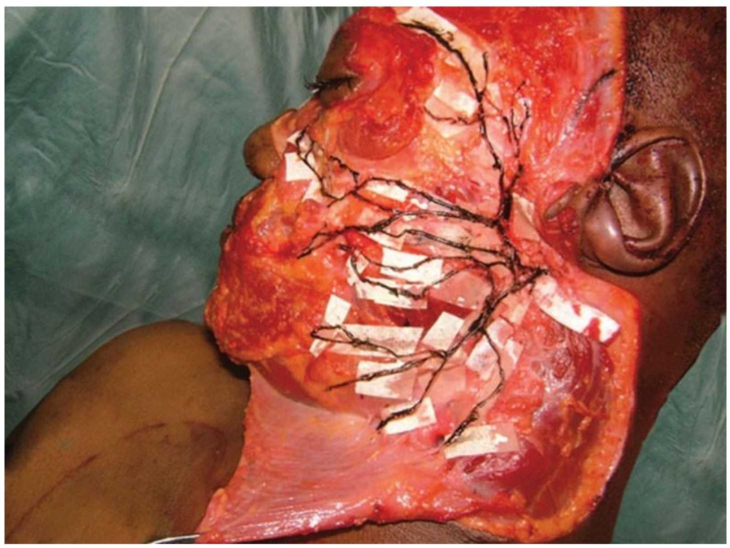

Figure 1. Major branches (frontal/temporal, zygomatic, buccal, marginal mandibular, and cervical) of the facial nerve. *From Roostaeian J, et al. Anatomical considerations to prevent facial nerve injury. Plast Reconstr Surg 2015;1318-27.*

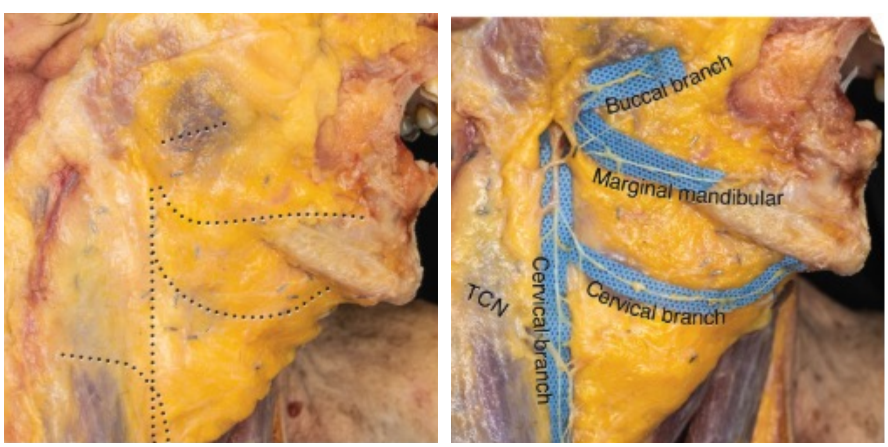

Figure 2. Lower branches of the facial nerve lie within the deep fascia of the head and neck. Above is before removal of a layer of deep fascia, while below is after removal. Note that the deep fascia still underlies the nerves after removal. *From Minelli L, et al. The Deep Fascia of the Head and Neck Revisited: Relationship with the Facial Nerve and Implications for Rhytidectomy. Plast Reconstr Surg 2024;1273-1288.*

        - Upper lip retractors
            - Levator labii superioris, levator anguli oris, zygomaticus major, zygomaticus minor
        - Lower lip depressors
            - Depressor anguli oris, depressor labii inferioris
- Functional groupings:
    - Forehead and eyelid animation
        - Frontalis, corrugator, orbicularis oculi
    - Perioral movement: antagonistic groups acting on the lips
        - Lip retractors (see above)
        - Orbicularis oris (acts as a sphincter to close the lips)
- Anatomic layers of mimetic muscles: the mimetic muscles are organized in distinct layers
    - Most superficial: depressor anguli oris, part of zygomaticus minor, orbicularis oculi
    - Deepest: buccinator, mentalis, levator anguli oris
- Motor innervation pattern:
    - Most mimetic muscles receive motor innervation from the deep surface of the muscle
        - Exception: buccinator, mentalis, levator anguli oris (deepest layer anatomically) are innervated from their superficial surface

CAUSES OF FACIAL PARALYSIS

Facial paralysis can be classified based on anatomic location, etiology, or clinical characteristics, such as time course and severity. The following section outlines key causes, organized by etiology.

I. Congenital
    - Idiopathic
        - Nerve compression injury during delivery or in utero
        - Absence of facial motor units or nerve
    - Syndromic
        - Moebius syndrome
            - Bilateral CN VI and VII paralysis; characterized by inability to abduct one or both eyes, absence of facial movement (spares cervical and marginal mandibular branches)
            - Imperative to put children in speech therapy (speech development, facial movement, saliva control)
        - Hemifacial microsomia: unilateral underdevelopment of facial structures
    - Non-syndromic
        - Absence or maldevelopment of facial musculature
        - Osteopetrosis: can cause nerve compression
        - Birth trauma (especially in neonates, where the facial nerve is more superficial)

II. Acquired
    - Idiopathic
        - Bell's Palsy: most common cause of unilateral facial palsy in adults; affects all portions of the facial nerve
            - Not addressed surgically; managed with corticosteroids and antivirals, stretching/exercises, and Botox for hyperactive muscles
            - Typically resolves within 6 months
        - Melkersson-Rosenthal syndrome: recurrent facial paralysis, orofacial swelling, fissured tongue
            - Autosomal dominant, treatment is nonsurgical, definitive diagnosis by lip biopsy
    - Traumatic
        - Central: penetrating injury, iatrogenic (i.e., intracranial surgery)
        - Intratemporal: petrous temporal bone fracture, penetrating injury, iatrogenic (i.e., middle ear surgery)

        - Facial: facial lacerations, blunt or penetrating trauma, mandibular fractures, iatrogenic (i.e. parotidectomy)
    - Tumor
        - Central: brainstem tumors
        - Intratemporal: glomus tumors, cholesteatoma, facial nerve schwannomas, SCC, rhabdomyosarcoma, arachnoid cysts or metastases
        - Facial: parotid tumors, tumors of the external auditory canal or middle ear, facial nerve schwannomas, metastatic lesions
    - Inflammatory
        - Herpes zoster oticus (Ramsay Hunt Syndrome), acute otitis media, malignant otitis externa, Lyme disease (often bilateral)
    - Neuromuscular
        - Myasthenia gravis
    - Additional considerations:
        - Timing matters with traumatic injury: Wallerian degeneration begins within 72 hours; allows intraoperative nerve stimulation up until 72 hours have passed
        - Medial to the lateral canthus: arborization complicates repair; exception exists for temporal and marginal mandibular branches, which lack cross-innervation
        - Frey syndrome: “gustatory sweating” from aberrant regeneration of the auriculotemporal nerve (CN V3)
        - Intratemporal injury presents with facial muscle paralysis, hyperacusis, partial loss of ipsilateral taste, decreased salivation, decreased nasal/lacrimal secretion
        - Extratemporal injury presents with facial muscle paralysis only

HISTORY AND PHYSICAL EXAM

A comprehensive evaluation of patients with facial paralysis should include a detailed history and structured physical exam. Both rest and dynamic facial movements must be addressed.

I. History

- Etiology
    - Inciting factors: trauma, surgery, hereditary conditions
    - Time since onset: important for determining eligibility for nerve repair
    - Patient-reported triggers: recent infection, delivery history, known tumors
- Functional impairments (“top-down” approach)
    - Ophthalmic symptoms: ocular dryness, incomplete eyelid closure, visual changes
    - Nasal complaints: nasal airway obstruction, nasal valve collapse
    - Oral symptoms: drooling, difficulty speaking or eating
    - Psychosocial impact: depression, social withdrawal, appearance-related distress
        - ¼ of patients have anxiety/depression (impaired smile is a predictor for anxiety/depression)
- General medical history
    - Comorbid conditions (i.e., diabetes, autoimmune disease)
- Prior surgeries, radiation, infections

II. Physical exam

- Forehead/ frontalis
    - Eyebrow elevation ability, degree of brow ptosis
    - Symmetry of forehead rhytids
    - Unilateral vs. bilateral involvement
- Eyes and eyelids/ orbicularis oculi
    - Function
        - Assess eye closure: orbicularis oculi

        - Check Bell's phenomenon (upward globe rotation with attempted eye closure)
    - Upper eyelid
        - Levator palpebrae superioris (CN II) and Mueller muscle (sympathetic)
        - Assess for dermatochalasis, lid retraction
    - Globe integrity
        - Visual acuity, dry eye signs, conjunctival injection, lagophthalmos
    - Lower eyelid
        - Ectropion, snap test (pull and release lower lid), position of inferior canalicular punctum
- Ears, nasal airway, and midface
    - Changes in hearing (i.e., stapedius dysfunction)
    - Nasal asymmetry or collapse on forced inspiration
    - Cottle's test for nasal valve patency (pull on cheek to see if airflow improves)
    - Asymmetry of nasolabial folds
    - Philtral deviation
- Mouth and perioral region
    - Commissure depression or deviation
    - Upper lip droop
    - Vermillion inversion
    - Tooth show and smile shape
    - Speech quality
    - Intraoral exam: dental hygiene, cheek biting, food pocketing
- Lower face
    - Asymmetric smile
    - Inability to keep cheeks puffed
    - Chin dimpling loss
    - Drooling/oral incompetence
- Synkinesis: involuntary contraction of muscles not normally activated together due to aberrant reinnervation
    - Common patterns: eyelid closure with smiling, brow wrinkling with mouth movement, lip twitching with eyelid closure
    - Assessment: evaluate each branch of CN VII
    - More proximal injuries often show greater synkinesis
    - Treatment: physical therapy/biofeedback, Botox, selective myectomy
- Other cranial nerves and vessels
    - Evaluate CN V, XI, XII for additional deficits and donor potential
    - Palpate facial and superficial temporal arteries for vessel access in free muscle transfer procedures

III. Clinical grading scales

- Provide a semi-quantitative assessment of facial paralysis for baseline and follow-up documentation
- Sunnybrook facial grading system
- House-Brackmann Facial Nerve Grading System (FNGS 2.0)
- The use of machine learning and digital facial grading tools is emerging and may be used as an adjunct to traditional grading scales

MANAGEMENT

Management of facial paralysis aims to restore facial symmetry and function, particularly eyelid closure, oral competence, and dynamic expression, while minimizing psychosocial distress. Treatment is highly individualized, depending on cause, duration of paralysis, and patient-specific goals (Fig. 3).

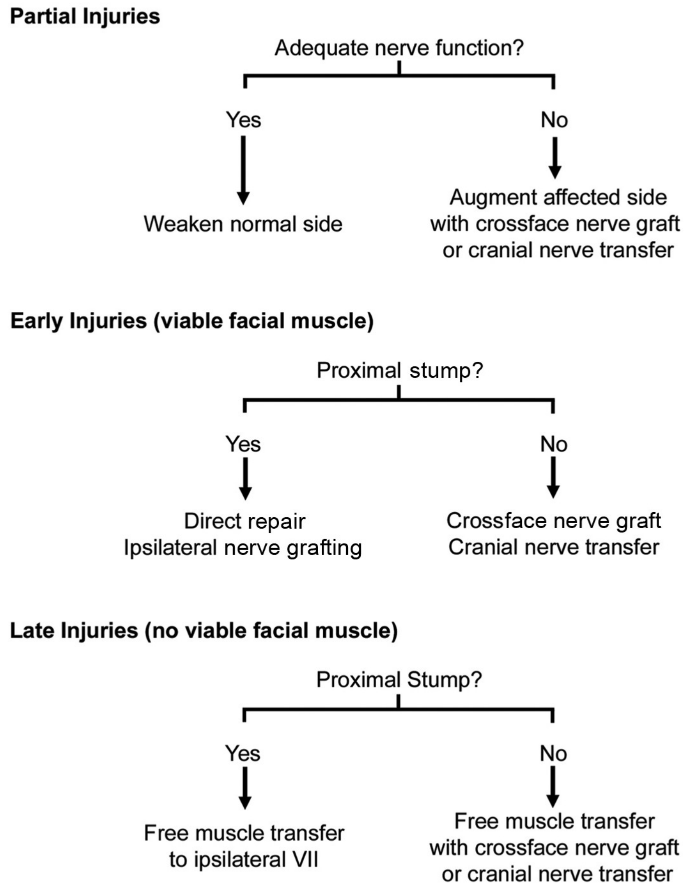

Figure 3. Approach to dynamic reconstruction in facial palsy. *From Fattah A., et al. Facial Palsy and Reconstruction. Plast Reconstr Surg 2011;340e-352e.*

- Treatment goals and principles
  - Restore facial movement (dynamic procedures) or improve resting tone/symmetry (static procedures)
  - Prevent complications such as corneal exposure and oral incompetence
  - Improve quality of life, psychosocial function, and nonverbal communication
  - Timing is critical: viable mimetic muscles may be reinnervated with in 12-18 months after onset of paralysis
- Pre-operative evaluation
  - History (see above)
  - Physical exam (see above)
  - Diagnostics
    - Clinical grading scales (see above)
    - Electromyography (EMG): needle insertion into muscle groups
      - Fibrillations indicate denervation
      - Does not become positive until 2-3 weeks after onset of paralysis (should be considered after 3 weeks)
    - Electroneurography: evaluates the nerve/muscle unit
      - Compound muscle action potentials (CMAPs): summation of the action potentials from muscle fibers innervated by queried nerve; compare normal side to the injured side

I. Non-surgical

- Non-operative care may be definitive in mild or early cases or serve as adjunctive therapy in more advanced stages
- Eye protection: ocular surface health should be maintained to prevent vision loss
  - Daytime use of artificial tears and nighttime lubricating ointments
  - Protective eye taping or moisture chambers during sleep, eye patches
  - Referral to ophthalmology for ongoing monitoring
  - Temporary tarsorrhaphy in refractory cases; permanent tarsorrhaphy is rare due to cosmetic concerns
  - Forced blinking exercises to strengthen eye closure
- Botulinum toxin injections: prevent acetylcholine release across the neuromuscular junction
  - Reduce hypertonicity and synkinesis
  - Weaken the contralateral non-paralyzed side to improve dynamic balance
  - Injections repeated every 3-4 months and remain mainstay for treating asymmetric movement and aberrant reinnervation
- Physical and speech therapy
  - Mirror biofeedback and EMG-assisted rehab can aid in motor retraining
    - The routine use of neuromuscular stimulation is controversial and not universally recommended
  - Massage therapy, thermal application, and neuromuscular stimulation can aid recovery
  - Speech therapy is essential for pediatric patients or those with oromotor dysfunction
- Psychosocial support: the significant burden of facial paralysis is increasingly recognized, and psychological interventions are core components of comprehensive care

II. Surgical

- Options are broadly categorized by their functional goals (dynamic vs. static), anatomical site, and timing after onset (Fig. 4)

Time from Facial Nerve Injury	Reconstructive Options
Immediate	• Primary repair for tension-free clean laceration • Nerve autografting from ipsilateral facial nerve proximal to injury
<12 mo	• CFNG if ipsilateral facial nerve is not available and contralateral facial nerve is available • Ipsilateral nerve transfer if distal facial nerve stumps intact (masseteric nerve preferred)
≥12 mo	If muscle intact: • CFNG with or without nerve transfer (nerve transfer may be used temporarily, ie, “babysitter procedures,” or may be permanent) If muscle not intact: • CFNG plus free functional muscle transfer • Nerve to masseter plus free functional muscle transfer • Static slings

Figure 4. Timing of reanimation following facial nerve Injury. *From Aronson, S, et al. Evidence-Based Practices in Facial Reanimation Surgery. Plast Reconstr Surg 2023;520e-533e.*

- Neurotization procedures: ideal for patients within 12-18 months of paralysis onset and with viable mimetic musculature

        - Masseteric nerve transfer (CN V to VII): offers strong motor unit input with rapid reinnervation
        - Hypoglossal nerve transfer (CN XII to VII): effective but may cause tongue weakness and partial tongue atrophy
        - Cross-facial nerve graft (CFNG): sural nerve graft connects contralateral facial nerve to the affected side
            - Used alone or as part of a two-staged procedure
            - Sural nerve from contralateral facial nerve tunneled across the upper lip and the ipsilateral side
            - Allow 9-12 months for nerve to grow across
        - Observe Tinel sign to confirm nerve growth (tapping over nerve elicits “pins and needles” in its distribution)
        - Can incorporate a “babysitter” procedure in which a temporary nerve donor (hypoglossal or masseteric) is connected to the paralyzed nerve while a CFNG is simultaneously placed to provide definitive reinnervation later
    - Free functional muscle transfer (FFMT): for long-standing paralysis where mimetic muscles are no longer viable
        - Two-stage technique: first, a CFNG is placed; after 9-12 months, a free muscle (usually gracilis) is transferred and coapted to the graft (Fig. 5)
            - Dual-innervated FFMT: coapting both the CFNG and masseteric nerve to the transferred muscle
        - Single-stage technique: use ipsilateral masseteric nerve as donor for gracilis muscle
            - Can reduce recovery time and financial burden on patient

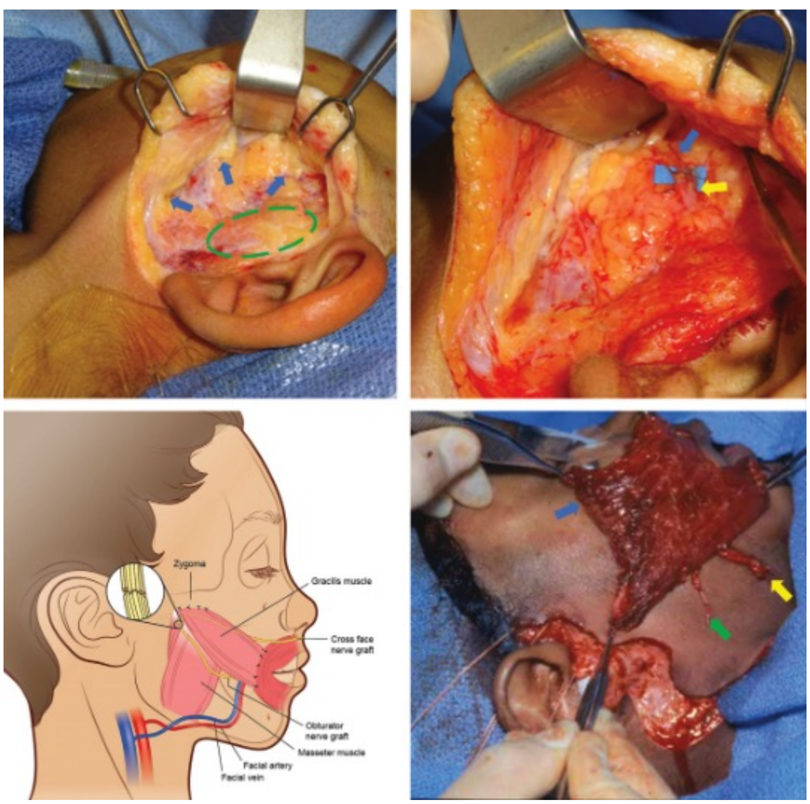

Figure 5. Two-stage approach to CFNG and free functional gracilis muscle transfer, showing the first stage (above, left), coaptation of nerve cable autograft from sural donor (above, right), second stage (below, left) showing CFNG traveling across the midline, and free functional muscle transfer from gracilis performed at subsequent surgery (below, right). *From Aronson, S, et al. Evidence-Based Practices in Facial Reanimation Surgery. Plast Reconstr Surg 2023;520e-533e.*

        - Gracilis is favored for its consistent anatomy, adequate excursion, and reliable neurovascular pedicle (other options: pectoralis minor, latissimus dorsi)
            - Innervated by the anterior branch of the obturator nerve
            - Blood supply from the medial circumflex femoral artery
            - Set tension based on resting tension at the donor site

- Contiguous regional muscle transfers: for long-standing facial paralysis when native mimetic muscles are no longer viable and a simpler alternative to free muscle transfer is preferred; useful for adults or as salvage options and have the advantage of shorter recovery
    - Temporalis transfer (McLaughlin or Rubin techniques): temporalis muscle is re-routed to the oral commissure for smile restoration
        - Blood supply: deep temporal artery
        - Innervation: deep temporal nerves (CN V3)
    - Masseteric muscle transfer: less common but can be used in specific reconstructions
        - Provide motion to the lower half of the face
- Static procedures: restore resting symmetry without voluntary movement, especially important for those who are not candidates for dynamic reanimation (i.e., elderly, massive facial defects after trauma or cancer, failed reanimation)
    - Facial slings: fascia lata, acellular dermal matrix (ADM), or synthetic grafts can support the oral commissure; multivector suture technique
    - Unilateral facelifts: can improve symmetry in the midface
    - Nasal valve collapse can be addressed with alar or spreader grafts
    - Brow lifting for brow ptosis (ipsilateral) and contralateral compensatory hypertonicity
- Region-specific interventions:
    - Brow and forehead
        - Brow lift to correct ptosis and restore visual field
        - Botox to contralateral frontalis to balance brow elevation
            - May cause ipsilateral brow ptosis
    - Eyelids
        - Gold or platinum eyelid weights to assist closure (eyelid loading), placed anterior to tarsal plate
        - Eyelid (palpebral) springs
        - Lower lid tightening procedures such as lateral canthoplasty, lateral canthopexy, or midface lift for ectropion
        - Corneal neurotization via nerve grafts can restore corneal sensation and protect ocular surface
    - Midface and nose
        - Use of spreaders and alar grafts to treat nasal valve insufficiency
            - Spreaders for internal valve collapse, alar for external valve collapse
        - Volume restoration with fat grafting or fillers to improve nasolabial fold symmetry
        - Unilateral facelift to address nasolabial fold asymmetry
    - Mouth and lower face: aim to restore oral competence and improve speech, eating, and social interaction
        - Unilateral face lift and static suspension of the oral commissure
        - Dynamic reanimation with muscle transfer (temporalis, masseter) and FFMT
        - Masseteric or hypoglossal to distal facial branches nerve transfers for smile

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Chapter 15
Breast Reconstruction

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BREAST ANATOMY

- Mastering breast anatomy is essential for understanding how the breast changes with aging and principles of reconstruction, reduction, and mastopexy (Fig. 1)

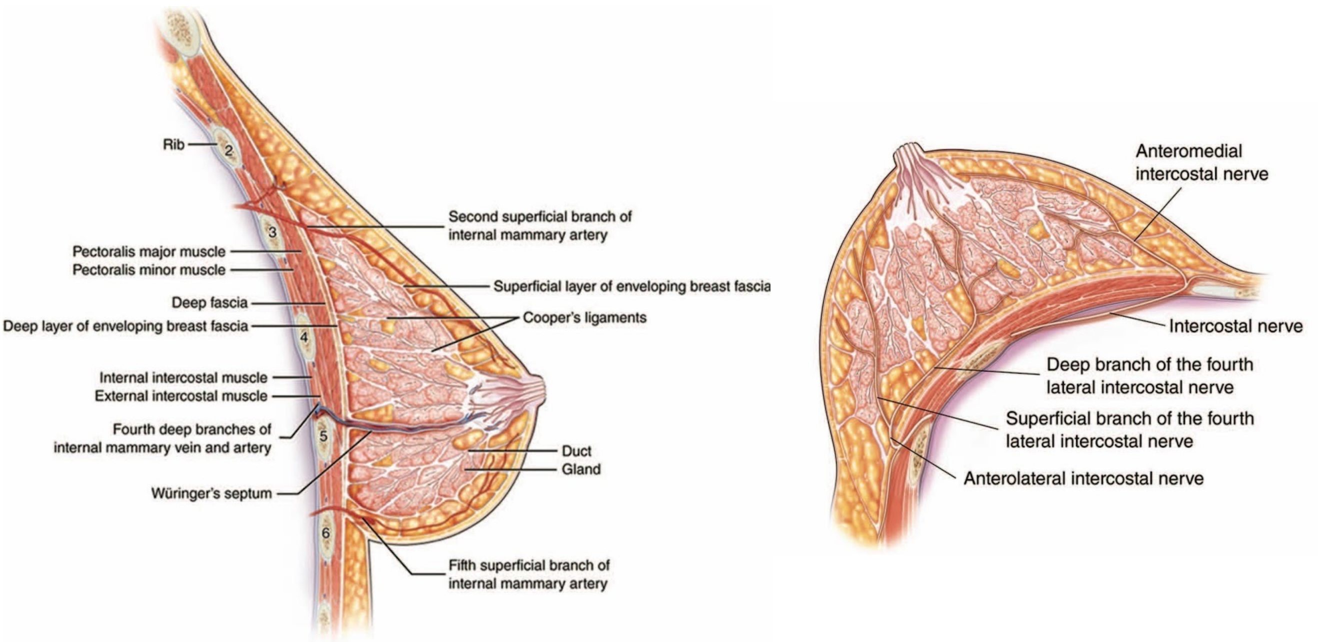

Figure 1. Anatomy of the breast. *From van Deventer P, et al. The Blood Supply of the Breast Revisited. Plast Reconstr Surg 2016;137(5):1388-1397.*

I. Breast tissue

- Glandular and adipose tissue are enclosed by superficial fascia and deep fascia overlying chest wall muscles
- Cooper's ligaments: suspensory attachment of the breast to the overlying fascia anteriorly; attenuation results in breast ptosis
- Boundaries for mastectomy:
  - Superior border is the clavicle
  - Inferior border is the rectus abdominis fascia/inframammary fold (IMF)
  - Medial border is the sternum
  - Lateral border is the anterior border of latissimus dorsi muscle
- Important elements in planning breast surgery:
  - Breast footprint: superior margin of the breast is lower than the clavicle
  - Conus: three-dimensional shape, projection, and volume of the breast tissue
  - Skin envelope: adequate quantity and quality to drape the conus
- Nipple areola complex (NAC)
  - Diameter 30-45mm
  - Aesthetic pleasing breast shape has NAC position:proportion 45:55 (Fig. 2)

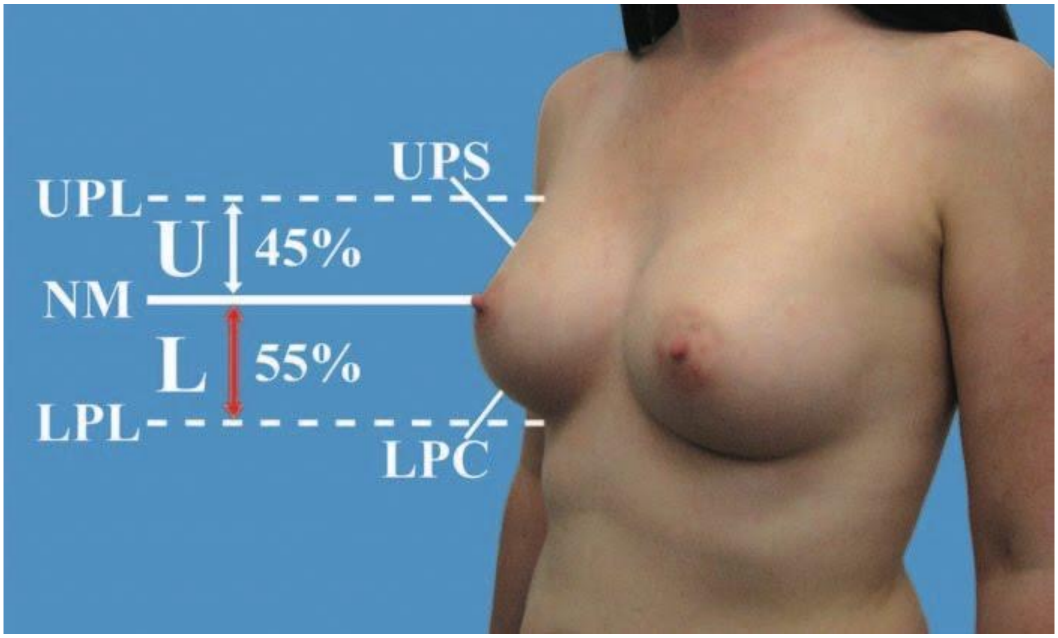

Figure 2. Ideal nipple position. UPL, upper pole line; NM, nipple meridian; LPL, lower pole line; UPS, upper pole slope; LPC, lower pole convexity. *From Mallucci P, et al. Population analysis of the perfect breast: a morphometric analysis. Plast Reconst Surg 2014;134(3):436-447.*

II. Vasculature

- Arterial supply (Fig. 3):
  - Internal mammary artery perforators (60%)
  - Lateral thoracic artery (30%)
  - Thoracoacromial artery: pectoral branches supply pectoralis major muscle and overlying breast tissue
  - Intercostal arteries 3, 4, 5
  - NAC receives blood supply through subdermal plexus and parenchymal vessels, dominant supply from 2nd and 3rd branches of IMA
    - After nipple sparing mastectomy, blood supply is the subdermal plexus
    - After breast reduction or mastopexy, the blood supply is the breast pedicle or parenchyma, as you must divide the skin and subdermal plexus to reposition the NAC

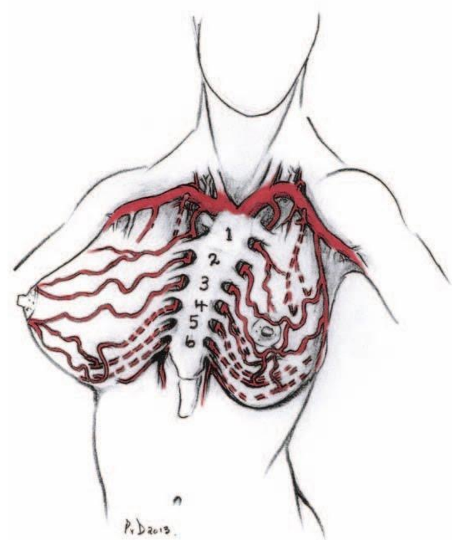

Figure 3. Arterial blood supply to the breast.

- Venous drainage (Fig. 4)
  - Mainly to axillary vein but some to internal mammary and intercostal veins
  - Veins are more superficial on the medial breast and deeper on the lateral aspect of the breast
  - NAC: superomedial/medial and inferior pedicles contain the most extensive and more reliable venous drainage patterns for NAC
- Lymphatics
  - Dominant drainage to axilla (97%)
  - To internal mammary nodes (3%)
  - Level I: nodes lateral to lateral border of pectoralis minor
  - Level II: nodes lying beneath pectoralis minor

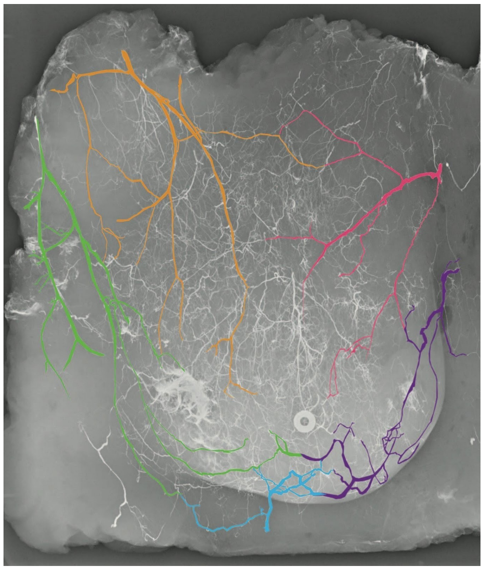

Figure 4. Resultant venogram of the right breast using plain radiography showing the venous drainage of the breast, including the inferolateral veins (green), superolateral veins (orange), medial veins (pink and purple), and inferior veins (blue). Note the anastomoses between the dominant veins around the nipple-areola complex. *From Le Roux C, et al. Preventing venous congestion of the nipple-areola complex: an anatomical guide to preserving essential venous drainage networks. Plast Reconst Surg 2011;127(3):1073-1079.*

- Level III: nodes medial to medial border of pectoralis minor and extending to apex of the axilla
- Nerve supply (Fig. 1)
  - Cervical plexus: sensory branches of C3-4 from supraclavicular nerve
  - Lateral branches of intercostal nerves: provide sensation to lateral side of breast
    - Lateral cutaneous branch of the 4th intercostal nerve provides major sensory innervation to nipple (T4 dermatome)
  - Medial branches of intercostal nerves 2-7 provide sensation to medial breast

RECONSTRUCTION

- Breast cancer now affects one in eight women over the course of their lifetime and is the leading cause of cancer-related death in women
- All patients that have undergone or will undergo mastectomy are entitled to breast reconstructive surgery covered by insurance (Women's Health and Cancer Rights Act, 1998)
  - Symmetry procedure for the contralateral breast is also covered
- Patients undergoing mastectomy should be offered a pre-operative referral to a plastic surgeon
  - In relation to the timing of the mastectomy, breast reconstruction can be:
    - Immediate: during the same anesthetic as the mastectomy
    - Delayed-immediate: tissue expander placed during time of mastectomy and then definitive reconstruction delayed until a later time
    - Delayed: during surgery separate from the mastectomy
- Possible preferences of patients:
  - No reconstruction or flat closure
    - Women may choose to wear an external prosthetic
  - Reconstruction of breast mound to attain close to natural breast shape, feel, contour
  - Breast mound reconstruction may or may not be followed with NAC reconstruction, depending on patient preference
    - Mastectomy defects frequently include loss of the NAC (such as in skin-sparing mastectomy)
- Mastectomy skin necrosis is the unplanned loss of skin due to inadequate blood supply following surgery
- Previous irradiation, such as in BCT, may cause difficulties with wound healing, skin contraction and discoloration, capsular contracture, and fat necrosis
- If desired, following unilateral breast reconstruction, the opposite breast can be contoured to obtain symmetry, using mastopexy, reduction or augmentation mammoplasty

I. Options based on type of oncologic surgery

- Breast conservative therapy (BCT) or partial mastectomy or lumpectomy: 50-70% of breast cancer patients; removal of the tumor only; requires post-operative radiation
    - Reconstructive options:
        - Oncoplastic surgery
            - Volume replacement: chest wall perforator flaps (LICAP, AICAP, MICAP, LTAP, TDAP), small implant
            - Volume displacement: mastopexy, breast reduction
        - Contralateral surgery for symmetry
- Mastectomy options:
    - Nipple-sparing mastectomy (NSM) or total skin-sparing mastectomy (TSSM): removal of all breast tissue with preservation of all skin, including NAC (Fig. 5)
        - Reconstruction can be with autologous tissue or implant-based
    - Simple (total) mastectomy: removal of all breast tissue, including NAC
        - Reconstruction in delayed fashion will require tissue expansion or autologous tissue
    - Modified radical mastectomy: removal of all breast tissue, NAC, pectoralis fascia, as well as level I-II lymph nodes
        - Same principles of reconstruction as for simple mastectomy
    - Halsted radical mastectomy: removal of all breast tissue, NAC, pectoralis major and minor muscles, muscular fascia, Level I-III lymph nodes
        - Does not improve disease control compared to modified radical mastectomy and is largely of historical interest now
    - Goldilocks mastectomy: performed through a Wise skin pattern; the inferior de-epithelized mastectomy flap is folded under the Wise pattern in order to obtain a breast mound
        - Can be fat grafted for further volume

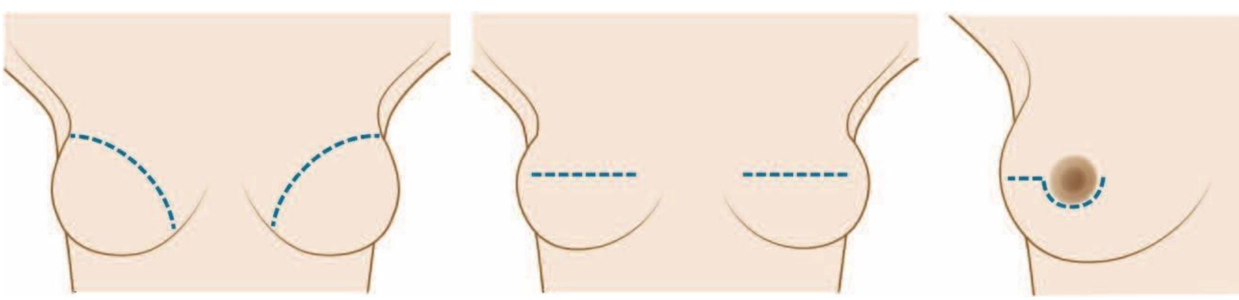

Figure 5. Examples of mastectomy incisions. *From Cordeiro P, et al. Two-Stage Implant-Based Breast Reconstruction: An Evolution of the Conceptual and Technical Approach over a Two-Decade Period. Plast Reconstr Surg 2016;138(1):1-11.*

II. Techniques

- Choose based on:
    - Patient preference
    - Need for adjuvant radiation before or after the breast reconstruction (Fig. 6, 7)
    - Uni- or bilateral mastectomy
    - Defect of the breast envelope: NSM, total simple mastectomy, mastectomy skin necrosis
    - Immediate or delayed reconstruction (increased skin requirements)
    - Habitus of the patient: BMI, size of the breast or desired size of the reconstructed breasts, possible donor sites for autologous reconstruction

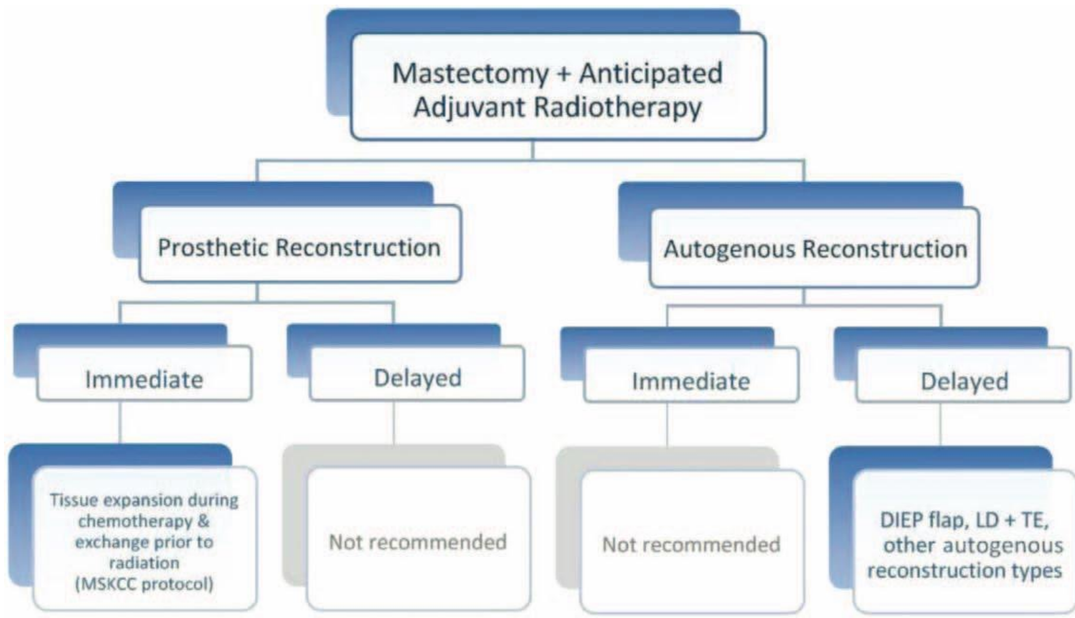

Figure 6. Decision algorithm for breast reconstruction in patient faced with mastectomy and post-mastectomy radiotherapy. MSKCC, Memorial Sloan-Kettering Cancer Center; LD, latissimus dorsi; TE, tissue expander. DIEP, deep inferior epigastric perforator. *From Zhong T, et al. Evidence-based medicine: breast reconstruction. Plast Reconstr Surg 2013;132(6):1658-1669.*

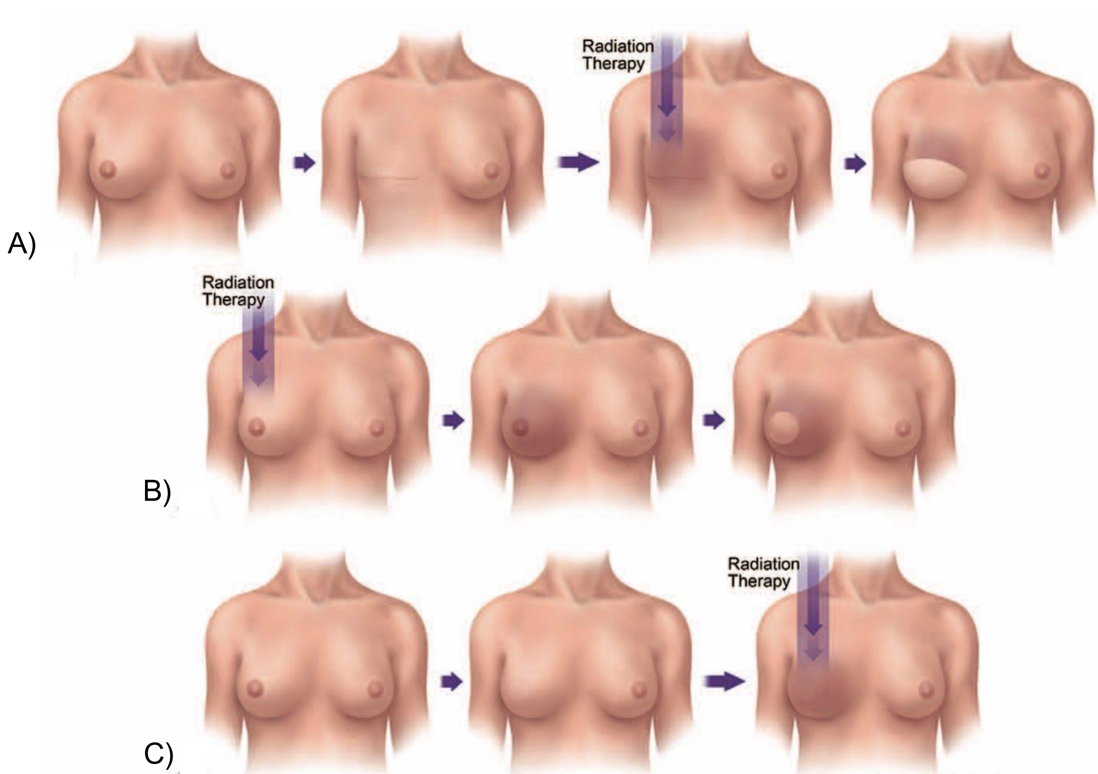

Figure 7. Options for timing of radiation in relation to autologous reconstruction. A) Mastectomy with radiation therapy of the chest wall and subsequent delayed autologous reconstruction. B) Pre-operative radiation therapy followed by mastectomy with immediate autologous reconstruction. C) Mastectomy, immediate autologous reconstruction followed by radiation therapy. *From Macadam S, et al. Evidence-Based Medicine: Autologous Breast Reconstruction. Plast Reconst Surg 2017;139(1):204e-229e.*

- Implant-based reconstruction
    - One- or two-stage options:
        - Direct-to-implant reconstruction: place implant at time of mastectomy
        - Use of tissue expanders (TE) with staged breast implant insertion once adequate skin expansion has occurred
    - Acellular dermal matrix (ADM) may be used for partial or total coverage of the device
    - Breast implants may be saline or silicone
    - Placement in relation to pectoralis muscle:
        - Total submuscular coverage
            - Placed under the pectoralis major without releasing its inferior origin and full coverage is achieved by recruiting serratus anterior and less commonly rectus sheath flaps
            - Excellent vascularized soft-tissue coverage
            - Greater risk of animation deformity and loss of strength
            - Inferior restriction limits ptosis, projection and definition
        - Partial muscle coverage (dual plane):
            - Implant covered superiorly by pectoralis major and inferiorly by the mastectomy flap ± ADM
            - Allows for lower pole expansion without flap recruitment, improving projection and shape
            - Loss of inferior muscle attachment can cause superior migration ("window-shading") and subcutaneous coverage at the lower pole reintroduces risks of visibility and palpability
        - Pre-pectoral
            - Several improvements since the 1960s have made this approach more feasible
                - Mastectomies have become less aggressive
                - Use of constructs with ADMs ± mesh
                - Devices that assess tissue perfusion
                - Techniques in fat grafting
                - Implant designs with less rippling
            - No animation deformity and preservation of muscle function
            - Less post-operative pain and shorter recovery
    - Breast-implant associated anaplastic large-cell lymphoma (BIA-ALCL): T-cell non-Hodgkin lymphoma, almost exclusively associated with textured breast implants
        - Patient presentation: late-onset, peri-implant effusion, or a discrete capsular mass approximately 8-10 years after implantation
        - Diagnosis: pathologic and cytologic evaluation (CD30 positive, ALK negative) of the implant capsule and seroma fluid
        - Treatment: en-bloc capsulectomy with implant removal (excellent prognosis)
    - Breast-implant associated squamous cell carcinoma (BIA-SCC): arises from metaplastic epithelium within implant capsule
        - Rarer than BIA-ALCL
        - Patient presentation: swelling, pain, and sometimes erythema years after implantation
        - Unlike BIA-ALCL, BIA-SCC behaves aggressively and has a higher mortality rate
- Autologous reconstruction
    - Pedicled flaps
        - Latissimus dorsi myocutaneous flap (Fig. 8)
            - For adequate volume of the reconstructed breast, usually combined with:
                - TE with or without ADM; after completion of the tissue expansion, the TE is eventually exchanged for a breast implant
                - Fat grafting

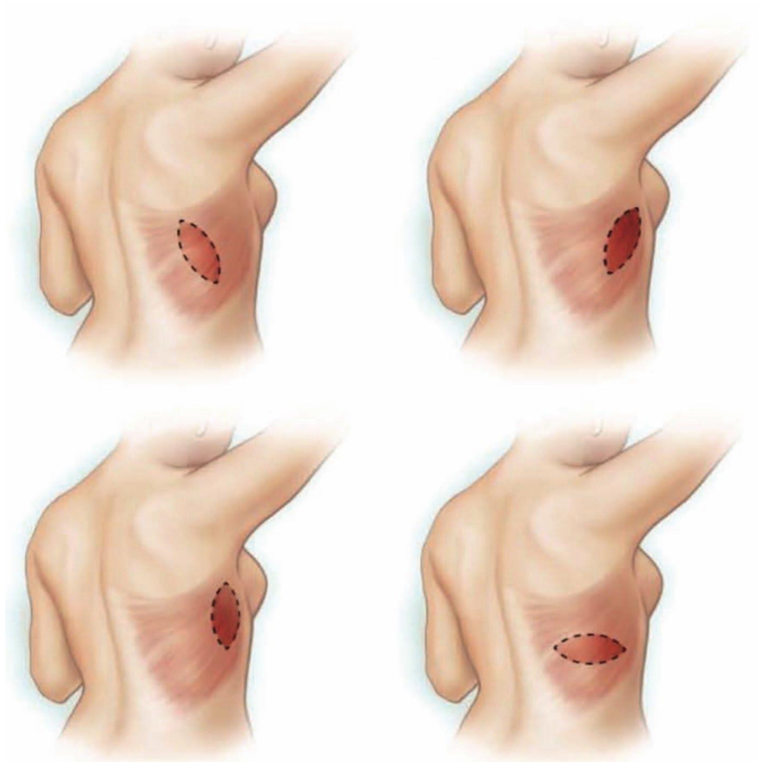

Figure 8. Three different skin paddles for the latissimus dorsi flap. (above, left) Oblique skin island design in two different orientations. (above, right) Vertical skin island design. (below, left) Horizontal skin island design at the bra line. *From Zhong T, et al. Evidence-based medicine: breast reconstruction. Plast Reconstr Surg 2013;132(6):1658-1669.*

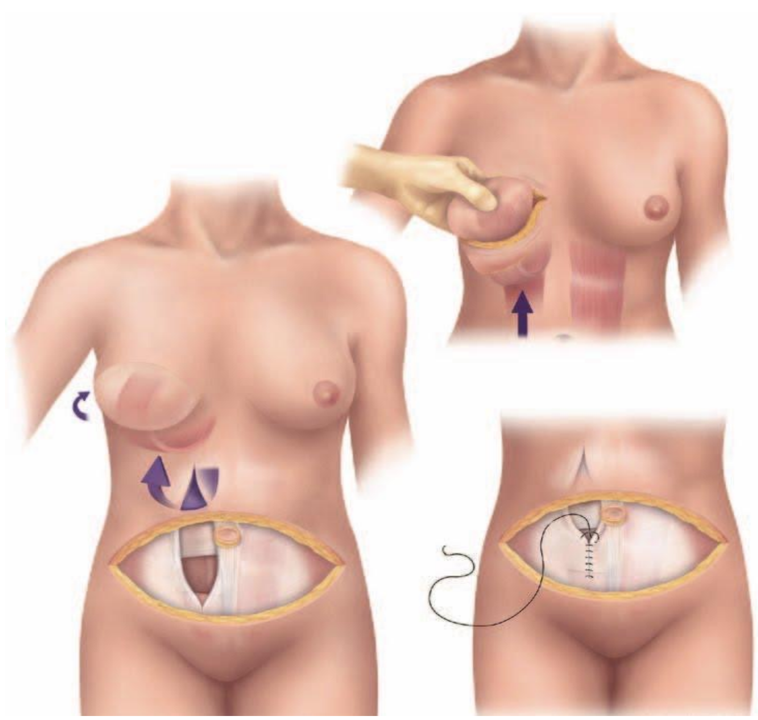

Figure 9. Pedicled TRAM flap. *From Macadam S, et al. Evidence-Based Medicine: Autologous Breast Reconstruction. Plast Reconstr Surg 2017;139(1):204e-229e.*

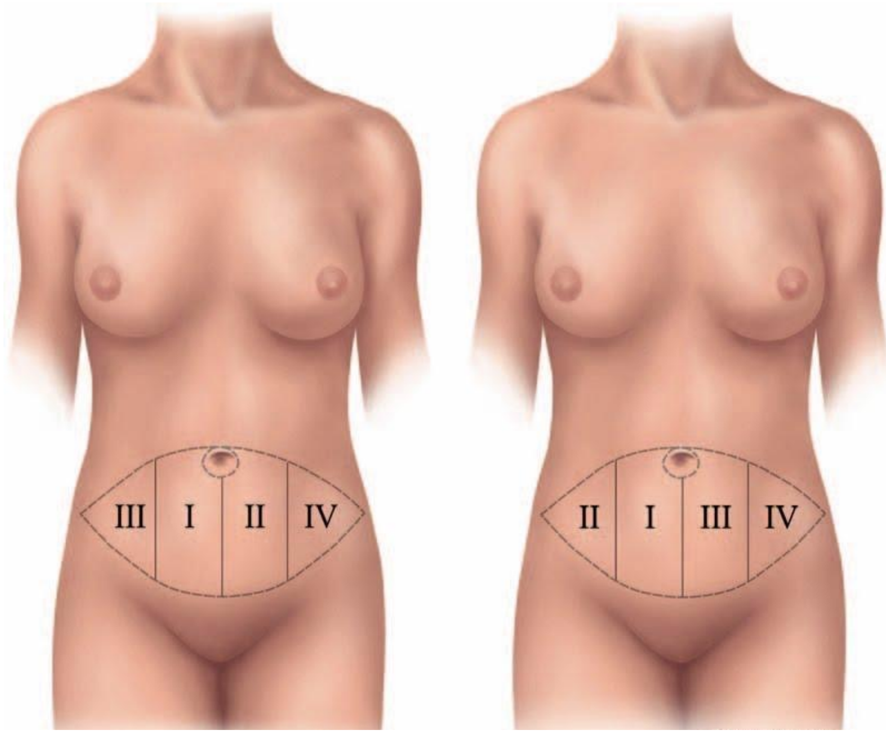

Figure 10. Hartrampf's classification of TRAM flap zonal blood supply. Hartrampf names zone I directly over the muscle pedicle and zone II lying across the midline. (Right) Ninkovic's classification of TRAM flap and deep inferior epigastric perforator flap zonal blood supply. Holm et al. performed an in vivo study of deep inferior epigastric perforator flaps with indocyanine green and concluded that although zone I remains the most reliably perfused zone, any flow across the midline is less than ipsilateral flow and proposed that Hartrampf's zone II should be renamed zone III. *From Macadam S, et al. Evidence-Based Medicine: Autologous Breast Reconstruction. Plast Reconstr Surg 2017;139(1):204e-229e.*

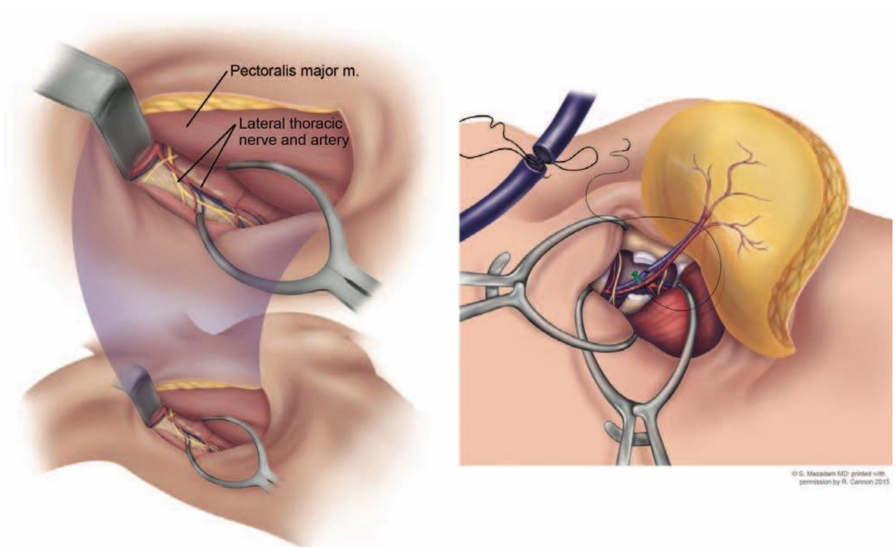

Figure 11. Exposure of the thoracodorsal recipient vessels (left) and internal mammary recipient vessels (right). *From Macadam S, et al. Evidence-Based Medicine: Autologous Breast Reconstruction. Plast Reconstr Surg 2017;139(1):204e-229e.*

    - Pedicled TRAM flap (Fig. 9, 10) using superior epigastric vessels for blood supply (rectus abdominus muscle is used as a “carrier” for the blood vessel)
- Free flaps
    - Technically more demanding, requiring microvascular techniques; flap is entirely disconnected and sewn to vessels in the chest
    - Recipient vessels may anastomosed to internal mammary vessels (or their perforators) or the thoracodorsal vessels (Fig. 11)
    - As compared to pedicled TRAM, lower risk of partial flap loss and fat necrosis, but potential total flap loss
    - Transverse rectus abdominis myocutaneous (TRAM) flap: rectus abdominus muscle, fat and skin on a transverse paddle, based on inferior deep epigastric artery (DIEA)
        - Requires abdominal wall reconstruction/anterior rectus sheath with mesh
    - Muscle-sparing TRAM flap (MS-TRAM):
        - Only a portion of the rectus muscle is harvested (Fig. 12)
        - In unilateral reconstruction, can harvest zones 1-3 (TRAM or MS- TRAM)
    - Deep inferior epigastric perforator (DIEP) flap: only skin and fat are harvested on perforating vessels from DIEA
        - Technically more demanding
        - Clinical relevance of not taking any muscle compared with muscle-sparing techniques is still under debate
        - CT angiography may help with perforator harvest planning (Fig. 13)
        - Uni-pedicled (Fig. 14) or double-pedicled (stacked)
    - Superficial inferior epigastric artery (SIEA) flap: SIEA has to be of adequate caliber (artery with a palpable pulse, vein >1 mm) to be used for anastomosis
        - Not all patients have an adequate SIEA, may be affected by the position of the lower abdominal incision
        - SIEV may be the dominant venous drainage and is commonly preserved in case it is needed for venous outflow
    - Gluteal artery perforator (GAP) flap on superior (SGAP) or inferior (IGAP) gluteal artery perforators (Fig. 15): typically reserved for patients without sufficient abdominal wall tissue or for those who are not candidates for abdominal based reconstruction
    - Transverse upper (TUG) gracilis flap (Fig.16) and vertical upper gracilis (VUG) flap
    - Profunda artery perforator flap (PAP) (Fig. 17): introduced in 2012 and has quickly become the preferred option from the thigh
        - Can be harvested in supine position with no need for position changes
    - Lumbar artery perforator flap (LAP) (Fig. 18): improved donor site versus SGAP
        - Requires position change
        - Requires harvest of DIEA and DIEV composite grafts to increase pedicle length and improve caliber match
    - Turbocharging:
        - Vascular augmentation using vascular sources within flap territory
        - Example: performing a DIEP flap to the recipient internal mammary vessels then anastomosing an additional vessel from this system
    - Supercharging:
        - Vascular augmentation using a distant source of vessels such as axillary or thoracodorsal vessels
        - Example: performing a pedicled TRAM flap, then augmenting the flow by anastomosing the deep inferior epigastric vessels to the thoracodorsal vessels

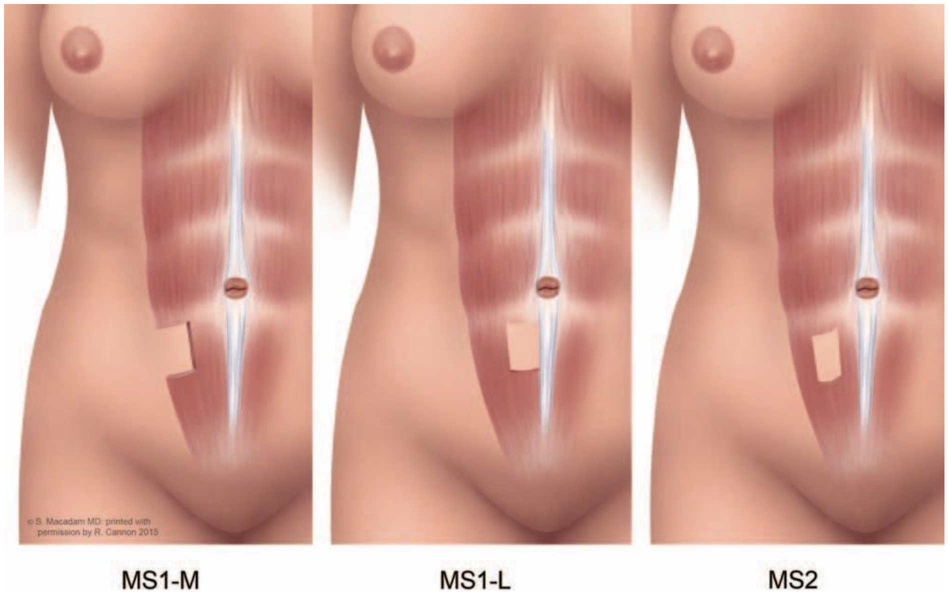

Figure 12. Classification of muscle-sparing free TRAM procedures. MS0 refers to sacrifice of the full width of the rectus muscle, MS1 preserves the lateral segment, MS2 preserves the lateral or medial segments, and MS3 preserves the entire muscle (equivalent to a DIEP flap). MS1 can be further subdivided into MS1-M and MS1-L, depending on whether it is the medial or lateral segment that is spared. *From Macadam S, et al. Evidence-Based Medicine: Autologous Breast Reconstruction. Plast Reconstr Surg 2017;139(1):204e-229e.*

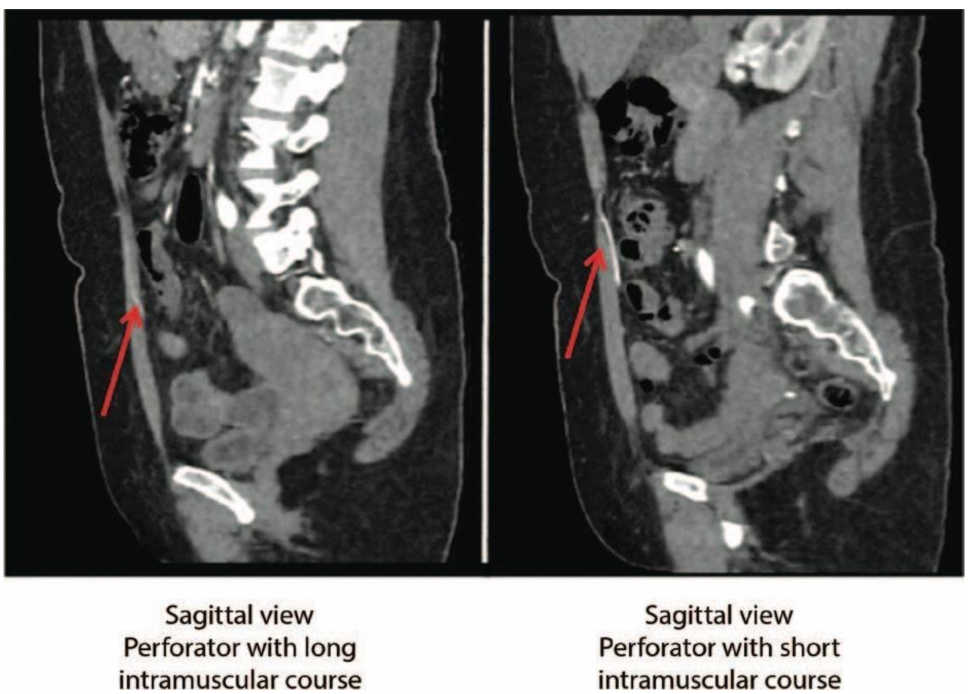

Figure 13. Computed tomographic angiography of abdominal perforators. *From Macadam S, et al. Evidence-Based Medicine: Autologous Breast Reconstruction. Plast Reconstr Surg 2017;139(1):204e-229e.*

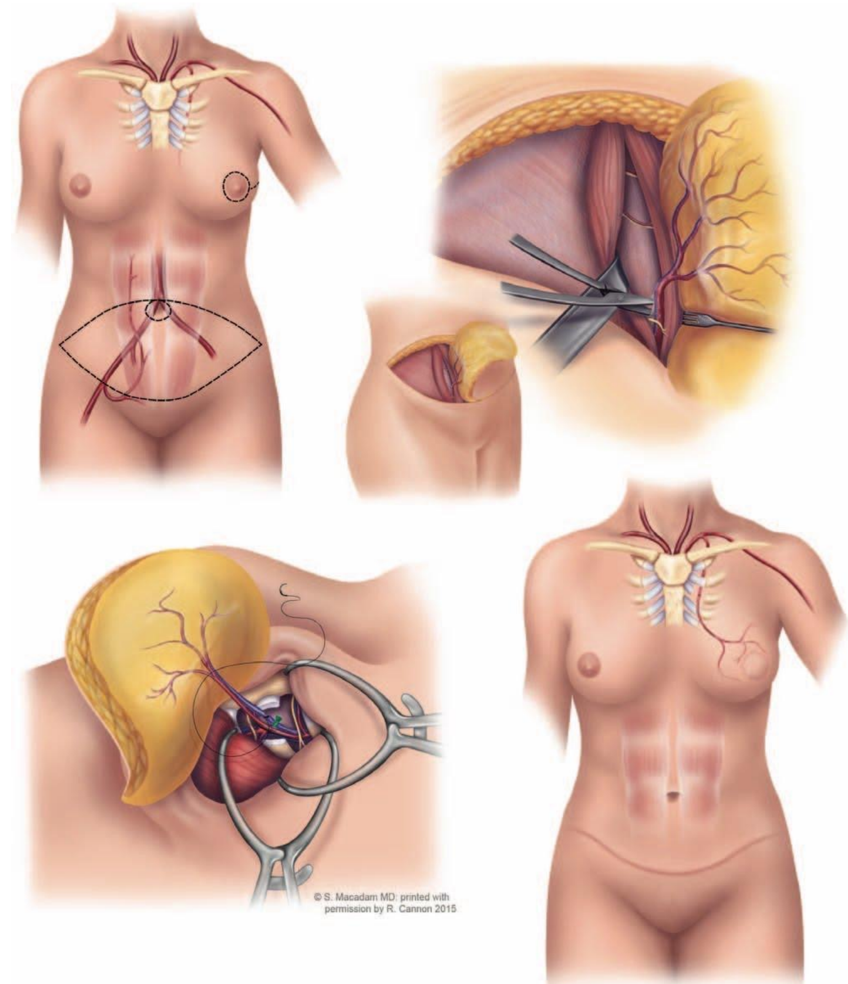

Figure 14. DIEP flap. *From Macadam S, et al. Evidence-Based Medicine: Autologous Breast Reconstruction. Plast Reconstr Surg 2017;139(1):204e-229e.*

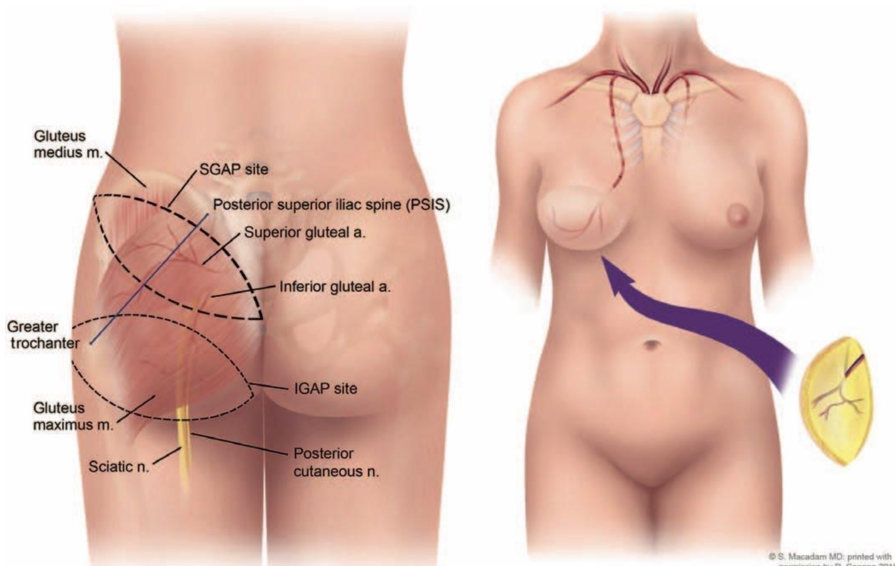

Figure 15. Superior gluteal artery perforator (SGAP) flap and inferior gluteal artery perforator (IGAP) flap. *From Macadam S, et al. Evidence-Based Medicine: Autologous Breast Reconstruction. Plast Reconstr Surg 2017;139(1):204e-229e.*

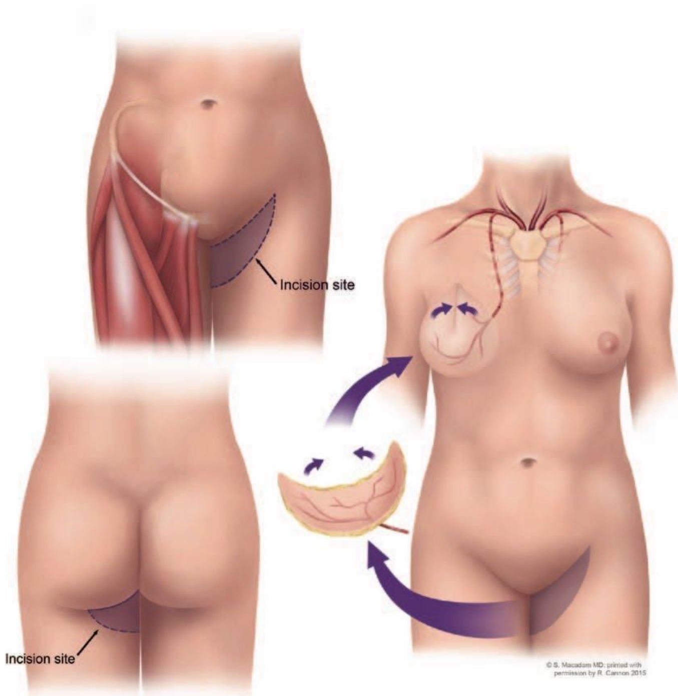

Figure 16. Transverse upper gracilis (TUG) flap. *From Macadam S, et al. Evidence-Based Medicine: Autologous Breast Reconstruction. Plast Reconstr Surg. 2017;139(1):204e-229e.*

Figure 17. Profunda artery perforator (PAP)flap. *From Teotia S, et al. Categorizing Patient Selection, Outcomes, and Indications in a Decade of 405 Profunda Artery Perforator Flaps. Plast Reconstr Surg. 2024;154(4):632e-640e.*

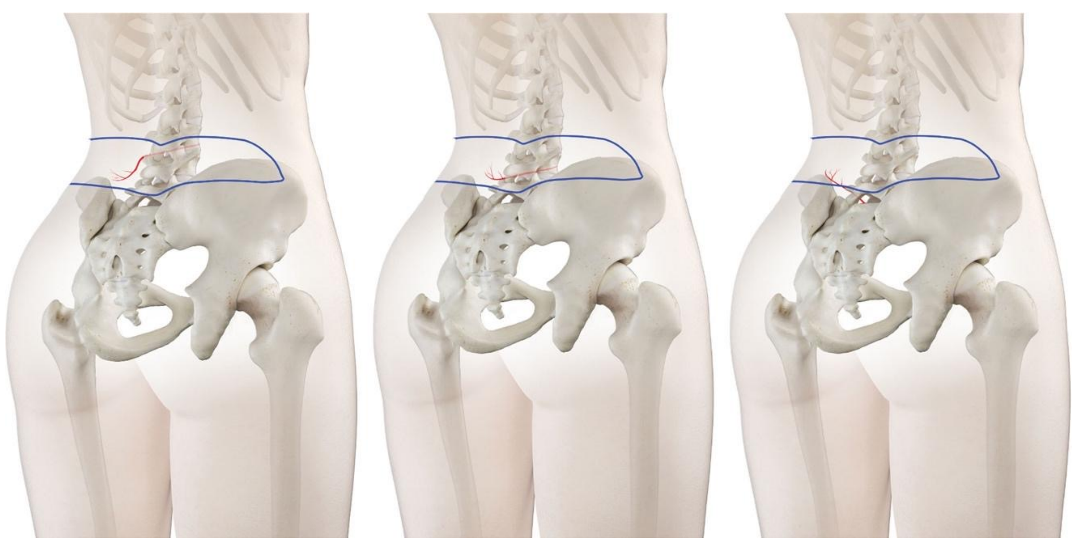

Figure 18. Lumbar artery perforator (LAP) flap. *From Teotia S, et al. Bilateral Lumbar Artery Perforator Flaps for Breast Reconstruction: A Perforator Classification System. Plast Reconstr Surg. 2024; 154(3):413e-420e.*

            - Minimally invasive techniques:
                - Laparoscopic assist and harvest
                    - Using CTA, an ideal DIEP perforator is selected based on location (low, central) and short intramuscular course
                    - Dissection occurs in the extraperitoneal space and all other collateral muscle branches are dissected from the undersurface of the rectus
                    - Pedicle is delivered through minimal fascial incision
                    - Preserves the lateral intramuscular and retrorectus course of the abdominal wall innervation
                - Robotic-assisted harvest:
                    - Flaps are elevated in standard fashion and the perforator is dissected down to posterior sheath
                    - Robot is used to intra-abdominally dissect the entire pedicle length while minimizing disruption of fascia or muscle except where the perforator exits the fascia
- Fat grafting
    - Does not increase the risk of breast cancer recurrence
    - Volume augmentation of a reconstructed breast
    - Improve shape of the breast, corrects contour deformities, commonly in the upper pole for fullness
- Ipsilateral corrections include:
    - Nipple reconstruction
    - Scar revisions
    - Volume adjustments either by reduction (i.e., direct resection or liposuction) or by augmentation (i.e., implants, additional flaps, or lipofilling)
    - Shape corrections: can be accomplished by repositioning and/or rotating the flap or implant, skin resections, and adjustments of the inframammary fold or other borders of the flap
- Symmetry is the goal of the reconstruction; the contralateral side may be adjusted by the common techniques of:
    - Augmentation
    - Reduction
    - Mastopexy
- Breast neurotization: involves nerve coaptation during breast reconstruction with the goal of restoring meaningful sensation to the breast
    - During a mastectomy, sensory nerves to the skin and nipples are often transected
        - Can pose significant quality of life implications for patients afterwards, including safety concerns (i.e., injuries acquired due to lack of sensation)
- Nipple-areola complex (NAC) reconstruction:
    - NAC is one of the aesthetic units of the breast; for the completeness of the aesthetic of the breast some women chose to have the NAC reconstructed
    - Nipple sharing (graft from the contralateral nipple) if available and dimensions adequate (Fig. 19)
    - Local skin flaps (C-V, C-Y, star flap, skate flap) with or without use of cartilage, ADM graft, revision with fat grafting to improve projection (Fig. 20)
    - Intra-dermal color tattoo to match opposite NAC:
        - May follow nipple reconstruction procedure
        - 3-D tattoo to simulate also the nipple projection from frontal view (no surgical nipple reconstruction)
    - In-situ or remote-donor skin graft (groin or labia majora/minora) may also be used for areola

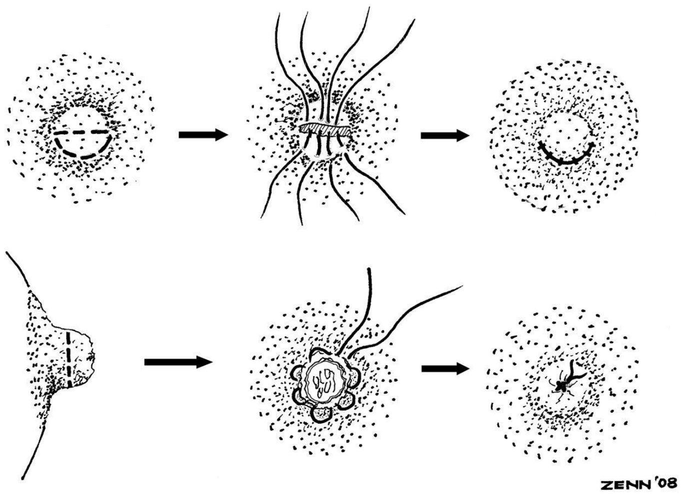

Figure 19. Drawings demonstrating the two commonly accepted techniques for nipple sharing. Both harvest 50 percent of the nipple. (Above) Drawings show sagittal harvest for nontubular nipples. The lower half of the nipple is taken and the donor site closed with simple interrupted sutures, leaving an imperceptible scar under the nipple. (Below) Drawings show coronal harvest for tubular, large nipples. Note that the donor site is closed with a purse-string suture, leaving a natural appearing nipple. *From Zenn M, et al. Unilateral nipple reconstruction with nipple sharing: time for a second look. Plast Reconstr Surg 2009;123(6):1648-1653.*

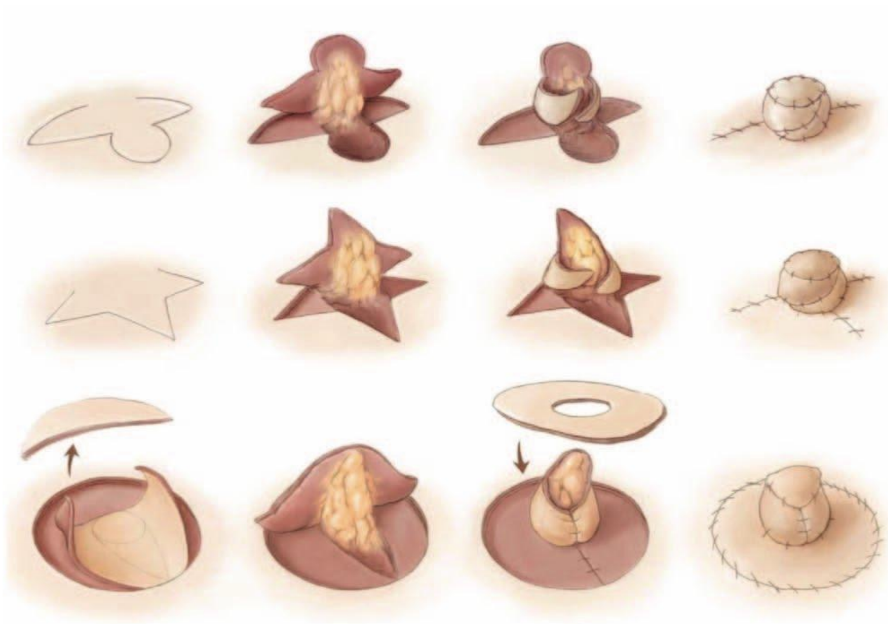

Figure 20. Different techniques for nipple reconstruction. (Above) CV flap. (Center) Star flap. (Below) Skate flap. *From Zhong T, et al. Evidence-based medicine: breast reconstruction. Plast Reconstr Surg 2013;132(6):1658-1669.*

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Chapter 16
Trunk Reconstruction

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There are three major areas to consider in trunk reconstruction–chest wall reconstruction, abdominal wall reconstruction, and spine reconstruction. This chapter is therefore divided into three sections to cover each of these topics.

CHEST WALL RECONSTRUCTION

I. Chest wall anatomy

- Skin and subcutaneous tissue
- Muscle layers (Fig. 1):
  - Pectoralis major (2 heads):
    - Sternocostal head: adduction, flexion, and internal rotation of the humerus
    - Clavicular head: flexion of the humerus
    - Blood supply: pectoral branch of the thoracoacromial artery, perforating branches from intercostal arteries
  - Pectoralis minor: stabilization of the scapula
  - Serratus anterior: protract and stabilization of the scapula
  - Latissimus dorsi: adduction, extension, and internal rotation of the humerus
    - Blood supply: thoracodorsal artery
  - Intercostal muscles: elevate and depress ribs
  - External: fibers run inferomedially
  - Internal: fibers run superomedially
  - Innermost: fibers run transversely
    - The neurovascular bundle containing the intercostal nerves, arteries, and veins run between the internal and innermost layers on the inferior aspect of respective ribs
  - Diaphragm: along with the intercostal muscles, serves as the primary muscle of respiration

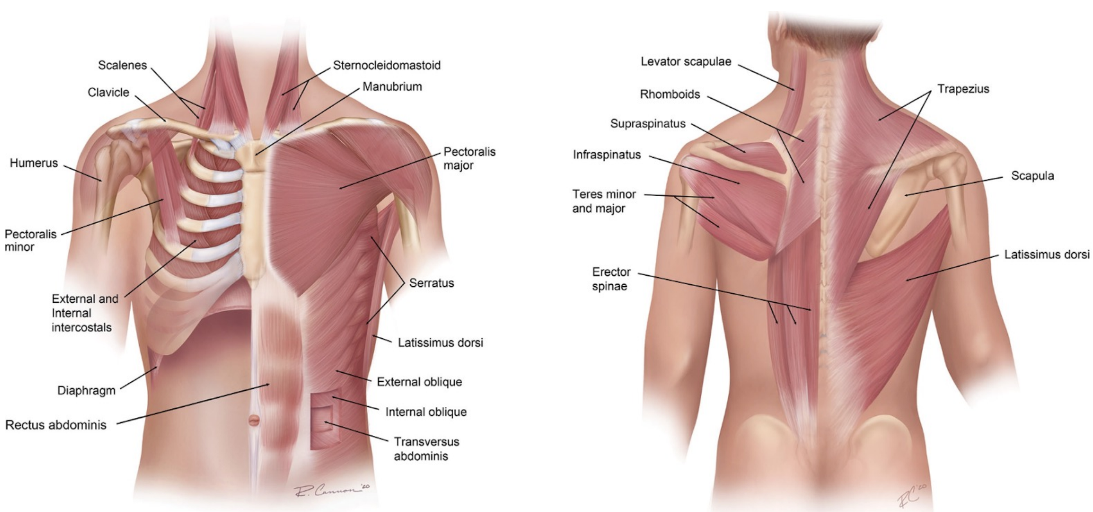

Figure 1. Chest wall anatomy. *From Isaac KV, Elzinga K, Buchel, EW. The Best of Chest Wall Reconstruction: Principles and Clinical Application for Complex Oncologic and Sternal Defects. Plast Reconstr Surg. 2022 Mar 1;149(3):547e-562e.*

- Bony structures: provide stable skeletal support to protect vital organs, contribute to both respiratory physiology and upper extremity function (Fig. 1)
    - Sternum (composed of manubrium, body, and xiphoid)
    - Ribs (12 total)
        - True ribs (1-7): articulate directly with the sternum
        - False ribs (8-12): articulate with costal cartilages instead of sternum
        - Floating ribs (11-12): do not communicate with either the sternum or the ribs superior to them
    - Clavicle
    - Thoracic vertebrae
- Pleura
    - Visceral pleura: covers the lung and hilar structures
    - Parietal pleura: lines the thoracic cavity

II. Common pathology requiring chest wall reconstruction

- Trauma
- Tumor resection (Fig. 2)
- Infection (including sternal osteomyelitis after median sternotomy)
- Congenital anomalies

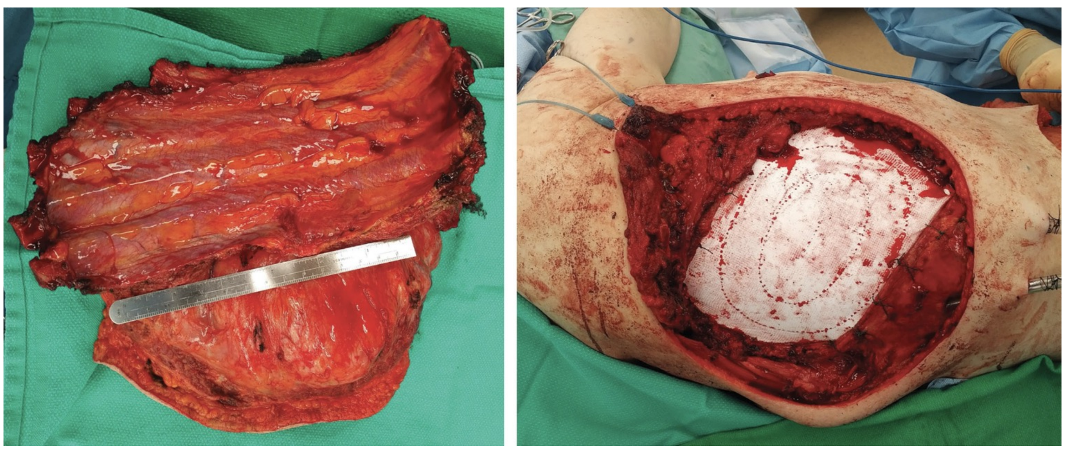

Figure 2. (Left) Oncologic specimen. (Right) Irradiated lateral chest wall defect with initial inset of a synthetic mesh. *From Isaac KV, Elzinga K, Buchel, EW. The Best of Chest Wall Reconstruction: Principles and Clinical Application for Complex Oncologic and Sternal Defects. Plast Reconstr Surg. 2022 Mar 1;149(3):547e-562e.*

III. Goals of reconstruction

- Rigid airtight thoracic cavity
- Protection of the thoracic and abdominal contents
- Optimization of respiration
- Obliteration of dead space for intrathoracic defects
- Stable soft-tissue coverage
- Control of infection
- Aesthetic reconstruction (when reasonably possible)

IV. Sternal reconstruction

- Usually these wounds/defects are related to postoperative infection after cardiac surgery
    - Complication rate after median sternotomy is 0.5-5.0%
    - More common when internal mammary artery (IMA) is harvested for coronary artery bypass grafting

- Sternal wounds can be classified based on anatomy, as well as presenting signs/symptoms
  - Starzynski classification of sternal defects:
    - Loss of upper sternal body and adjacent ribs: minimal physiologic effect
    - Loss of entire sternal body and adjacent ribs: moderate physiologic deficit
    - Loss of manubrium and upper sternal body with adjacent ribs: severe physiologic deficit
  - Pairolero and Arnold in 1984 proposed a classification based on time to infection:
    - Type 1: within the first three days postoperatively
      - Treatment: exploration, debridement, primary closure
    - Type 2 : within first three weeks postoperatively
      - Treatment: exploration, debridement, serial dressing changes or negative pressure wound therapy (NPWT), flap closure in staged manner
    - Type 3: draining sinus tract from chronic osteomyelitis that typically presents months to years after surgery
      - Treatment: exploration, debridement, serial dressing changes/NPWT, flap closure in staged manner
- Typical flap selection for sternal wounds include pectoralis major, omentum, and vertical rectus abdominis muscle flaps
  - Pectoralis major: based on the pectoral branch of the thoracoacromial artery
    - Most often used as an advancement flap where both pectoralis major muscles are released from skin and undermined then advanced towards midline
    - Can also be used as turnover flap if IMA is still intact
  - Omentum: based on right or left gastroepiploic artery
    - Typical indication is for sternal wounds requiring dead space obliteration, inferior wounds that pectoralis major muscle is suboptimal for, or secondary reconstruction when pectoralis major has already been utilized
  - Vertical rectus abdominis muscle (VRAM): based on superior/inferior epigastric artery
    - Typically used in setting of failed initial reconstruction or reconstruction requiring skin island
    - Important to consider if one or both IMA were harvested for use in bypass grafting, as inferior epigastric arteries are continuations of IMAs

V. Non-sternal reconstruction

- Most frequently indicated in setting of malignancy or locally destructive benign pathology
  - Malignant pathology:
    - Lung carcinoma
    - Locally advanced breast carcinoma
    - Soft tissue sarcoma
    - Chondrosarcoma
    - Ewing sarcoma
    - Metastatic disease
  - Benign pathology:
    - Osteochondroma
    - Chondroma
    - Fibrous dysplasia
    - Desmoid tumor
    - Osteomyelitis
    - Osteoradionecrosis
    - Trauma
- Skeletal reconstruction:
  - Goals:
    - Minimize paradoxical motion

        - Aid/palliate respiratory mechanics
        - Protect thoracic viscera
        - Maintain chest wall aesthetics
    - Indication: if defect is > 4 contiguous ribs or is > 5 cm
        - Defects above this size are prone to result in a flail segment which will produce paradoxical motion of the chest wall and negatively impact respiratory mechanics
        - Note: previous radiation from oncologic treatment can result in stiffening of chest wall that may decrease the negative effects of these size defects on respiratory mechanics
    - Reconstructive options:
        - Alloplastic material
            - Widely available, however can be expensive and intolerant of bacterial contamination
            - Mesh: oolypropylene, PTFE (Gore-Tex)
            - Methylmethacrylate: rigid, forms by exothermic reaction, relatively higher infection and extrusion rates
            - Titanium: radiopaque and requires underlay of a different mesh
            - Acellular dermal matrices: semirigid and expensive, but less prone to infection
        - Autologous material: bone grafts (can be associated with poor wound healing and high donor site morbidity)
            - Split rib, iliac crest, fibula
        - Soft-tissue reconstruction: typically locoregional options are explored before utilizing free tissue transfer
            - Locoregional flaps:
                - Pectoralis major: anterior wounds and intra-thoracic
                - Serratus anterior: based on serratus branch off the thoracodorsal artery, commonly used for intra-thoracic applications
                - Latissimus dorsi: can be utilized for anterior, lateral, and posterior chest wall wounds as well as intra-thoracic space obliteration
                - Rectus abdominis
                - External oblique
                - Thoracodorsal artery perforator flap
                - Intercostal artery perforator flap
                - Omentum: used for intra-thoracic space obliteration
            - Free flaps: commonly used for larger wounds related to oncologic resection, osteoradionecrosis, or results of severe infection
                - Commonly used in conjunction with alloplastic materials and ADM
                - Provide significant reconstructive freedom, however patients may have suboptimal recipient vessels or be poor overall candidates for free flaps
                - Recipient vessels: internal mammary artery/vein, thoracodorsal artery/vein
                - Commonly utilized flaps: anterolateral thigh (ALT) flap, latissimus dorsi flap (contralateral side if lateral), rectus abdominis

VI. Congenital chest wall reconstruction

- Poland syndrome:
    - Etiology: due to kinking of the subclavian artery around week six of gestation leading to vessel hypoplasia
    - Characteristics (Fig. 3):
        - Absence of sternal head of the pectoralis major muscle

- Hypoplasia of the breast or nipple
- Deficiency of the subcutaneous fat or axillary hair
- Bony abnormalities of the anterior chest wall
- Syndactyly or hypoplasia of ipsilateral extremity
- Shortened ipsilateral forearm

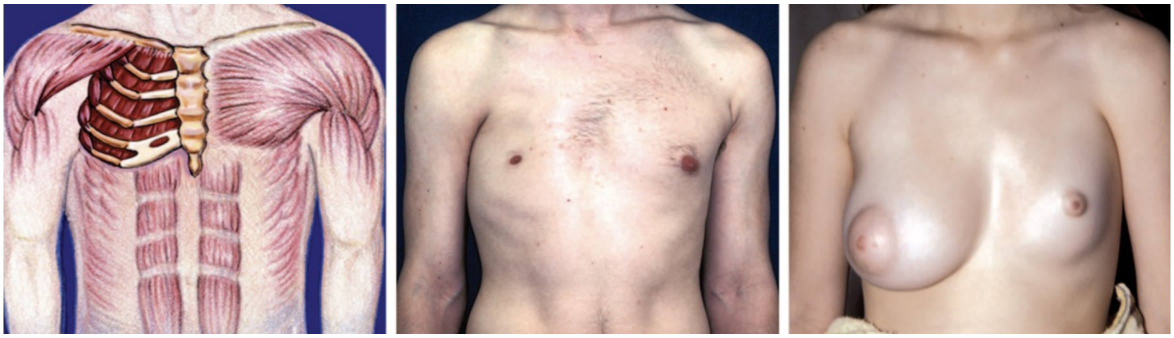

Figure 3. Schematic an anterior view of Poland syndrome in a male patient and a female patient. Notice the asymmetric axillary folds. *From Seyfer AE, Fox JP, Hamilton CG. Poland syndrome: evaluation and treatment of the chest wall in 63 patients. Plast Reconstr Surg. 2010 Sep;126(3):902-911.*

- Treatment:
    - For adolescent females, can place a tissue expander for breast reconstruction and perform serial expansions during puberty
    - Once at full development, an ipsilateral innervated latissimus dorsi flap for creation of anterior axillary line, with an implant for breast reconstruction
- Pectus excavatum:
    - Characteristics: depression of the sternum that can lead to cardiovascular/respiratory abnormalities and/or cosmetic deformities
    - Treatment: performed in multi-disciplinary fashion with pediatric surgery (first three options usually for symptomatic patients with compromised cardiorespiratory function)
        - Sternal osteotomies for repositioning
        - Posterior strut for support (if required)
        - Nuss procedure: utilize steel bars for support
        - There are also implantable prostheses that can be used for cases without cardiovascular compromise to restore normal chest wall contour
- Pectus carinatum:
    - Excessive protrusion of the sternum
    - Treatment: performed in multi-disciplinary fashion with pediatric surgery
        - Repositioning of the sternum and abnormal costal cartilage to restore normal contour
        - Mild cases in females can often be camouflaged with breast implants

ABDOMINAL WALL RECONSTRUCTION

I. Abdominal wall anatomy

- Layers of the abdominal wall (Fig. 4)
    - Skin
    - Subcutaneous tissue
    - Scarpa's fascia: superficial fascial system
        - Usually approximated during abdominal closure for aesthetic purposes as well as for strength properties
    - Medial musculature
        - Rectus abdominis: originates from the costal cartilages of ribs 5-7 and inserts onto pubic crest; main function is flexion of the trunk

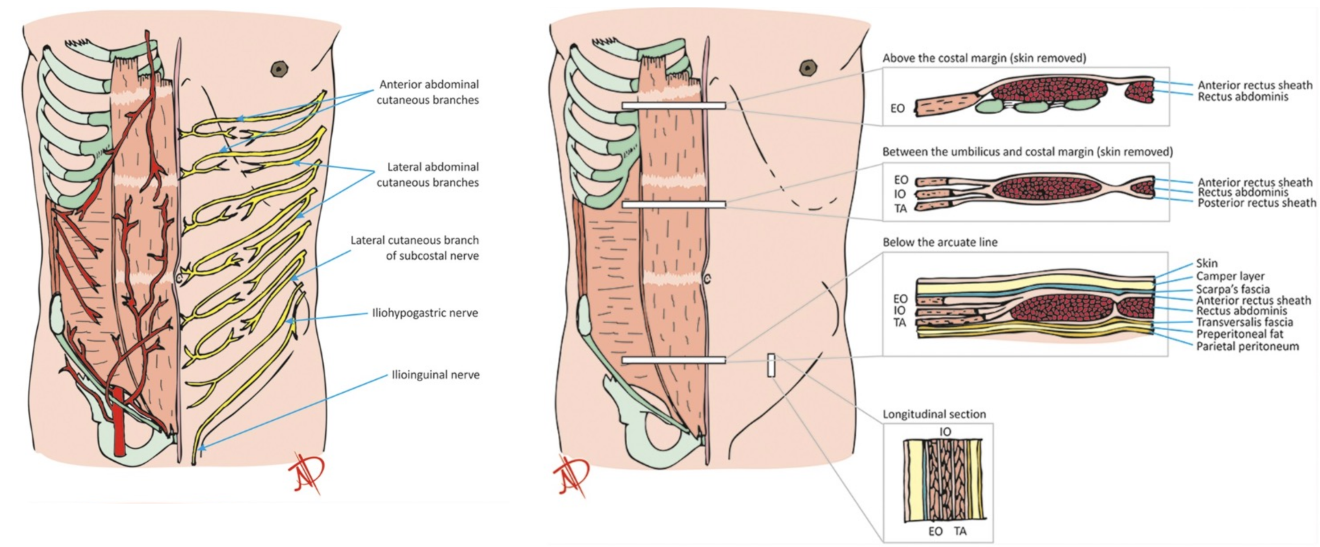

Figure 4. Abdominal wall anatomy. *From Patel NG, Ratanshi I, Buchel EW. The Best of Abdominal Wall Reconstruction. Plast Reconstr Surg. 2018 Jan;141(1):113e-136e.*

            - Above the arcuate line:
                - Anterior rectus sheath: composed of external oblique and internal oblique fascial confluences
                - Posterior rectus sheath: composed of internal oblique and transversus abdominis fascial confluences
                    - Note: the internal oblique contributes to both the anterior and posterior rectus sheaths above the arcuate line
            - Below the arcuate line:
                - Anterior rectus sheath: composed of external oblique, internal oblique, and transversus abdominis fascia
                - No posterior sheath (layers posterior to rectus abdominis at this level are transversalis fascia and parietal peritoneum)
        - Transversalis fascia
        - Parietal peritoneum
    - Lateral musculature:
        - External oblique: functions in trunk flexion and contralateral rotation of the torso
            - Fibers run inferomedially
        - Internal oblique: functions in trunk flexion and contralateral rotation of the torso
            - Fibers run superomedially
            - Note: the neurovascular bundles lie between the internal oblique and the transversus abdominis muscle
            - Ventral rami T7-L4 supply motor innervation to the abdominal wall
        - Transversus abdominis: fibers run transversely
- Huger zones: used to delineate anatomic regions of perfusion
    - Zone 1: region between xiphoid, pubic symphysis, and linea semilunaris
        - Perfused by the deep inferior epigastric arteries
    - Zone 2: region between anterior superior iliac spines bilaterally, pubic symphysis, and groin creases
        - Perfused by superficial circumflex femoral arteries, external pudendal arteries, and superficial inferior epigastric artery
    - Zone 3: region lateral to rectus muscles
        - Perfused by intercostal perforators

II. Goals of reconstruction

- Provide protection for intra-abdominal viscera

- Repair and prevent recurrence of hernia with strong fascial support
- Restore abdominal wall function by maintaining innervation allowing for proper contractility

III. Common abdominal wall pathology requiring reconstruction

- Ventral hernia or recurrent ventral hernia
    - Relevant hernia terminology:
        - Reducible: hernia contents are able to be easily manually pushed back into the abdominal cavity
        - Nonreducible: hernia contents cannot be manually pushed back into the abdominal cavity
        - Incarcerated: hernia contents are not able to be reduced back into the abdominal cavity and cause pain or bowel dysfunction
        - Strangulated: hernia contents are devascularized and ischemic inside the hernia sac; surgical emergency
        - Incisional hernia: hernia through a prior fasciotomy site (usually from prior midline laparotomy procedure); rates of incisional hernia vary between 10-30%
        - Spigilean hernia: ventral hernia through the linea semilunaris
        - Lumbar hernia: hernia of the posterior trunk which usually involves retroperitoneal structures
- Trauma
- Tumor resection
- Infection (e.g., mesh infection from prior hernia repair, necrotizing infection)
- Congenital abdominal wall defects (gastroschisis, omphalocele)

IV. Reconstructive considerations and algorithm

- Primary closure
    - Can be reasonably utilized when fascial defect is <3 cm in diameter
    - Defects this small are relatively uncommon if plastic surgery is consulted
- Mesh considerations: indicated in cases of defects with tension
    - Types of mesh:
        - Synthetic mesh: can be absorbable (Vicryl, Dexon) or non-absorbable (polypropylene, PTFE)
        - Biologic mesh: human, porcine, and bovine acellular dermal matrices (ADMs)
            - Utilizes tissue remodeling process to aid in tissue incorporation
            - More infection-resistant that synthetic meshes, but more costly
    - Planes of mesh placement:
        - Intraperitoneal: mesh placed deep to the fascial repair
            - Mesh adheres to abdominal wall through forces of intraabdominal pressure
        - Retrorectus: mesh placed between the posterior sheath and the rectus muscle
            - Considered to be the ideal layer for mesh placement because mesh has protection from outside environment as well as viscera
        - Overlay: mesh is placed superficial to the fascial repair
            - Mesh is high risk for exposure in setting of wound healing complications
        - Interposition bridge: mesh is sutured as a bridge between the fascial edges of the hernia defect; high risk of hernia recurrence
    - Mesh infections: synthetic is usually less tolerant of contamination than biologic mesh
        - If mesh becomes infected, it should be explanted
- Component separation:
    - Anterior release (Fig. 5):
        - Involves division of the external oblique aponeurosis lateral to the semilunar line, separating the external oblique from the internal oblique to allow for medial advancement; can be performed with or without separation of the rectus abdominis muscle from the posterior sheath

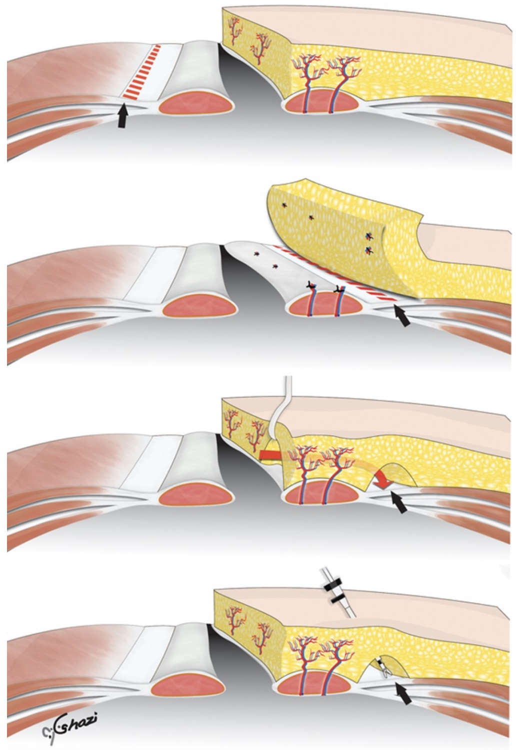

Figure 5. Component separation with anterior release. *From Althubaiti G, Butler CE. Abdominal wall and chest wall reconstruction. Plast Reconstr Surg. 2014 May;133(5):688e-701e.*

        - Advancement of each hemi-abdominal flap with anterior release
            - Epigastrium: 5 cm
            - Umbilicus: 10 cm
            - Suprapubic: 3 cm
    - Posterior release (TAR):
        - Begins with dissection in the retrorectus plane; then the posterior lamella of the internal oblique aponeurosis is incised (medial to intercostal nerve to rectus muscle) allowing access to the transversus abdominis. Transversus abdominis is then divided and the plane between the transversus abdominis and the transversalis fascia is developed from medial to lateral
        - Can provide 8-12 cm of advancement per side
    - Utilization with mesh is possible; ideal placement of mesh is in the retrorectus plane
- Tissue expansion: utilized for defects involving the skin and subcutaneous tissue
- Pedicled flaps: pedicled ALT flap, pedicled rectus femoris flap, and pedicled tensor fascia lata flap have all been described
- Free flaps: free ALT and free latissimus dorsi muscle flaps
- NPWT: can be utilized for the open abdomen in an acute setting or for chronic soft tissue wounds of the abdominal wall skin and subcutaneous tissue

SPINE RECONSTRUCTION

I. Back anatomy

- Paired paraspinous muscles run parallel to spine, function to stabilize and extend vertebrae
    - 3 distinct muscle bellies: iliocostalis, longissimus, spinalis
- Trapezius muscle
- Latissimus dorsi
- Serratus posterior

II. Indications

- Cervical, thoracic, lumbar level spine surgery requiring watertight hardware coverage
- Instrumentation of the spine can be performed due to deformity, malignancy, trauma, or degenerative conditions

III. Considerations

- Is instrumentation being placed? If so, has the patient had prior surgeries or instrumentation?
- Infectious history?
- Is hardware high-profile or low-profile?
- Underlying factors affecting wound healing (nutritional status, prior wounds, history of radiation)?
- Concern for CSF leak?

IV. Surgical approach

- Debridement: critically important step
    - Prior wound edges should be excised, unincorporated bone graft should be removed
    - Goal is to maintain hardware, as it provides stability to spinal cord (and wound); note difference from areas such as extremity reconstruction
- Cervical:
    - Modern spine surgery often utilizes an anterior approach to the cervical spine, but the posterior approach is sometimes still indicated
        - Due to the constant motion of the neck and shoulder girdle, as well as thin skin and soft tissue coverage, posterior approaches are more likely to develop infection or wound complications
    - Options: paraspinous flaps, trapezius muscle flaps, or fasciocutaneous advancement perforator flaps
- Thoracic:
    - Wounds, infections, or fluid collections are all possible indications for soft tissue coverage of the thoracic spine
    - Paraspinous muscle flaps are the workhorse of soft tissue coverage of the thoracic spine
    - Latissmus dorsi muscle flaps, either as an advancement flap or a turnover flap, can also provide coverage
    - Omentum: based on gastroepiploic arteries, requires tunneling through the retroperitoneum
- Lumbosacral:
    - Lumbar spine wounds can be associated with instrumentation or less commonly sacrectomy defects
    - Paraspinous flaps are the workhorse soft coverage flap choice in the lumbar spine
    - Reverse latissimus dorsi flap
    - Lumbar artery perforator flap
    - Omentum
    - For sacrectomy defects: gluteal fasciocutaneous V-Y flaps are a mainstay for posterior approach sacrectomies
        - For anterior/posterior approach sacrectomies (less common), a vertical rectus abdominis muscle flap can be tunneled transpelvically
- Bony defects:
    - Large (>4.5 cm) bony spinal column gaps have a relatively high fail rate with when treated with non-vascularized bone graft
        - Clinical indications:
            - Sacrectomy, oncologic vertebrectomy, osteoradionecrosis, osteomyelitis
    - Surgical techniques:
        - Pedicled rib, pedicled iliac crest, pedicled calvarium, free bone flap (fibula)

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Chapter 17
Pelvic Reconstruction

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There are several major areas to consider in pelvic reconstruction. These include perineal reconstruction, which is commonly indicated in the reconstruction of defects related to colorectal and anal cancer. Second is genitourinary reconstruction, which includes reconstruction of the vulva, vaginal canal, penis, and scrotum. Regardless of the origin of the pathology, the treatment of pelvic wounds requires multidisciplinary care.

ANATOMY

The perineal area is the region between the scrotum/vagina and the anus. It can be divided into an anterior (urogenital) triangle and a posterior (anal) triangle.

I. Borders

- Anterior: pubic arch/arcuate ligament of pubis
- Posterior: tip of coccyx
- Medial/lateral: inferior pubic rami and ischial tuberosity
- Superior: pelvic floor
- Inferior: skin/fascia

II. **Male perineum** (Fig. 1)

- Penis: radix, corpus, and glans
  - Skin, dartos fascia (superficial), and Buck's fascia (deep)
  - Neurovascular bundle - deep dorsal vein, dorsal artery, paired dorsal nerves
  - Erectile tissue - paired corpus cavernosum, corpus spongiosum
  - Penile urethra
- Scrotum: contains testes, epididymis, and ductus deferens

III. **Female perineum** (Fig. 1)

- Vulva
- Mons pubis
- Labia majora: skin, Camper's fascia and Colle's fascia (superficial fascia)
- Labia minora: folds of skin without fat
- Clitoris: derived from the undifferentiated phallus, and has paired corpora, vestibular bulbs, and glans
- Vestibule
- Vagina

IV. Blood supply

- Internal pudendal artery: branches into perineal artery (supplies perineum and scrotum/vulva) and the common penile artery (bulbourethral, dorsal, and deep cavernosal branches)
- Superficial and deep external pudendal arteries: branch off common femoral artery and anastomose with branches of the internal pudendal artery
- Testicular/ovarian arteries: branch off aorta

V. Innervation

- Pudendal nerve (S2-S4) runs with internal pudendal artery
  - Multiple branches to perineal and genitalia structures
- Ilioinguinal nerve (L1): gives branches to upper scrotum/labia

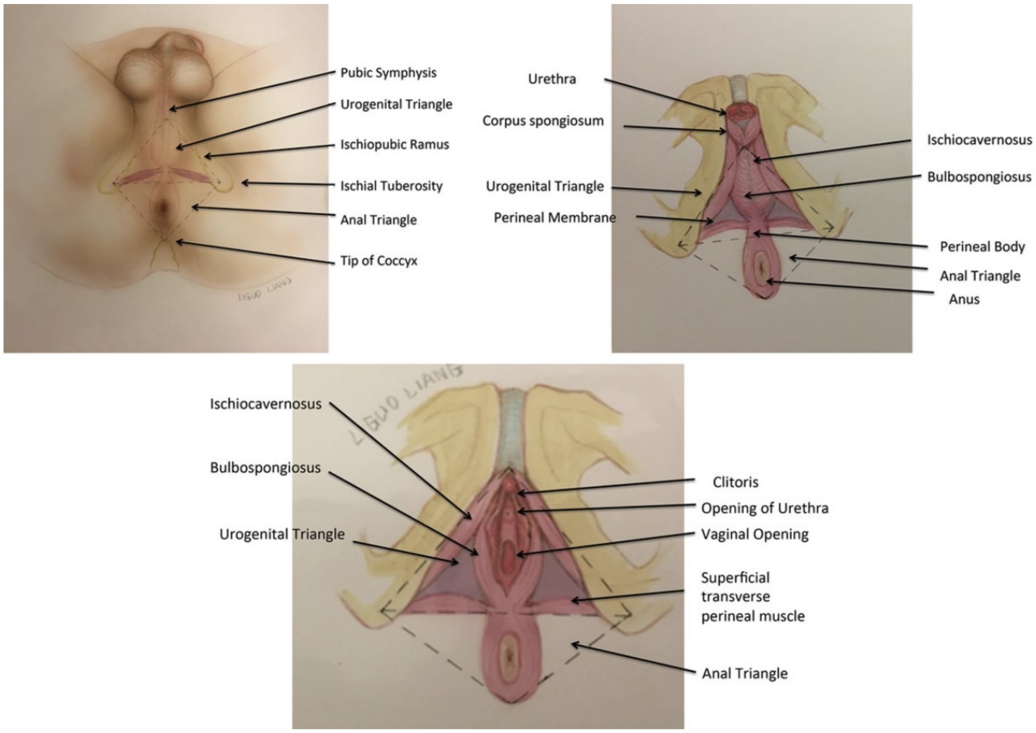

Figure 1. Male and female perineal anatomy. *From Weichman KE, Matros E, Disa JJ. Reconstruction of Peripelvic Oncologic Defects. Plast Reconstr Surg. 2017 Oct;140(4):601e-612e.*

ETIOLOGY OF PERINEAL WOUNDS

- Benign conditions:
    - Hidradenitis suppurativa
    - Necrotizing fasciitis
    - Fournier's gangrene
    - Trauma
    - Autoimmune conditions
    - Human papillomavirus (HPV)
    - Vaginal agenesis: variable, ranging from congenital absence to incomplete development
        - Range of presentation results in a range of reconstructive options including non-surgical and surgical options
    - Hypospadias: incomplete development of the urethra where the urethra exits ventrally and penile shaft has a ventral curvature
    - Epispadias: urethral opening on the dorsal aspect of the penis
    - Peyronie's disease: connective tissue disease resulting in penile curvature during erection
- Malignant conditions:
    - Colorectal cancer
    - Vulvar cancer
    - Vaginal cancer
    - Uterine cancer
    - Penile cancer
    - Bladder cancer

PRINCIPLES OF RECONSTRUCTION

- Benign conditions: treating underlying conditions and wound debridement and preparation are paramount
- Malignant conditions: discuss care with multidisciplinary team, consider radiation needs (neoadjuvant vs. adjuvant), assess likely defect size

RECONSTRUCTIVE OPTIONS

- Debridement and wound bed preparation are paramount
- Skin grafts: difficult to bolster, but can be ideal for superficial wounds
- Local flaps: suboptimal in radiated wound beds due to radiation injury to local tissue
  - Random pattern flaps
  - V-Y advancement flaps
  - Perforator flaps
- Regional flaps:
  - Vertical rectus abdominis muscle (VRAM) (Fig. 2)
    - Workhorse flap in perineal reconstruction
    - Based on deep inferior epigastric artery
    - Commonly used for large defects left after abdominoperineal resection (APR), vaginal reconstruction
    - Obliterates pelvic dead space

Figure 2. Schematic of use of VRAM flap for partial vaginectomy defect. *From Cordeiro PG, Pusic AL, Disa JJ. A classification system and reconstructive algorithm for acquired vaginal defects. Plast Reconstr Surg. 2002 Sep 15;110(4):1058-65.*

  - Gracilis flap: based on medial circumflex femoral artery
    - Can be utilized as a muscle only flap or with a skin paddle
    - Can be utilized bilaterally for larger reconstructive needs
  - Anterolateral thigh (ALT): based on descending branch of lateral femoral circumflex artery
    - Must be tunneled deep to rectus femoris and sartorius muscle if being used in perineal reconstruction
  - Singapore flap (pudendal thigh flap): island neurovascular flap based on the labial artery (branch from pudendal arteries)
  - Posterior thigh flap: based on inferior gluteal arteries
    - Ideal when abdomen is not available as an option
  - Omental flap: based on gastroepiploic arteries
    - Ideal for eliminating dead space in the pelvis to help prevent pelvic hernia
- Free flaps: rarely indicated considering number of local options

ANATOMIC-BASED TREATMENT ALGORITHM

- Penis:
  - Penile loss from oncologic disease or trauma
    - Goals for reconstruction: cosmetically acceptable, ability for standing micturition, preserved sensation, and sexually functional (most options require prosthetic)
      - Skin grafting: for partial thickness or skin only defects (as seen in Paget's disease for example)
      - Radial forearm free flap

            - Free or pedicled ALT
            - Free fibula flap
            - Abdominal flaps
            - Urethral reconstruction using skin grafts or vein or mucosal grafts
        - In setting of amputation, replantation can be attempted
            - Use superficial dorsal artery for arterial repair, prefer multiple nerve coaptations
            - Successful replantation can be performed after 6 hours of warm ischemia or 16 hours of cold ischemia
    - Hypospadias: occurs in 1:150-300 males; most commonly meatus is in distal third
        - Surgical correction usually between age 6 months - 9 months
            - Surgical principles are based on anatomic location but are based on releasing chordee, create new urethra, and advancing the urethral meatus to tip of penis
    - Epispadias: urethral opening on the dorsal aspect of the penis; occurs much less commonly than hypospadias
        - Surgical options based on urethral opening locations
    - Peyronie's disease: affects 3-9% of the population aged 40-60
        - Surgical considerations:
            - Indications: inability to engage in sexual activity, failed conservative management
            - Surgical techniques can involve plication of tunica or dermal grafts depending on severity
- Scrotum: defects are most commonly related to Fournier's gangrene, HPV, squamous lesions, or other cutaneous malignancy
    - Split thickness skin grafts: temporize with NPWT
    - Gracilis flap
    - Pedicled fasciocutaneous flaps (Singapore, perforator flaps, lateral thigh flaps)
    - Reconstruction needs to be able to provide temperature regulation to preserve testicular function
- Vulva:
    - Defects can arise from oncologic defects, HPV, squamous cell carcinoma
    - Options can include:
        - Singapore flaps
        - Fasciocutaneous thigh perforator flaps
        - Pedicled gracilis flaps
        - Groin flaps
- Vagina:
    - Oncologic wounds, HPV, and vaginal, cervical, uterine, colorectal malignancies can result in vaginal canal defects
    - Defect classification is shown in Fig. 3

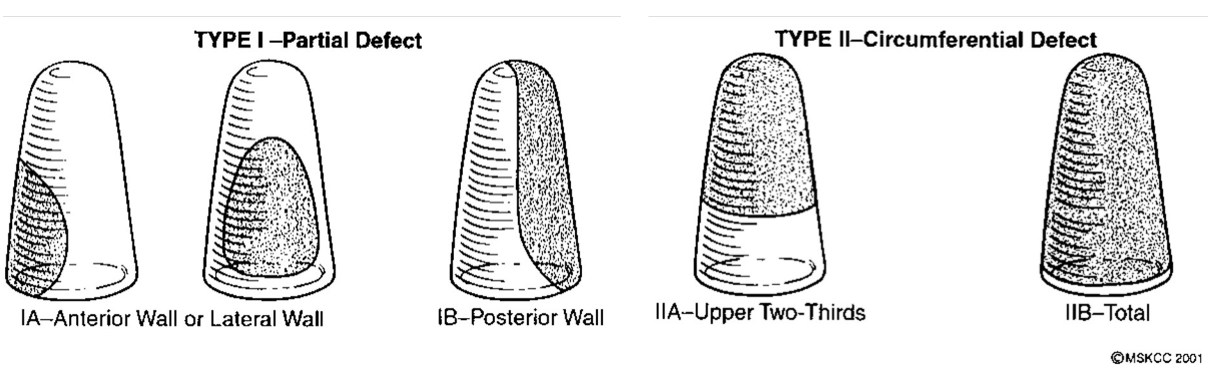

Figure 3. Vaginal defect classification system as proposed by Cordeiro et al. *From Cordeiro PG, Pusic AL, Disa JJ. A classification system and reconstructive algorithm for acquired vaginal defects. Plast Reconstr Surg. 2002 Sep 15;110(4):1058-65.*

- Based on defect location and size, reconstructive options can vary (Fig. 4)
    - Partial defects:
        - Anterior/lateral wall: Singapore flaps
        - Posterior wall: VRAM (Fig. 5)
    - Circumferential defects:
        - Upper two-thirds: VRAM
        - Total: bilateral gracilis flaps
            - Intestinal flaps have also been utilized (ileum, sigmoid colon)
- Mons pubis (Fig. 4):
    - Local flaps (random pattern or advancement flaps) can give successful reconstruction when wound is not radiated
    - In setting of radiation, regional fasciocutaneous or myocutaneous flaps are required (commonly ALT)
- Perianal (Fig. 4, 5):
    - Commonly from anal cancer or rectal cancer requiring abdominoperineal resection (APR)
    - Utilize the VRAM flap if abdomen is available, if not bilateral gluteal advancement flaps can be performed
        - Bilateral gluteal advancement flaps can be performed in conjunction with an omental flap to eliminate pelvic dead space if abdomen is available but VRAM unavailable

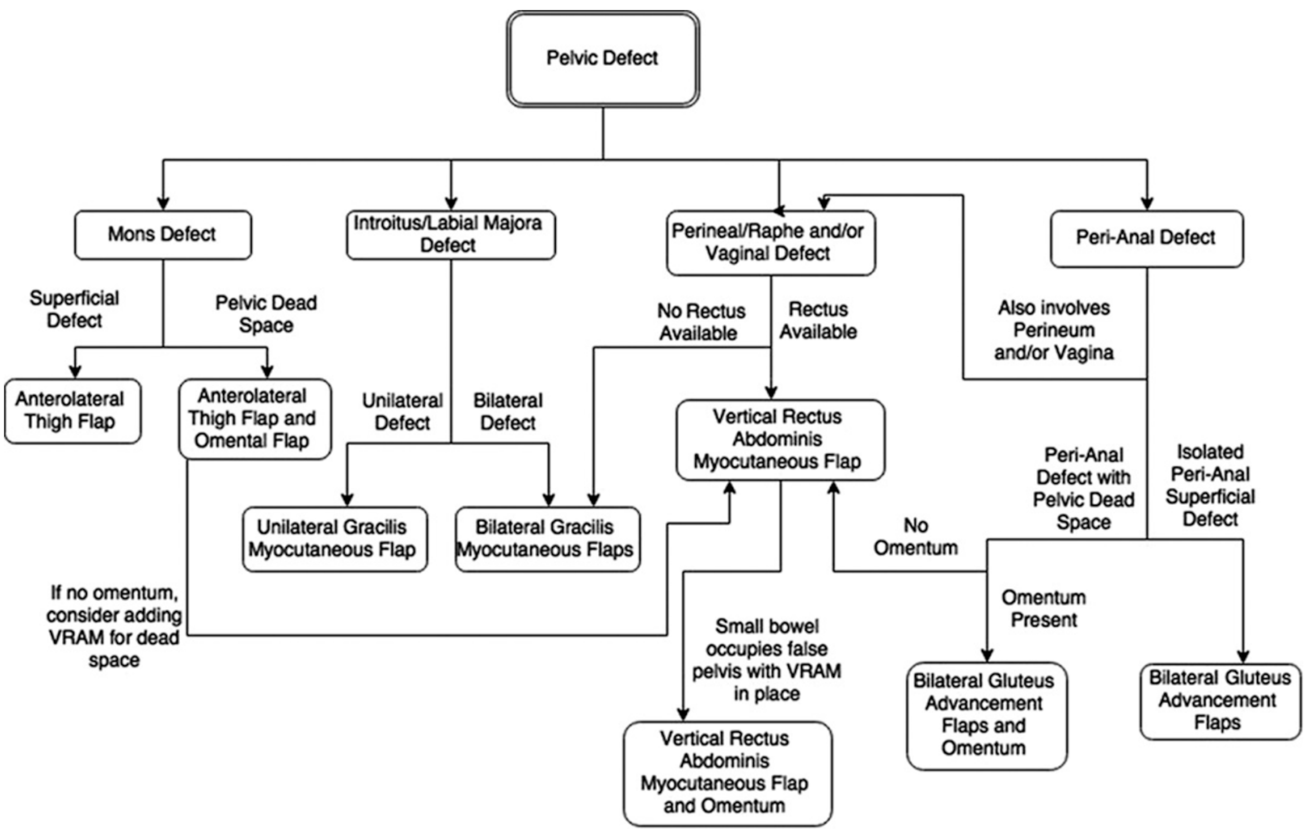

Figure 4. Perineal reconstruction algorithm. *From Mericli AF, Martin JP, Campbell CA. An Algorithmic Anatomical Subunit Approach to Pelvic Wound Reconstruction. Plast Reconstr Surg. 2016 Mar;137(3):1004-1017.*

COMPLICATIONS

- Complication rates will depend on the pathology and type of reconstruction
    - Notably APR performed after neoadjuvant chemotherapy and radiation can have wound complication rates of 40-60% without flap reconstruction

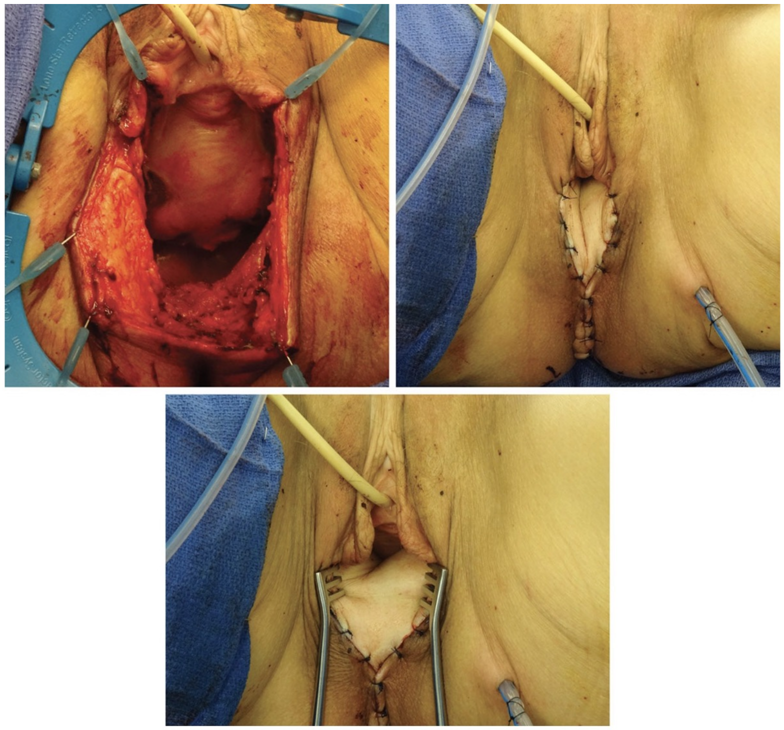

Figure 5. Inset of a VRAM flap into the perineum for a combined vaginal, perineal raphe, and perianal wound. *From Mericli AF, Martin JP, Campbell CA. An Algorithmic Anatomical Subunit Approach to Pelvic Wound Reconstruction. Plast Reconstr Surg. 2016 Mar;137(3):1004-1017.*

- Wound/scars
- Infection
- Chronic pain
    - Utilization of pelvic therapy after perineal reconstruction can be helpful in treatment
- Sexual dysfunction
- Urinary dysfunction
- Vaginal stenosis

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Chapter 18
Pressure Injuries

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TERMINOLOGY

- "Pressure injury" is the preferred term over "pressure/decubitus ulcer" or "bed sore"
- Decubitus was a term to describe lying position; however, any position that causes sustained pressure to an area (e.g., sitting/supine/side position) can cause a pressure injury
    - Can also occur due to casting or splinting after surgical procedures
- Pressure injury, defined: ischemic tissue loss resulting from pressure, usually over a bony prominence

STAGING

- National Pressure Injury Advisory Panel (NPIAP) redefined the definition of pressure injuries in 2016 (Fig. 1)
    - Stage I: non-blanchable erythema of intact skin
    - Stage II: partial thickness skin loss with exposed dermis
    - Stage III: full-thickness skin loss
    - Stage IV: full-thickness skin and tissue loss with exposed fascia, muscle, tendon, ligament, cartilage, or bone
    - Unstageable: full-thickness skin and tissue loss in which the extent of tissue damage cannot be determined because it is obscured by slough or eschar
    - Deep tissue injury: persistent non-blanchable deep red, maroon, or purple discoloration

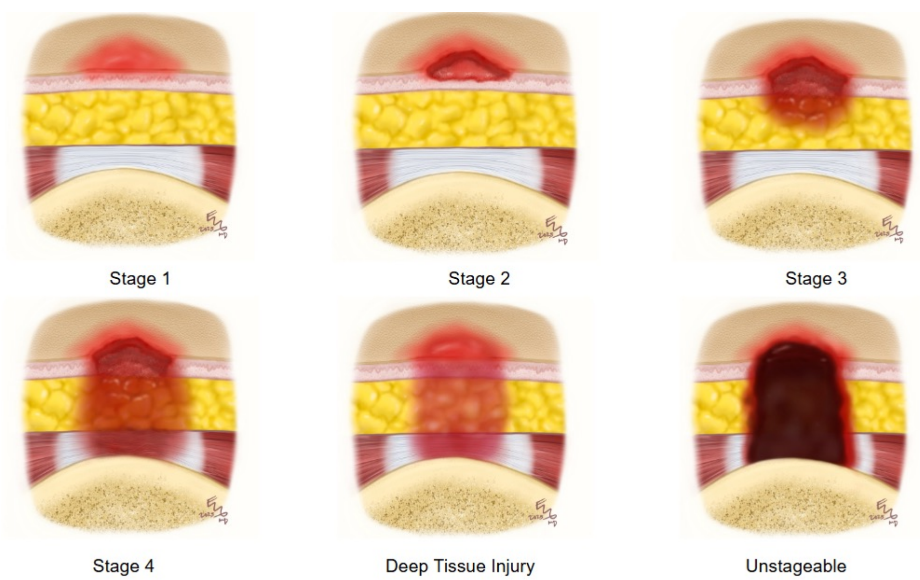

Figure 1. Staging system for pressure injuries. Reference: Emily Geisler, MD

"ICEBERG PHENOMENON"

The skin damage visualized often underestimates the true depth and extent of the underlying tissue injury. This is due to underlying muscle being more susceptible to ischemia than skin.

EPIDEMIOLOGY

Pressure injuries are a common complication with costly implications to the healthcare system. This reflects systemic issues in mobility, nutrition, and access to care.

- Acute inpatient care: the prevalence of pressure injuries is 12.7%, with a hospital-acquired incidence of 10%
- Quadraplegic (tetraplegic) patients:
    - Prevalence of pressure injuries is 33.9% in long-term care settings, with some studies reporting that up to 73.4% of tetraplegic spinal cord-injured individuals experience a pressure injury at some point post-injury.
- Bedbound hospital patients (general hospitalized patients):
    - Prevalence of pressure injuries is 12.8% and the incidence of hospital-acquired pressure injuries is 8.4%
- Intensive care unit (ICU) patients:
    - Prevalence of pressure injuries in ICU patients is 16.9–26.6%, and the incidence ranges from 10% to as high as 25.9%.
- Hip fracture patients:
    - Incidence of pressure injuries during hospitalization is 22.7–27%
    - In geriatric hip fracture patients, the postoperative pressure injury rate is 5.15%

COST

In the United States, the average incremental cost per hospital acquired pressure injury is approximately $21,767 per patient, with higher costs for more severe injuries. Nationally, hospital-acquired pressure injuries are estimated to cost the US healthcare system up to $26.8 billion annually, with the majority of costs attributable to advanced-stage (stage III and IV) injuries. For surgical patients, hospital acquired pressure injuries add about $8,200 to the cost of a hospital stay, representing a 44% increase over baseline costs.

AFFECTED BODY AREAS

- Often form on skin that covers bony areas (Fig. 2)
- Most common (order varies in literature): sacrum/coccyx > heels > ischial tuberosities (in spinal (general/ICU/hip fracture patients) > other bony prominences
- Spinal cord injury patients: ischial tuberosities > sacrum/coccyx, heels, and trochanters
- Bedbound hospital patients: sacrum > heels > hips/trochanter
- ICU patients: sacrum > heels > hips/ trochanter > ears and shoulders
- Patients with hip fractures: sacrum > heels

RISK FACTORS

- Extrinsic: non-physiologic, environmental factors
    - Pressure (perpendicular force) leads to deep necrosis; can develop after 2 hours of unrelieved pressure
    - Shear (parallel force) leads to superficial necrosis due to perforator compromise
    - Friction
    - Moisture

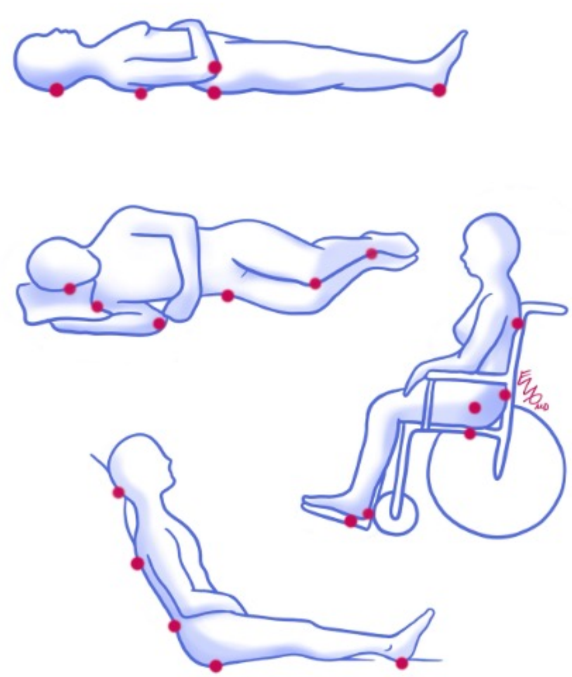

Figure 2. Pressure injury locations.
Reference: Emily Geisler, MD

- Intrinsic: physiologic factors
  - Altered activity/mobility
  - Cognitive deficit or altered consciousness
  - Decreased autonomic control (e.g., incontinence)
  - Infection → sepsis/ischemia
  - Increased age
  - Sensory loss
  - Chronic illness: vascular disease/anemia
  - Malnutrition
  - Medications/immunocompromised (e.g., steroids)
- Risk assessment:
  - Braden risk assessment scale: measures pressure injury risk using 6 domains (sensory perception, moisture, activity, mobility, nutrition, and friction/shear)
  - Norton risk assessment scale: measures pressure injury risk using 5 domains (physical condition, mental condition, activity, mobility, and incontinence)

TREATMENT

I. Non-surgical

- Prevention is the best treatment
  - Skin care and moisture control
  - Repositioning: supine turn every 2 hours (avoid dragging/shearing skin of the patient while repositioning), seated lift every 10 minutes
  - Optimizing nutrition and comorbidities
  - Manage spasticity
  - Relieving pressure using air mattresses, cushions, heel protectors
  - Air-fluidized beds (Clinitron®) gold standard for pressure injury prevention
- Systemic infection/sepsis unlikely with pressure injury (unless immunocompromised): look for other sources, e.g., urinary tract infection or respiratory tract when patients with pressure injuries presenting with fevers and leukocytosis
- If localized infection is present (look for signs of local cellulitis), topical antimicrobial agents (Silvadene®, Sulfamylon®) can be used and, if needed, oral or IV antibiotics
- Bone biopsy is the gold standard to assess osteomyelitis
- Can direct antibiotic therapy to treat osteomyelitis, but virtually impossible to eradicate infection with antibiotics alone
  - MRI may be helpful as imaging study, while bone scans are often non-specific due to presence of periostitis associated with open wounds
  - Long-term antibiotics are not indicated
  - Pressure0injury closure may be accelerated using topical protein growth factors
  - Stage III-IV patients require sharp debridement, highly absorptive dressings (alginates, hydrocolloid beads, foams, hydrogels)
  - Negative pressure wound therapy (NPWT) may be beneficial to assist closure

II. Surgical

- Patient motivation is an important determinant of recurrence risk in the alert patient
- Pre-operative planning to consider: social history (smoking history, support system, etc.), spasticity management, bladder habits (urinary diversion/urostomy), bowel regimen (diverting colostomy), nutritional status (assess baseline labs, including ESR, CRP, albumin, and prealbumin), wound cultures, wound care, and postoperative positioning and resources
- Due to high recurrence rates, surgery tends to be reserved for patients with reversible pathologies and stage III/IV pressure injuries
- Excisional debridement of pressure injury and bursa and any heterotopic calcification is necessary

- Closure of the wound should be performed using healthy, durable tissue that can provide adequate padding over the bony prominence (myocutaneous vs. fasciocutaneous flap) and is tension-free, keeping in mind post-operative positioning
- Reconstruction of pressure injuries varies by anatomic site:
    - Sacrum: lumbosacral fasciocutaneous flap, unilateral/ bilateral gluteal fasciocutaneous or myocutaneous rotation flap, bilateral gluteal myocutaneous V-Y advancement flap
    - Ischium: gluteal fasciocutaneous or myocutaneous rotation flap, posterior hamstring myocutaneous V-Y advancement flap, posterior thigh fasciocutaneous flap, gracilis flap, tensor fascia lata (TFL) flap
    - Trochanter: TFL flap ± vastus lateralis
- Girdlestone procedure is utilized for trochanteric pressure injuries for extensive bony involvement
    - Partial or complete ostectomy to reduce bony prominence – may lead to new pressure injuries elsewhere (be careful when off-loading)
- Aftercare including appropriate surfaces and wound management are paramount
    - Lifestyle and activity modification often required in order to reduce recurrence risk
- Complications and recurrence:
    - Hematoma, infection, wound dehiscence
    - Recurrence: overall 7-82%
    - Long-term complications include Marjolin's ulcer

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Chapter 19
Hand and Upper Extremity

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The hand conveys dexterity, sensation, and strength—factors essential to patient function and identity. For the plastic surgeon, mastery of hand surgery reflects the understanding of intricate anatomy, structural problem solving, and patient goals. Hand surgeons have a broad practice including acute trauma, congenital abnormalities, peripheral nerve, microsurgical reconstruction and replantation, elective hand surgery, and dermatological conditions. The hand poses challenges that require both technical skill and an appreciation of form and function. Advances in microsurgery, nerve transfers, tendon repair, and biologic scaffolds continue to transform outcomes for patients. This chapter provides the fundamental knowledge in anatomy, pathophysiology, and surgical decision-making. We provide a comprehensive overview of recent technical advances in hand surgery essential for all practitioners engaged in the care of patients with upper extremity complaints.

HAND ANATOMY

- Nerves
    - Sensory: median, ulnar, radial sensory nerves (Fig. 1)
    - Motor: intrinsic muscles of hand
    - Median nerve: thenar muscles, radial lumbricals
    - Ulnar nerve: interossei, ulnar lumbricals, hypothenar muscles
- Muscles and tendons (Table 1)
    - Flexor system (Fig. 2)
        - Extrinsic flexors
            - Flexor digitorum profundus (FDP): attaches to distal phalanx and bends the distal interphalangeal joint (DIPJ), proximal interphalangeal joint (PIPJ), and metacarpal phalangeal joints (MCPJ)
            - Flexor digitorum superficialis (FDS): attaches to middle phalanx and bends PIP and MCPJ
        - Intrinsic flexors: lumbricals and interossei contribute to MCPJ flexion
    - Extensor system (Fig. 3)
        - Extrinsic extensors:
            - Join the extensor hood at the proximal phalanx and extend the MCPJ
            - Extrinsic extensor tendon trifurcates and the central slip inserts on the dorsal middle phalanx and the remaining tendon splits to form the lateral slips, which are joined by the lumbricals to form the conjoined lateral band
        - Intrinsics: interossei and lumbricals; pass volar to the axis of the MCPJ (where they act as flexors) and move dorsal to the axis of the PIPJ to insert on the dorsal distal phalanx
            - Act as extensors of the PIP and DIP joints
            - Conjoined lateral band converges distally to form the terminal tendon and inserts onto the dorsal distal phalanx base and extends the DIPJ
        - At the wrist, the extensors are encased on the extensor retinaculum, which is superficial and prone to injury (Fig. 4)

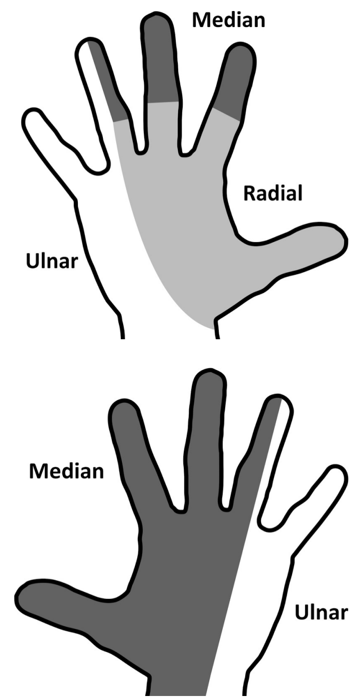

Figure 1. Hand sensory distribution.

Table 1. Hand muscle actions and innervations.

Region	Muscle Name(s)	Anatomical Compartment/Location	Main Action(s) at Joint(s)	Nerve Supply
Extensor Musculature Dorsal Hand	• Abductor pollicis longus, • Extensor pollicis brevis	1st dorsal extensor compartment	Thumb abduction/extension	Radial
	• Extensor carpi radialis longus • Extensor carpi radialis brevis	2nd dorsal extensor compartment	Wrist extension, radial deviation	Radial
	• Extensor pollicis longus	3rd dorsal extensor compartment	Thumb extension (IP)	Radial
	• Extensor digitorum comminus • Extensor indicis	4th dorsal extensor compartment	Finger extension (MCP, PIP, DIP)	Radial
	• Extensor digiti minimi	5th dorsal extensor compartment	Small finger extension	Radial
	• Extensor carpi ulnaris	6th dorsal extensor compartment	Wrist extension, ulnar deviation	Radial
Flexor Musculature Volar Hand	• Flexor digitorum superficialis • Flexor digitorum profundus	Carpal tunnel (deep to flexor retinaculum)	Finger flexion (MCP, PIP, DIP)	Median/Ulnar
	• Flexor pollicis longus	Carpal tunnel	Thumb flexion (IP)	Median (AIN)
	• Flexor carpi radialis • Palmaris longus	Carpal tunnel (FCR in own sheath)	Wrist flexion	Median
	• Flexor carpi ulnaris	Guyon's canal (superficial to retinaculum)	Wrist flexion, ulnar deviation	Ulnar
Intrinsic Hand Musculature	• Thenar muscles (APB, FPB, OP)	Thenar compartment	Thumb opposition, abduction, flexion	Median/Ulnar
	• Hypothenar muscles (ADM, FDM, ODM)	Hypothenar compartment	Little finger opposition, abduction, flexion	Ulnar
	• Adductor pollicis	Adductor compartment	Thumb adduction	Ulnar
	• Lumbricals	Central compartment	MCP flexion, IP extension	Median/Ulnar
	• Dorsal/Palmar interossei	Interosseous compartments (variable)	Finger abduction/adduction, MCP flexion, IP extension	Ulnar

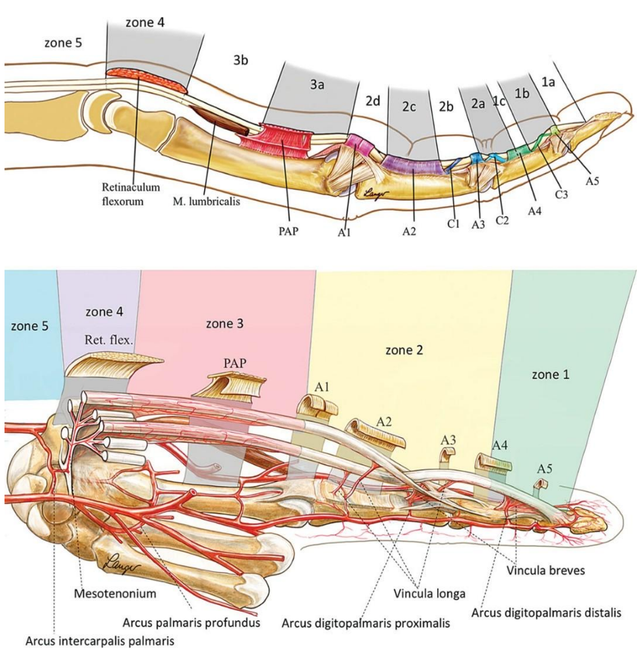

Figure 2. Flexor tendon system. *From Khor WS, Langer MF, Wong R, Zhou R, Peck F, Wong JKF. Improving Outcomes in Tendon Repair. Plast Reconstr Surg. 2016;138:1045e–1058e.*

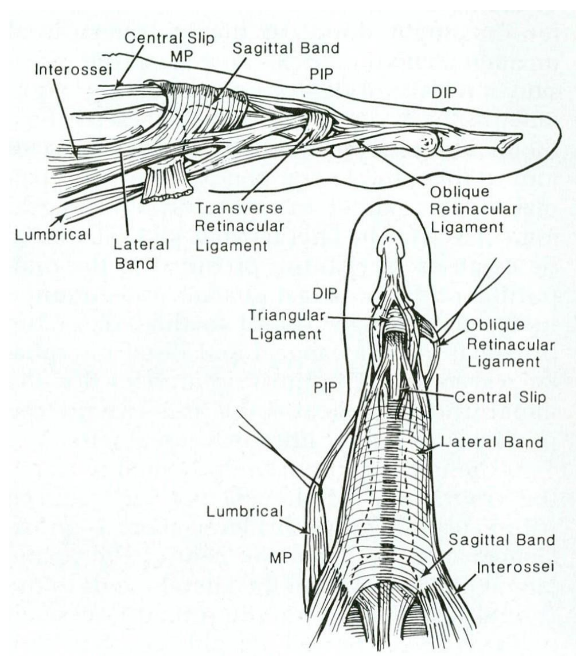

Figure 3. Extensor tendon system. *From Rockwell WB, Butler PN, Byrne BA. Extensor tendon: anatomy, injury, and reconstruction. Plast Reconstr Surg. 2000;106: 1592-603, 1673.*

• Skeleton (Fig. 5)

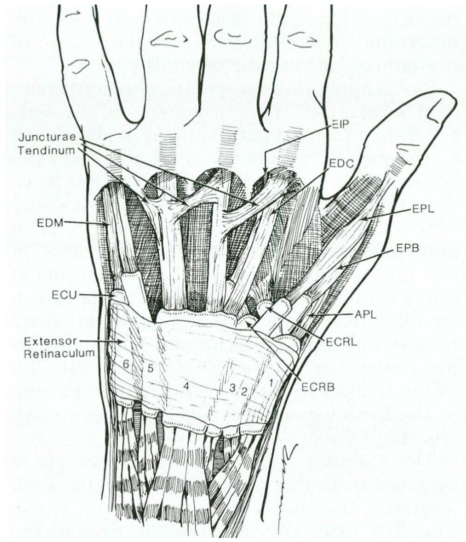

Figure 4. Extensor compartments of the hand: (1st) APL, EPB; (2nd) ECRL, ECRB; (3rd) EPL; (4th) EDC, EIP; (5th) EDQ; (6th) ECU. *From Rockwell WB, Butler PN, Byrne BA. Extensor tendon: anatomy, injury, and reconstruction. Plast Reconstr Surg 2000;106:1592-603, 1673.*

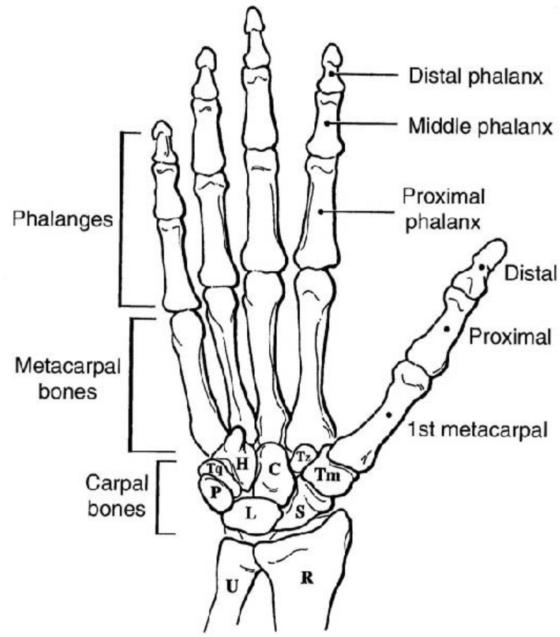

Figure 5. Bones of the hand. *From Marks M, Marks C. Fundamentals of Plastic Surgery. Philadelphia:W.B. Saunders Co., 1997.*

INITIAL EVALUATION OF THE INJURED HAND

- Evaluation of ABC's
  - Hand injuries are frequently associated with multisystem trauma
  - Patient must be stable and cleared from a trauma standpoint before further evaluation
- History
  - Time and place of accident
  - Mechanism of injury (position of hand while injured)
  - Right- or left-hand dominance
  - Occupation
  - Age
  - Comorbidities and medications
- Examination
  - Observation
  - Position of fingers: the resting cascade of the fingers is in slight flexion and pointing towards the scaphoid due to the relative pull of the flexors superseding the extensors
    - An abnormally straight finger might indicate a flexor tendon injury (the unopposed extensors hold the finger straight)
    - Great way to evaluate for malrotation in the setting of fractures.
  - Sweating patterns: lack of perspiration may indicate denervation, or increased vasomotor activity might indicate complex regional pain syndrome (CRPS)
  - Anatomic structures beneath the injury
- Sensory: must test prior to administering anesthesia
  - Tools
    - Two-point discriminator (subjective assessment)
    - Semmes-Weinstein Monofilament testing (objective assessment)
  - Test all sensory territories (median, ulnar, radial)
  - Test both sides of each finger to test radial and ulnar digital nerves

- Motor:
  - Profundus: stabilize PIP joint in extension, ask patient to flex fingertip (Fig. 6)
  - Superficialis: stabilize other DIP joints in extension to neutralize profundus action
    - Ask patient to flex unstabilized finger (Fig. 7)
  - Motor branch of median nerve; test palmar abduction of thumb against resistance
  - Motor branch of ulnar nerve; ask patient to fully extend fingers, then spread fingers or cross fingers
  - Extensor tendons
    - Ask patient to extend fingers at MCP joints with hand flat on table (tests long extensors)
    - Ask patient to extend PIP, DIP joints with MPs flexed (tests intrinsic extensors)

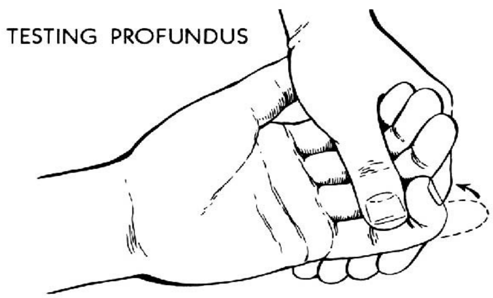

Figure 6. Testing profundus function.

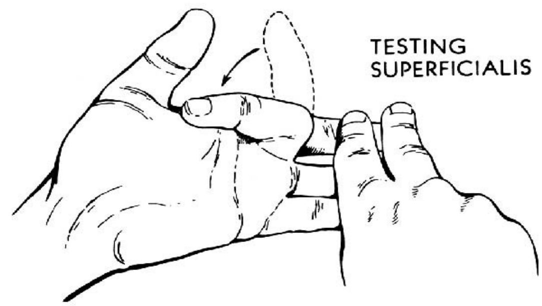

Figure 7. Testing superficialis function.

- Vascular
  - Color: nailbed should be pink, blanch with pressure, and show capillary refill around two seconds
  - Temperature: finger or hand should be similar in temperature to uninjured parts
  - Turgor: pulp space should be full without wrinkles
  - Pulse oximetry/doppler are useful adjuncts to physical exam findings
- Management:
  - Initial:
    - If there is significant bleeding, apply direct pressure or wrap with a pressure dressing to the affected area
      - Do not clamp vessels
      - Lidocaine with epinephrine can aid in exploration but only after neuro examination is completed
        - Avoid epinephrine in the digits if there is a concern that the vascular supply is compromised
      - Tourniquet at 250 mmHg may be used as last resort, but must be released intermittently
        - Do not use a tourniquet longer than two hours
    - Splint in safe position if possible (Fig. 8)
      - Intrinsic plus position:
        - Collateral ligaments are at maximum tension, so motion can be regained with least effort
        - Wrist extended (30^o), MCP joints flexed ($60\text{-}70^o$), IP joints straight, thumb abducted and rotated in opposing position
        - Proper splinting prevents further injury, prevents vessel obstruction, prevents further tendon retraction
    - All flexor tendon, nerve and vascular injuries, open fractures, and complex injuries are managed in the operating room

            - Many injuries can be treated in the emergency department or clinic using field blocks, digital blocks or wrist blocks
        - Tetanus prophylaxis and antibiotic coverage as indicated
    - Definitive:
        - Thorough cleaning of entire hand and forearm, with wound protected
        - Apply sterile drapes
        - Inspect wound: use tourniquet or BP cuff for hemostasis
        - Wound irrigation with normal saline
        - May need to extend wound to inspect all vital structures
        - Assure hemostasis with fine clamps and cautery
        - Nerve injuries should be repaired with magnification
        - Tendons should be repaired primarily if possible
            - Flexor tendon injuries in Zone II, classically referred to as ”no man’s land” (Fig. 9), should be repaired by a trained hand surgeon
            - Primary repair depends on laceration thickness (full or partial)
                - Partial thickness injuries (<50%) may benefit from nonoperative intervention (if no clinical symptoms, like triggering, are present) or epitendinous suture alone
                - Full thickness injuries require 4-core strand suture technique at a minimum
                    - Epitendinous sutures are used to reduce gapping and improve tendon gliding
            - If a hand surgeon is not available, clean and suture the skin wound, splint the hand, and refer as soon as possible for delayed primary repair
                - Repair should be done within 14 days
        - Reduce all fractures and dislocations, apply internal or external fixation if needed
        - Irreducible dislocations require operative management
        - Post-operative dressings
            - Splinting should be in safe position when possible
            - Dressings should not be tight to anticipate swelling

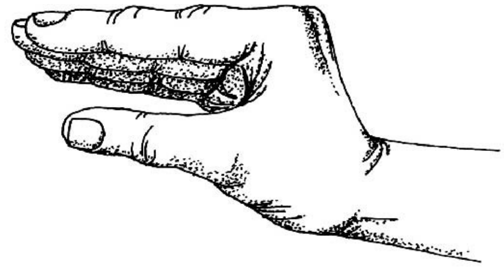

Figure 8. Position of safety

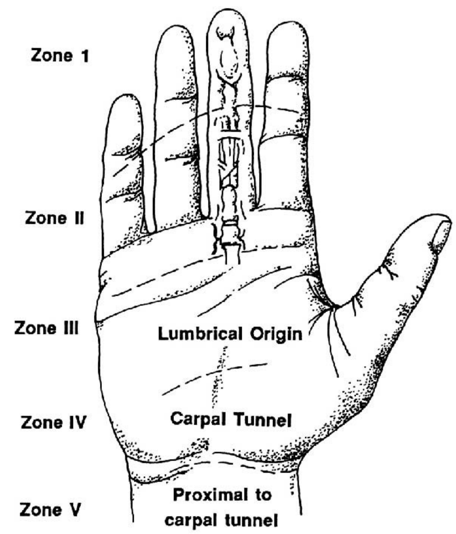

Figure 9. Flexor tendon zones of the hand.

SPECIAL INJURIES

- Fingertip: most common injury
    - Tip amputations
    - Basic principles: maintain length, bulk and sensibility
    - Treatment options include secondary healing, skin graft, local flap
    - Pediatric amputations: children under 4 years old have enhanced rates of neovascularization, so composite grafting of the amputated tip sometimes leads to repair without microsurgical techniques
        - Composite amputations should be reserved for young children, with clean amputated tips undergoing sharp (not crush or avulsion) injuries

- Nailbed injury:
  - Nailbed typically repaired with fine resorbable suture
  - Nail can be cleaned and replaced as a splint, or silastic sheet used as splint to prevent adhesion of the eponychial fold to the nailbed
- Amputation:
  - Indications for replantation: thumb, multiple digits, proximal amputations such as hand or arm, zone 1, and children
    - Relative contraindications to replantation include segmental defects, single finger (non-thumb) in zone II injuries, severe crush or avulsion injury, significant comorbidities, or life-threatening trauma
  - Care of amputated part
    - Remove gross contamination and irrigate with saline
    - Wrap part in gauze moistened in saline, place in clean plastic bag or specimen cup, seal
    - Lay plastic bag/container on ice, or float on ice cubes in water; don't immerse part directly in ice water or pack directly in ice
    - Include amputated segment in the X-ray
- Burned hand:
  - Initial treatment
    - Cleanse wound, debride blisters
    - Determine depth of burn and body percentage
    - Evaluate blood supply; circumferential full thickness burns may require escharotomy
    - Layered dressing: apply antimicrobial layer (such as bacitracin or other ointments), non-stick layer (Vaseline-impregnated gauze), absorbent layer, and compressive layer
  - Elevate burned limb, immobilize in safe position to prevent contractures
    - Refer to plastic surgeon if burn is extensive or may require grafting
  - Hand therapy may be needed to maintain motion
- Frostbite:
  - If acute needs rapid rewarming in a water bath at 38-42^{o}C for 15 min intervals
  - Elevate, debride clear blisters, leave hemorrhagic blisters intact
  - Referral to burn center for evaluation and further management

INFECTIONS

- General principles:
  - Infection can be localized by finding:
    - The point of maximum tenderness
    - Fluctuance is associated with an abscess, and often has a central opening with draining pustular fluid
    - Area of erythema and edema; erythema or ascending lymphangitis usually denotes lymphatic involvement
    - Pain with motion
- Pressure from edema and purulent fluid in a closed space can produce necrosis of tendons, nerves, blood vessels, and joints in a few hours
  - Extreme cases can lead to amputation and even death
- Infections that need immediate operative drainage or debridement:
  - Flexor tenosynovitis
    - Evaluate for Kanavel's four cardinal signs (semi flexed position of finger, dactylitis (sausage digit), tender over flexor sheath, pain with passive extension)
    - Treatment is to open and irrigate tendon sheath
      - Untreated infection can destroy the tendon
    - Broad-spectrum antibiotics
  - Deep space infections of the hand

    - Septic arthritis (beware the fight bite, often tooth penetrates and seeds bacteria into MCPJ)
    - Necrotizing fasciitis (necrotizing soft tissue infection, NSTI)
        - Clinical diagnosis, life-threatening
        - Exam often shows pain out of proportion, bullae, crepitus
        - Subcutaneous emphysema can be seen on XR
        - LRINEC score can also be helpful
        - Do not wait for advanced imaging for operative debridement if there is a suspicion for NSTI
    - Treatment principles:
        - Surgical drainage, cultures
        - Immobilization in safe position, elevation
        - Antibiotics
- Common infections:
    - Paronychia: infection of the lateral nail fold
        - Treatment:
            - If early, incision along the margin left open to drain
            - If late, with pus under nail, must remove nail
    - Felon: Infection pulp space of fingertip; closed space without ability to expand so very painful
        - Treatment is drainage utilizing a midvolar incision
            - "Fishmouth" or transverse incisions are contraindicated due to potential injury of the neurovascular bundle
            - Approach on the ulnar side for the index, long and ring fingers
            - Approach on the radial side for the thumb and small finger
            - Septate of pulp must be divided to ensure adequate drainage
    - Subcutaneous abscess: incise and drain with care not to injure digital nerve
        - Be alert to possibility of foreign body
    - Bite injuries:
        - Debride, cleanse thoroughly, culture
        - Screen patients for rabies prophylaxis based on wound and local exposure risk – intralesional immunoglobulin postexposure prophylaxis can be indicated in addition to the rabies vaccine
        - Must rule out penetration of joint space – may need to explore in OR
        - Do not close wound
    - Special considerations stratified by vehicle
        - Human bite: concern for *Eikenella corredens* (Augmentin), evaluate for possible zone V extensor tendon injury
        - Dog bite: concern for *Pasteurella spp* (Augmentin)
        - Cat bite: concern for *Pasteurella* and *Bartonella* (Augmentin), increased risk of occult infection due to inoculation depth

FRACTURES

- General principles:
    - Evaluate digits for angulation or malrotation, palpate for tenderness, check range of motion
    - XR in multiple planes:AP, true lateral, oblique
    - Anatomic reduction
        - Restoration of bony alignment, joint congruence and rotational stability
        - Minimizes abnormal loading to prevent traumatic arthritis, malunion or nonunion
    - Immobilize for fracture healing
        - Prevent micromotion at the site of repair
    - Hand therapy to maintain motion – immobilization leads to stiffness
- Specific fractures:
    - Metacarpal fractures:

        - Generally unstable fractures, can accept 10-40° angulation depending on metacarpal affected (greater angulation tolerated in ulnar MCs), if no malrotation present
        - Assess malrotation/scissoring – have patient make a fist slowly, if involved finger overlaps another, there is rotation at the fracture site, which must be reduced
        - If angulation/malrotation are acceptable – treatment with splinting with buddy taping may be sufficient
        - If fracture is unstable with malrotation, closed fixation with percutaneous pinning, open reduction with plates and screws, or intramedullary headless compression screws may be performed
    - Phalangeal fractures:
        - Unstable fractures require internal or percutaneous fixation
    - Tuft fractures (distal phalanx):
        - If crushed, mold to shape
        - Repair associated nailbed injury if needed (see above)
        - Splint for comfort (DIP only) for 1-2 wks
    - Intra-articular fractures:
        - Definitive management depends on the level of stability (see below, joint Injuries)
        - Stable intra-articular fractures can be managed with immobilization and rehabilitation with joint protection
        - Unstable fractures, or fractures with > 2mm of step off require operative fixation to improve patient reported and functional outcomes

JOINT INJURIES

- Dislocation
    - If already reduced, test for stability through arc of motion
        - Test collateral ligament stability with radial and ulnar stressing at affected joint
        - Test MPJ in flexion and IP joints in extension
        - Compare laxity to contralateral side to establish baseline
    - Most can be treated with closed reduction; open reduction is be necessary when closed reduction fails, often soft tissue prevents the reduction
- Ligamentous injury: usually lateral force
    - Skier's thumb: acute rupture of the ulnar collateral ligament of the MCP joint, requires operative repair
    - Gamekeeper's thumb: chronic rupture of ulnar collateral ligament of MCP joint due to repetitive valgus stress and attenuation
        - Requires operative reconstruction
    - Wrist injury: multiple ligaments can be involved
        - Diagnosis may require MRI arthrogram or arthroscopy
        - Clinical diagnosis by pattern of pain, x-rays, palpation for abnormal movement
- Treatment
    - Immobilize 2-3 weeks for digital joint injury (MP or IP dislocation), then protected motion
    - Thumb MPJ and wrist sprains require 6 weeks immobilization (some, e.g., thumb ulnar collateral ligament, might need operative repair)

NERVE INJURIES

- Traumatic peripheral nerve injuries
    - Anatomy
        - Nerve is comprised of neurons, supportive glial cells (including Schwann cells which produce myelin) and connective tissue
        - Motor nerves originate from the anterior horn of the spinal cord, while sensory nerves carry afferent nerve signals from the periphery to the dorsal root ganglion
        - Neurons are structured in specific layers linking form and function (Fig. 10)

- Specialized connective tissue called the endoneurium surrounds the nerve fibers which are separated into fascicles
- Timing:
  - Classically, nerves heal 1 mm a day (metric) or 1 inch a month (imperial)
  - 3-to-6 months: injuries may be neuropraxic or axonometic (see below), which carry excellent recovery rates
    - Performing electromyography (EMG) helps tease out recovery potential and need for surgical intervention
  - 6-to-12 months: injuries explored at this time may have recovery potential if distal, but recovery distance to distal target may preclude repair

    For very distal targets from the injury, nerve transfer may be indicated
  - 12 months and beyond: low recovery potential, should consider tendon transfers or free functional muscle transfer (FFMT, typically gracilis)

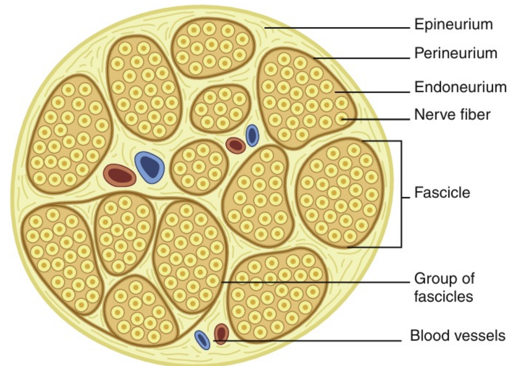

Figure 10. Anatomy of a peripheral nerve. *Republished with permission from Green's Operative Hand Surgery, 7th edition.*

- Initial management of injury:
  - Perform motor and sensory exam after injury
  - Thoroughly irrigate and close all wounds if not emergent, or explore emergent or highly contaminated wounds in the operating room
- Mechanisms of injury:
  - Nerve injuries occur through sharp, crush, avulsion and blast mechanisms in the hand and upper extremity
  - Sharp injuries: treat with primary coaptation of transected distal and proximal segments with 8-0 nylon suture under loupe or microscope visualization
    - Early management leads to better outcomes
  - For non-sharp injuries, resect proximal and distal segments until healthy fascicles are appreciated
    - Perform direct coaptation if possible
  - If nerve gaps exist
    - <3 cm: perform interposition reconstruction using nerve autograft or allograft
    - >3 cm: perform with interposition cable grafting from autologous nerve (sural most common donor nerve)

- Nerve pathology:
  - Classification of nerve injury
    - Nerve injury is classically defined by the Sunderland classification (Fig. 11)

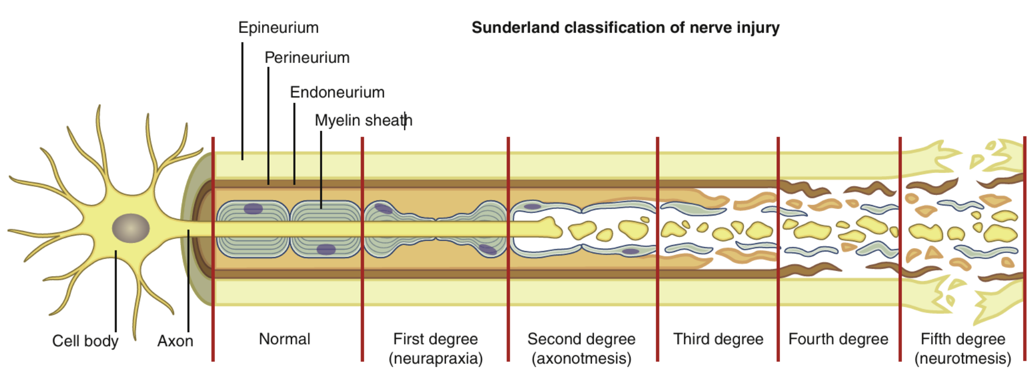

Figure 11. Sunderland classification of nerve injury. *Republished with permission from Green's Operative Hand Surgery, 7th edition.*

- A terminal neuroma occurs due to disorganized healing of injured fascicles at site of injury
  - These clinically lead to both phantom limb pain and residual limb pain
  - Diagnosis includes a positive Tinel sign (electrical symptoms elicited by tapping at the site of neuroma), improvement of pain with lidocaine injection at the site or neuroma, or ultrasound imaging
  - Surgical management of neuromas and transected nerves (amputation)
    - Excision, traction neurectomy, burying nerve in muscle or bone
    - Regenerative peripheral nerve interface (RPNI): implantation of the terminal nerve end into a free, nonvascularized muscle graft
    - Targeted muscle reinnervation (TMR): coaptation of the terminal nerve end into a sacrificed motor nerve branch of a local muscle
    - Centro-central coaptation: Direct coaptation of both digital nerve ends of the same finger centrally within the pulp
    - TMR and RPNI creates an EMG signal which can control a myoelectric prosthesis
- Nerve transfers
  - Sacrificing nonessential nerve functions to enhance recovery of essential function
- Brachial plexus injury
  - Anatomy
    - Brachial plexus is derived from the spinal roots C5-T1 and further subdivided by trunks, divisions, cords and branches (Fig. 12)
    - Injuries are characterized based on their location relative to the dorsal root ganglion
      - Preganglinotic injuries compromise root avulsions from the spinal cord
      - Postganglionic injuries compromise traction injuries or lacerations distal to the dorsal root ganglion

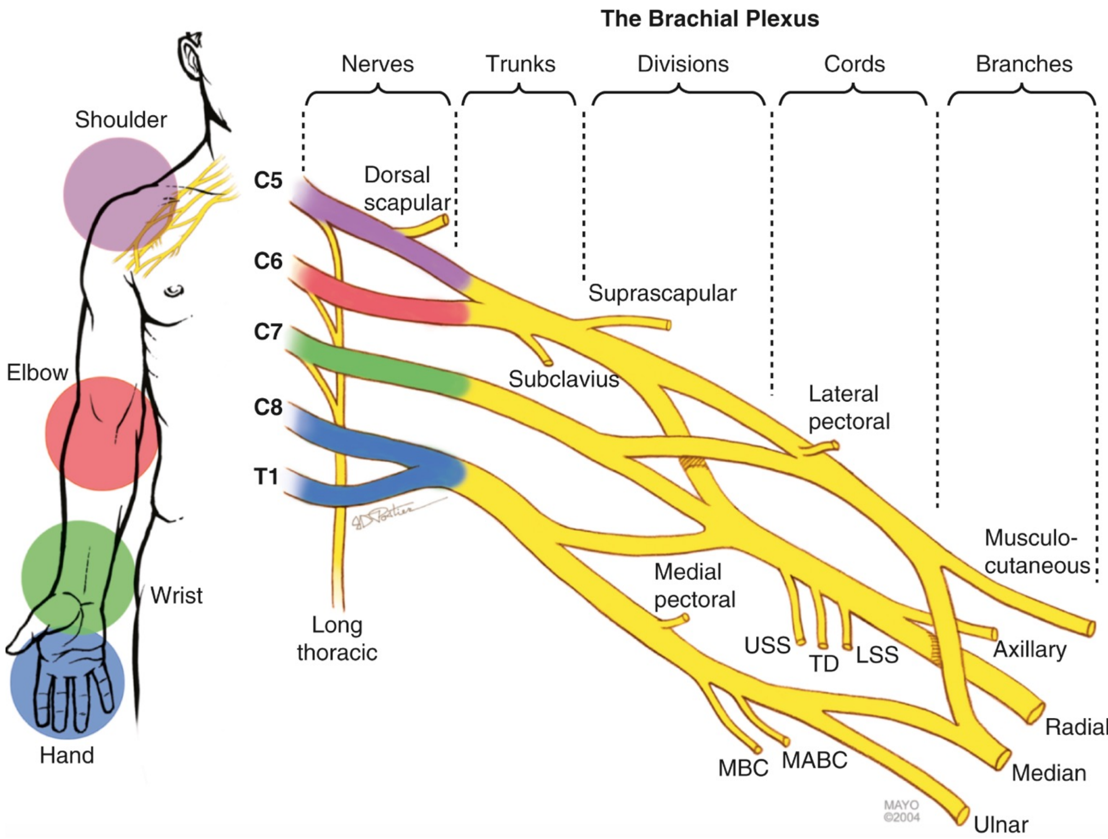

Figure 12. Brachial plexus. *Republished with permission from Green's Operative Hand Surgery, 7th edition.*

        - Injuries can be diagnosed with MRI to assess for pseudomeningocele in root avulsions, EMG to assess postganglionic stimulation and intraoperative sensory nerve action potentials (SNAPs)
        - Recovery potential depends on location of injury and timing
            - For non-recoverable nerve injuries, nerve transfers are indicated to restore essential functions of the upper extremity, primarily elbow flexion, shoulder stability and hand function
- Nerve compressions: compression of nerve by overlying muscle, ligament or fascia
    - Common examples:
        - Carpal tunnel: compression of median nerve by transverse carpal ligament at the wrist
        - Cubital tunnel: compression of ulnar nerve at elbow
            - Major sites of compression of the ulnar nerve around the elbow include the medial intramuscular septum proximally, Arcade of Struthers, Osborne's ligament, aponeurosis of the two heads of the FCU (can be contiguous with Osborne's) and the deep flexor/pronator aponeurosis distally. In 11% of the population, an accessory muscle, the anconeus epitrochlearis, replaces Osborne's ligament and is an additional site of compression
    - Diagnosis by symptoms, exam, and EMG
        - Tinel's sign: percussion of area leads to radiating pain through nerve distribution
        - Muscle wasting of hands (intrinsics for ulnar nerve compression, thenar for median nerve)
    - Treatment options include splinting, NSAIDs, steroid injections, surgical release

CONGENITAL DEFECTS

- Common defects:
    - Polydactyly: most common
        - Duplication of fingers, usually border digits
            - Duplication of 5th finger is common autosomal dominant trait in African-Americans
              Thumb duplication often requires reconstructive surgery, and is characterized by the Wassel classification system
    - Syndactyly: 2nd most common
        - May be simple, involving skin and soft tissue only, complex, involving bone, and complicated, involving additional abnormalities including extra bones, abnormal tendons or ligaments
- Treatment: goal to decrease deformity and improve function
    - Some problems are treated in infancy (e.g., splinting for club hand, thumb reconstruction)
    - Some treated by 12 months, before handedness develops – e.g. separation of syndactyly
    - Some require multi-stage procedures

HAND TUMORS

- Benign:
    - Ganglion cysts: most common tumor of upper extremity
        - Synovial cyst of joint or tendon sheath
        - Most common location scapholunate ligament
        - Treatment is observation, aspiration, or excision (aspiration with high recurrence, less so in children)
    - Giant cell tumor: second most common tumor, arises from proliferation from tendon sheath
    - Glomus tumors: tumors of thermoregulatory neuromyoarterial apparatus
      Presents with pain and temperature sensitivity at base of nail
        - Located in nail matrix
    - Bone tumors: enchondroma, osteoid osteoma

- Malignant:
    - Skin cancers (e.g., basal cell, squamous cell, melanoma)
    - Malignant bone tumors are uncommon in hand

MISCELLANEOUS

- Rheumatoid arthritis: synovial hypertrophy leads to severe joint destruction
    - Less commonly seen now with disease modifying drugs
    - Hand surgeons can perform synovectomy, joint replacement, carpal tunnel release
- Dupuytren's contracture: fibrous contraction of palmar fascia causes flexion contractures of fingers
    - Treatment is surgical excision, percutaneous release with a needle (needle aponeurotomy) or Xiaflex (collagenase) for MCPJ contractures
        - Surgical intervention is often indicated when there is PIPJ contractures
- Compartment syndrome: surgical emergency characterized by increased pressure within a closed myofascial space
    - Leads to compromised tissue perfusion, ischemic complications when capillary perfusion pressures are exceeded by intra-compartmental pressures from trauma and/or infection
    - Key clinical exam features include pain out of proportion to injury (earliest and most reliable clinical sign), pain with passive range of motion, paresthesias with tense swollen compartments
        - Late signs include paralysis, pallor and pulselessness.
            - Late findings often indicate advanced, irreversible damage
    - Diagnosis is primarily through clinical exam
        - In the instance of unreliable exams (obtunded, sedated or pediatric patients), direct intracompartmental pressure measurement is performed
    - Treatment is emergent fasciotomy and release of the compressive forces
- Complications of missed diagnosis or late diagnosis are permanent motor or sensory deficits, rhabdomyolysis from muscle breakdown and renal failure, limb loss or Volkmann's contracture

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Chapter 20
Lower Extremity

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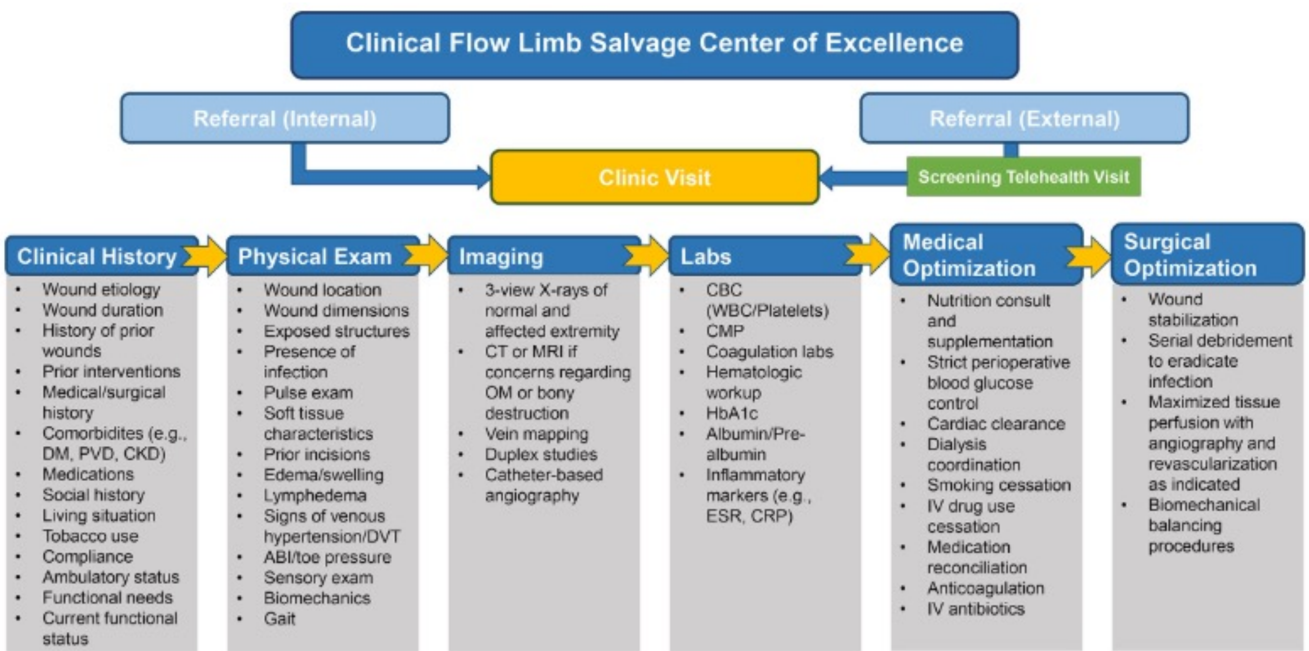
The plastic and reconstructive surgeon is often called upon to treat many defects of the lower extremity. These include chronic wounds of various etiologies, traumatic wounds, and oncologic resections with extensive soft-tissue loss or exposed critical structures such as bone, tendon, or vessels. A multidisciplinary approach that emphasizes patient-centered and defect-centered reconstruction is critical to success.

CHRONIC WOUNDS

Each wound requires accurate diagnosis. Not all lower extremity wounds will require surgical intervention when appropriate management is pursued. The key to healing includes wound hygiene, correction of the underlying problem, treatment of any concurrent infection, optimizing nutrition, and specific surgical intervention when appropriate. The plastic surgeon is an integral member of the multidisciplinary treatment team from the onset of the problem (Fig. 1). Remember that two different predisposing conditions may occur in the same patient. If so, the treatment must address both conditions.



Current clinical flow for patients with chronic lower extremity wounds who are referred to the limb salvage team at MedStar Health Department of Plastic and Reconstructive Surgery, Washington Hospital Center. *CKD*, chronic kidney disease; *DVT*, deep venous thrombosis; *ABI*, ankle brachial index; *CT*, computed tomographic; *MRI*, magnetic resonance imaging; *OM*, osteomyelitis; *CBC*, complete blood count; WBC, white blood cell; *CMP*, complete metabolic panel; *HbA1C*, hemoglobin A1C; *ESR*, erythrocyte sedimentation rate; *CRP*, C-reactive protein; *IV*, intravenous.

Figure 1. Clinical flow diagram for management of complex lower extremity wounds. *From Parikh RP, Sacks JM. Limb Salvage for Chronic Lower Extremity Wounds. Plast Reconstr Surg. 2025 Jun 1;155(6):p 1056e-1070e.*

I. Venous stasis ulcer

- Etiology: venous hypertension related to venous valvular incompetence that results in chronic inflammation and eventual skin breakdown
- Appearance:
  - Usually found over medial malleolus
  - Increased edema
  - Increased hemosiderin deposition (dark discoloration)
- Treatment:
  - Most heal if venous hypertension controlled
    - Compression is first-line: bandages (i.e., ACE wraps), bandage-like systems (i.e., Unna boots), stockings (customizable), intermittent pneumatic compression
      - Unna boots may heal ulcers in patients who are noncompliant with bedrest or must continue to work
    - Decrease edema with constant bedrest and foot elevation in addition to compression whenever possible
    - Pressure gradient stocking and a commitment to avoiding standing for long periods of time are necessary for long-term success
  - Surgery
    - Debridement:
      - Removes non-vitalized and/or infected tissue
      - Jumpstarts healing with fresh tissue edges that have growth factors
    - Skin substitutes can be utilized with success following debridement
    - Free tissue transfer may be required if critical structures are exposed (bones, nerves, tendons)
      - Important considerations pre-operatively include evaluating the superficial and deep venous systems
      - Anastomoses to both the superficial and deep systems may be necessary
    - Other surgical treatments include ablative surgery (laser, endovenous, or open) for refluxing veins and valvuloplasty

II. Ischemic ulcer

- Etiology: proximal arterial occlusion resulting in decreased perfusion and resultant tissue ischemia
- Appearance:
  - Usually more distal on the foot than venous stasis ulcers
  - Most often on lateral aspects of great and fifth toes, and dorsum of foot
  - No edema
  - No change in surrounding pigmentation
  - Painful
  - Surrounding skin may be shiny and hairless due to lack of nutrients
- Diagnosis: doppler ankle/brachial indices (ABI)
  - 0.9 to 1 is normal, 0.75-0.9 is moderate peripheral arterial disease (PAD), 0.5-0.75 is severe atherosclerotic disease, and <0.5 is critical limb ischemia
  - Diabetes can falsely elevate ABIs (often >1) due to calcification of vessels
- Treatment:
  - Most require revascularization based upon angiographic findings
  - Following revascularization, wounds should be debrided to healthy bleeding tissue
  - Provided that the wound is clean and revascularization is successful, reconstruction can be performed
  - A more proximal amputation may be required if revascularization is not possible
  - Usually a skin graft will close the wound; free tissue transfer may be required if critical structures or bone are exposed

III. Diabetic ulcer

- Etiology: multifold; decreased sensation (neurotrophic) results in unperceived traumas that then go untreated, calcified vessels can lead to decreased perfusion, and hyperglycemia negatively affects wound healing
- Appearance:
  - Usually on plantar surface of foot over metatarsal heads or heel
  - Edema ±
  - No change in surrounding pigmentation
- Treatment:
  - Debride necrotic tissue and use topical and systemic antibiotics to control the infection
  - Be conservative in care; early amputation is detrimental since patients often have limb-threatening infections in the other leg within a few years
  - After control of bacterial contamination, small ulcers may be excised and closed primarily; larger ulcers may require flap coverage (local or free tissue transfer)
  - Treatment should also include resection of underlying bony prominence
  - Post-operative diabetic foot care at home is paramount to proper management. Patient education in caring for and examining their feet is extremely important

IV. Pyoderma gangrenosum

- Etiology: neutrophilic dermatoses, often associated with autoimmune diseases
- Appearance:
  - Violaceous, cutaneous ulcers that rapidly evolve
  - May be associated with purulence if there is superimposed infection
- Treatment: very difficult to treat
  - May include anti-inflammatory drugs or immunosuppressives, as well as local wound care enzymatic agents
  - Success in treatment has been reported with hyperbaric oxygen in conjunction with local wound care
  - Surgical treatment is often contraindicated as excision causes perpetuation and worsening of wounds (pathergy)

ACUTE TRAUMA

Lower extremity trauma is frequently very complex, and often requires a team approach involving the orthopedic, vascular, and plastic surgeons ("orthoplastic" approach). Functional limb restoration, defined as functional, pain-free ambulation is the goal of extremity salvage operations.

- Initial management
  - All patients with lower extremity trauma should be evaluated for associated injuries, and treated according to advanced trauma life support (ATLS) criteria
  - Surgical debridement and irrigation of the wound in the operating room is the proper initial management
    - Specific management depends upon 1) the level of injury and 2) presence or absence of vascular, nerve, and/or bony injury
  - Limb-threatening injuries, vascular interruption, or open fracture are best assessed and treated in the OR
  - Fasciotomy is often required to maintain tissue perfusion in severe high energy or crush injuries when compartment syndrome exists
- Fractures of the lower leg are usually classified by the Gustilo system (Table 1)
  - Type I and II fractures usually have a good outcome with varied treatment
  - Gustilo Type III injuries have a worse prognosis and often require plastic surgical intervention

Table 1. Gustilo classification of open fractures of the lower leg	
Type I	Open tibial fracture with a wound <1 cm
Type II	Open tibial fracture with a wound >1 cm, without extensive soft tissue damage
Type IIIA	Open tibial fracture with adequate soft-tissue coverage despite extensive laceration or flaps, or high-energy injury accompanied by any size wound
Type IIIB	Open tibial fracture, extensive soft-tissue loss with periosteal stripping and bone exposure
Type IIIC	Open tibial fracture with arterial injury requiring repair

ONCOLOGIC

The primary goal for the oncologic surgeon is to achieve negative margins, which can result in a variety of defects involving heterogeneous tissues with or without exposure of vital structures. Additionally, these patients require neoadjuvant/adjuvant radiation and/or chemotherapy. Much like in traumatic reconstruction, the plastic surgeon is an integral part of a multidisciplinary team to provide durable, functional, and successful reconstruction.

- Pre-operative considerations:
    - Discussion with the surgical oncologist to determine likely defect (size, depth, structures involved)
    - Pre-operative radiation therapy may render local flap options unusable
    - Functional status of the patient and patient goals
    - Final pathology with negative margins should be confirmed
- Reconstruction goals:
    - Durable soft tissue coverage – important for the patient to be able to undergo postoperative radiation (generally initiated within 6 weeks post-operatively)
    - Functional restoration

TREATMENT

I. Non-surgical

- Wound vac/negative pressure wound therapy
    - Applies negative pressure to aid in wound healing
    - Valuable for stabilization of wounds and maintaining wound bed sterility
    - Can accelerate wound healing in smaller defects without exposed vital structures

II. Surgical care

- Indications for limb salvage versus amputation:
    - Several assessment tools exist but none have been shown to be useful as a sole guide/predictor in management
        - Consider co-morbidities, baseline patient mobility and function, social factors, patient goals, concomitant injuries, and whether multi-level injury
    - Posterior tibial nerve function as the determinate has been challenged
        - Some patients who initially lack plantar sensation have improvement postoperatively
    - Plastic surgery may still be involved in amputations to preserve length for prosthesis or optimize functional outcomes
        - Fillet flaps: use tissue from amputated part to close surgical site and preserve limb length
        - Concomitant targeted muscle reinnervation (TMR) or regenerative peripheral nerve interface (RPNI) for neuropathic pain prevention
- Essentials:
    - Adequate debridement

- Timing
    - Classic Godina study from 1986 advocated early coverage within 72 hours
        - Has been challenged, especially for more extensive injuries where patient may not be able to undergo coverage due to other critical injuries
        - Wound vac has probably helped increase the safe period between time of injury and time of reconstruction
    - Cover all vital structures (nerves, vessels, tendons, joints, hardware) within 7 to 10 days
- Zone of injury
    - Need to debride all damaged, non-vitalized tissue
    - If performing flap coverage, be aware of potential microscopic vessel injury in surrounding tissue (i.e., from atherosclerosis, trauma, radiation)
        - This zone of injury may affect flap or recipient vessel choice

- Need for vascularized tissue coverage (i.e., flap coverage)
    - Exposed bone and/or hardware is the most common indication for vascular tissue coverage versus skin substitute or skin graft coverage
    - A skin graft or skin substitute requires a healthy vascular wound bed to heal
    - Defect-centered reconstruction that replaces like-with-like is critical
- Location: traditional upper, middle, and lower third leg options
    - Upper third:
        - Gastrocnemius
            - Blood supply: medial and lateral sural vessels
            - May use medial or lateral head, although medial head is more often used due to larger size and more favorable arch of rotation by avoiding crossing over the fibula
            - Peroneal nerve at risk for injury with lateral head
    - Middle third:
        - Soleus
            - Blood supply: popliteal vessels (proximal), posterior tibial vessels (medial belly), and peroneal vessels (lateral belly)
            - Divide distally to rotate into defect
            - May split in half if necessary
    - Lower third:
        - Considerations:
            - Pick a reconstruction that will support weight-bearing and/or restoring protective sensation
            - While local flaps exist, lower third injuries generally require free tissue transfer
        - Free flaps:
            - Considerations with flap selection: pedicle length, OR positioning (concomitant injuries), durability on heel, bony need, sensation
                - Defect-centered reconstruction that optimizes contour and replaces tissue loss is essential (Fig. 2)
                - Fasciocutaneous flaps may be easier to re-elevate for secondary hardware operations
            - Recipient vessel selection:
                - Consider pre-operative imaging with CT angiography (diagnostic only) or formal angiography (allows intervention), especially if concerns for vessel injury, peripheral vascular disease, or large zone of injury
                - End-to-side anastomoses recommended when critical to preserve blood flow or vessel depleted limbs (i.e., single vessel limb)
                - Vein grafts may be needed if large zone of injury

Figure 2. Pure skin perforator superficial circumflex iliac artery perforator flap for dorsal foot reconstruction. A 71-year-old woman presented with a dorsal foot wound and exposed tendon allograft following repair of a ruptured left tibialis anterior tendon. The patient had comorbid PVD and DM (hemoglobin A1C of 9.7). Attempts at skin substitute application with podiatry had failed and, ultimately, required free tissue transfer to bring vascularized tissue to heal the wound. (Above, right, and below, left) A pure skin perforator superficial circumflex iliac artery perforator flap from right groin was selected, as thin skin coverage was required for dorsal foot resurfacing. (Below, right) The 3-month postoperative outcome shows a well-healed flap and good contour for footwear. *From Parikh RP, Sacks JM. Limb Salvage for Chronic Lower Extremity Wounds. Plast Reconstr Surg. 2025 Jun 1;155(6):1056e-1070e.*

        - Reverse sural flap
            - Blood supply: peroneal vessel perforators
            - Controversy over whether reliable and truly more simple than free flap
                - If chosen, consider surgical delay to improve the perfusion and delineate viable tissue
        - Medial plantar flap
            - Blood supply: medial plantar vessels
            - Sensate flap
- Free-style perforator flaps
    - Locoregional flaps based off perforators near the defect
    - Not necessarily a simpler option, need to consider zone of injury
- Bony gaps may be filled with grafts, flaps, or distraction techniques depending on length and quality of remaining bone
- Post-operative care
    - Elevate extremity
    - Splinting
    - Dangle protocols
        - Want to slowly get flap used to being in a dependent position as it will swell and get congested at first

    - 2-vein repair may help with congestion
    - No hard evidence for best timeline of when to start and how quickly to advance
- Physical therapy to help patient improve mobility with their new acute limitations post-operatively

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Chapter 21
Facial Aesthetic Surgery

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Michael Plastini, MD

FOUNDATIONAL PRINCIPLES IN FACIAL AESTHETICS

I. Facial Aging

- Several factors are cumulatively responsible for the aging face, each requiring unique strategies to mitigate their effects (Fig. 1)
- Skin changes:
  - Thinning of the dermis, reduced collagen and elastin → fine lines and wrinkles
  - Increased solar elastosis and pigmentation → dyschromia and rough texture
  - Decreased hydration and sebaceous activity → dull, dry skin appearance
- Soft tissue descent and volume loss:
  - Deflation of facial fat compartments (especially in midface, temples, periorbital areas)
  - Descent of fat pads, notably the malar and jowl fat, due to ligament laxity
  - Results in deep nasolabial folds, marionette lines, tear troughs, and jowling
- Ligamentous laxity:
  - Facial retaining ligaments (e.g., zygomatic, mandibular) weaken with age, reducing soft tissue support
  - Contributes to ptosis and deepening of facial folds

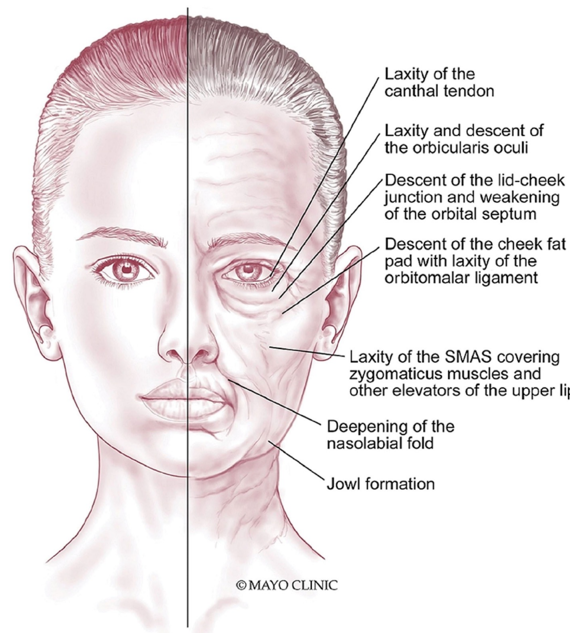

Figure 1. Common patterns of facial aging. *From Bustos SS, et al. Pharmacologic and Other Noninvasive Treatments of the Aging Face: A Review of the Current Evidence. Plast Reconstr Surg. 2024 Oct 1;154(4):829e-842e.*

- Muscle changes:
  - Hyperactivity of facial mimetic muscles (frontalis, orbicularis oculi, corrugators) leads to dynamic wrinkles: forehead lines, crow's feet, glabellar rhytids
  - Muscle thinning may also occur with age
- Skeletal remodeling;
  - Bone resorption affects the orbit (enlarged), maxilla (retruded), and mandible (narrowed angle, reduced projection)
  - Leads to loss of structural support, particularly around the eyes, midface, and jawline

II. Relevant anatomy

- Aesthetic units (AUs) are often used to describe the face, dividing it into sections that can be addressed individually or in groups
  - Include forehead, ear, eyebrow, upper eyelid, lower eyelid, cheek, upper lip, lower lip, chin, anterior neck
- Zones of adherence (ZA): anatomic areas of the face where tissues are “'ixed"
  - Areas are of interest in facial rejuvenation and can be linear or diffuse
  - Become relevant in face lifts seeking to re-drape tissue naturally across the face

- Facial fat pads (Fig. 2):
    - Superficial fat pads: located above the SMAS (superficial musculoaponeurotic system) layer, within the subcutaneous tissue
        - Partitioned by retaining ligaments (e.g., zygomatic, mandibular)
        - Major contributors to facial contour and surface volume
        - Undergo descent and deflation with aging, leading to hollowing and skin laxity
    - Deep fat pads: located beneath the SMAS, deep to facial muscles and ligaments
        - Provide central facial support and maintain youthful projection
        - Tend to deflate with aging, contributing to midface hollowing and tear troughs

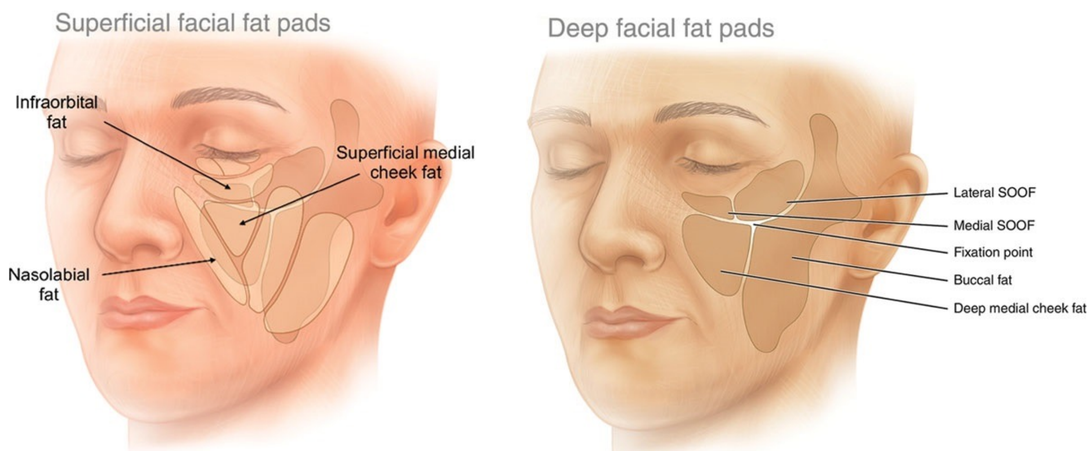

Figure 2. Fat pads of the face. *From Rohrich RJ, Avashia YJ, Savetsky IL. Prediction of Facial Aging Using the Facial Fat Compartments. Plast Reconstr Surg. 2021 Jan 1;147(1S-2):38S-42S.*

- Facial nerve:
    - Function: provides motor innervation to muscles of facial expression.
    - Course: exits the stylomastoid foramen, enters the parotid gland, and divides into five major branches
        - Five main motor branches (mnemonic: “To Zanzibar By Motor Car”)
            - Temporal: at risk in brow lifts and upper SMAS dissection
            - Zygomatic: innervates orbicularis oculi; at risk in deep plane dissection
            - Buccal: innervates muscles around nose, lip, and cheek
            - Marginal mandibular: innervates depressor anguli oris; vulnerable near mandibular border
            - Cervical: innervates platysma
    - Surgical danger zones:
        - Temporal branch: courses within the "zone of caution" — between a line from 0.5 cm below the tragus to 1.5 cm above lateral brow
        - Marginal mandibular branch: typically 1-2 cm below the mandibular border anteriorly but variable; often superficial near the anterior facial artery
- Blood supply:
    - Facial artery: major supplier to lower face; courses over the mandible anterior to the masseter, then ascends toward the medial canthus (as angular artery)
    - Superficial temporal artery: supplies lateral forehead and scalp
    - Transverse facial artery: crosses superficial to parotid duct, supplying cheek
        - Critical to avoid the facial artery during filler injections and in flap design
        - Facial vein follows a similar course to the facial artery, draining into the internal jugular vein
            - No valves in facial veins → risk of retrograde infection (e.g., cavernous sinus thrombosis from danger triangle of face)

- Danger zones in injections: use blunt cannulas, aspiration, and slow, low-pressure injection in high-risk zones
    - Glabella (supratrochlear/supraorbital arteries)
    - Nasolabial fold (angular artery)
    - Nasal sidewalls and tip (dorsal nasal and lateral nasal arteries)
    - Forehead (temporal artery branches)

II. Facial analysis

The process of evaluating facial proportions, contours, symmetry, and aging patterns to guide cosmetic or reconstructive procedures. A systematic approach ensures that treatments (e.g., fillers, facelifts, rhinoplasty) enhance the natural harmony of the face rather than overcorrect or distort it. Below is a systematic approach one could employ in performing a comprehensive facial analysis.

1. Divide the face into thirds
    - The face is classically divided horizontally into three equal parts:
        - Upper third: hairline to glabella (between eyebrows)
        - Middle third: glabella to subnasale (base of the nose)
        - Lower third: subnasale to menton (chin point)
    - Disproportion (e.g., a long lower third) may signal chin retrusion, lip imbalance, or vertical maxillary excess (treated with orthognathic surgery)
2. Assess facial fifths
    - Vertically, the face is divided into five equal segments, each roughly the width of one eye:
        - The central fifth includes the nose
        - Lateral fifths contain the ears and hairline
    - Facial symmetry and harmony are assessed using these proportions
3. Evaluate facial shape
    - Common aesthetic facial shapes:
        - Oval (ideal): balanced proportions
        - Round: short lower face, wide cheeks
        - Square: strong jawline
        - Heart: wide forehead, narrow chin
    - Shape guides filler placement, fat grafting, or skeletal augmentation
4. Analyze skin and soft tissue
    - Skin quality: wrinkles, texture, pigmentation
    - Volume loss: especially in midface (malar fat pads), temples, lips
    - Laxity: sagging skin, jowls, or nasolabial folds
    - These help determine if a patient needs lifting, volumization, or resurfacing
5. Assess key areas
    - Forehead/brows: position and symmetry
    - Eyes: lid position, tear troughs, periorbital hollowing
    - Nose: dorsal height, tip projection, deviation
    - Lips: volume, definition, proportion (ideal ratio: upper:lower ≈1:1.6)
    - Chin/jawline: projection and definition, especially in profile
    - Neck: skin laxity, platysmal bands, fat deposits
    - Each area may need a tailored intervention such as neuromodulators, fillers, or surgery
6. Perform profile analysis
    - Ideal angles:
        - Nasolabial angle (columella-lip): ~95-105° in women (more acute in men)
        - Mentocervical angle (chin-neck): ~105-120°
        - Facial convexity: A straight or gently convex profile is often preferred
    - Guides surgical planning for rhinoplasty, genioplasty, or neck lift

NON-SURGICAL AESTHETIC INTERVENTIONS

A more comprehensive review of nonsurgical aesthetic interventions that may be employed in facial rejuvenation can be found in Chapter 24.

UPPER THIRD: BROW AND PERI-ORBITAL AESTHETICS

- Brow lift (Fig. 3):
  - Relevant anatomy:
    - Brow is supported by the frontalis muscle, opposed by brow depressors (procerus, corrugator supercilii, orbicularis oculi), and receives innervation from the facial nerve's temporal branch
    - Sensory innervation is from the supratrochlear and supraorbital nerves, which exit near the orbital rim
    - Understanding the retaining ligaments (e.g., orbital retaining ligament, temporal ligamentous adhesion) is essential for safe and effective release during elevation
  - Indications:
    - Lateral or medial brow ptosis
    - Asymmetry
    - Visual field obstruction (in functional cases)
    - Aesthetic rejuvenation of the upper face and periorbital region
  - Patient evaluation:
    - Brow symmetry, position (normally at/above the supraorbital rim in women, slightly lower in men)
    - Skin quality
    - Forehead height
    - Hairline position
    - Dynamic function (muscle overactivity) and contribution to upper lid hooding
    - Photographic analysis and functional visual field testing (for insurance coverage)
  - Coronal brow lift:
    - Long incision behind the hairline
    - Lifts entire forehead and brow en bloc
    - Excellent exposure and control; risk of scalp numbness or alopecia
  - Endoscopic brow lift:
    - Multiple small incisions behind the hairline
    - Minimally invasive; uses a camera and instruments to release brow depressors and elevate brow
    - Less scarring, faster recovery; technically demanding
  - Hairline (pretrichial) brow lift:
    - Incision at the hairline, ideal for patients with long foreheads (>6 cm)
    - Preserves or lowers hairline height; risk of visible scar
  - Direct brow lift:
    - Incision immediately above the eyebrow hairs
    - Used in older male patients or in cases needing strong correction (e.g., facial palsy)
    - Visible scar is main drawback
  - Lateral temporal (limited Incision) brow lift:
    - Short incision at the lateral hairline or temporal scalp
    - Elevates lateral brow only; often combined with blepharoplasty
    - Limited effect medially
  - Pearls:
    - Release brow depressor muscles for durable elevation
    - Tailor approach to hairline, forehead height, and aesthetic goals
    - Protect sensory nerves (especially supraorbital/supratrochlear)

- Pitfalls:
    - Overcorrection → unnatural expression
    - Nerve injury (temporal branch or supraorbital/supratrochlear)
    - Visible scarring in direct or hairline approaches
    - Asymmetry if release is incomplete
- Upper blepharoplasty: upper eyelid rejuvenation (Fig. 3)
  - Relevant Anatomy:
    - Upper eyelid consists of five layers: skin, subcutaneous tissue, orbicularis oculi muscle, orbital septum, and preaponeurotic fat, with the levator aponeurosis lying deep to the fat pad and inserting into the tarsus
    - Supratarsal crease forms where the levator extends to the skin
    - Lacrimal gland lies superolaterally and must be preserved
    - Supraorbital and supratrochlear nerves supply sensation and course just deep to the orbital rim
  - Indications:
    - Dermatochalasis (redundant upper eyelid skin)
    - Visual field obstruction (often confirmed by visual field testing)
    - Aesthetic concerns including loss of eyelid crease or hooding
    - Asymmetry or eyelid contour deformity
    - Adjunct to brow ptosis correction or lower blepharoplasty
  - Patient evaluation:
    - Skin excess, fat prolapse, and levator function
    - Brow position (to rule out brow ptosis masquerading as dermatochalasis)
    - Presence of asymmetry, eyelid crease height, and fat distribution
    - Snap-back test and dry eye evaluation (Schirmer's or OSDI if indicated)
    - Standardized photography (frontal, oblique, profile, and gaze positions)
    - Visual field testing if surgery is to be considered medically necessary
  - Surgical approaches:
    - Skin-only resection:
      - For mild dermatochalasis without fat herniation
      - Incision placed in the natural supratarsal crease
    - Skin-muscle resection:
      - Removes both skin and orbicularis muscle for a more sculpted lid
      - Can be combined with fat modification
    - Fat pad management:
      - Selective removal or repositioning of medial and central fat pads
      - Avoid over-resection to prevent hollowing
    - Crease re-formation (Asian blepharoplasty)
      - May involve fixation of skin to levator aponeurosis
      - Preserves ethnic features while enhancing crease definition
  - Pearls:
    - Preserve at least 10-12 mm of upper eyelid skin to avoid lagophthalmos
    - Conservative fat removal prevents postoperative hollowing
    - Mark incisions with the patient sitting upright and looking forward
    - Symmetry depends on careful pre-operative planning and brow evaluation
    - Consider brow ptosis correction first if contributing to upper lid hooding
  - Pitfalls:
    - Over-resection of skin → lagophthalmos, dry eye
    - Excessive fat removal → hollow upper lids, A-frame deformity
    - Asymmetric markings or lid crease height
    - Undiagnosed brow ptosis → persistent hooding postoperatively
    - Damage to levator aponeurosis → ptosis
    - Injury to lacrimal gland laterally → dry eye complications

Figure 3. The above image demonstrates correction of brow ptosis and dermatochalasis with brow lift and upper blepharoplasty. *From Vaca EE, Alghoul MS. Upper Blepharoplasty with Endoscopically Assisted Brow Lift to Restore Harmonious Upper Lid Arc Curvatures. Plast Reconstr Surg. 2020 Nov;146(5):565e-568e.*

- Lower blepharoplasty: lower eyelid rejuvenation (Fig. 4)
  - Relevant anatomy:
    - Anterior lamella: skin and orbicularis oculi muscle
      - Skin is thin and prone to retraction; muscle contributes to lower lid tone
    - Middle lamella: orbital septum and orbital fat pads
      - Three distinct fat compartments: medial, central, lateral
      - Orbital septum attenuates with age, allowing fat herniation
    - Posterior lamella: tarsal plate and conjunctiva
      - Tarsal plate provides structural integrity
      - Levator aponeurosis (for upper lid) has no role here, but lower lid retractor and capsulopalpebral fascia are relevant
  - Indications:
    - Orbital fat herniation (puffy lower eyelids)
    - Skin laxity and fine rhytids
    - Tear trough deformity or hollowing
    - Eyelid malposition (e.g., lid laxity, ectropion)
    - Aesthetic lower eyelid rejuvenation or functional concerns
  - Patient evaluation:
    - Lid ptosis vs. brow ptosis
      - Differentiate lower-lid laxity from gravitational descent of midface and brow
      - Brow ptosis may exacerbate lower lid redundancy
    - Assess canthal support
      - Snap-back test and distraction test assess horizontal lid laxity
      - Canthal tendon integrity determines need for canthopexy or canthoplasty
    - Perform vector analysis
      - If the globe is anterior to the malar eminence (negative vector), patient is at higher risk for ectropion and scleral show
      - Midface support evaluation is critical in surgical planning
  - Surgical approaches:
    - Transconjunctival:
      - Incision through the conjunctiva; avoids anterior lamella dissection
      - Ideal for patients with fat herniation but good skin tone
      - Lower risk of ectropion, preserves pretarsal orbicularis and septum
    - Subciliary:
      - Incision 1-2 mm below the lash line
      - Allows skin and muscle excision, fat manipulation
      - Greater risk of lower lid malposition, especially in patients with poor tone

- Fat management strategies:
  - Fat preservation
    - Selective debulking of herniated fat pads without over-resection
    - Prevents hollowing and A-frame deformity
  - Fat repositioning
    - Transposes fat over the orbital rim into the tear trough (preperiosteal or subperiosteal planes)
    - Smooths lid-cheek junction and restores volume
- Pearls/pitfalls:
  - Canthopexy: reinforces lateral canthal tendon; prevents lid malposition
    - Recommended in patients with marginal laxity or negative vector
  - Orbital fat grafting: augments hollowed tear trough or midface
    - May be autologous (fat) or synthetic (fillers); complements volume preservation
- Complications and prevention:
  - Retrobulbar hematoma:
    - Emergency vision-threatening complication due to orbital compartment syndrome
    - Signs: sudden pain, vision loss, proptosis, afferent pupillary defect
    - Avoid by maintaining meticulous hemostasis; treat emergently with lateral canthotomy/cantholysis
  - Ectropion and scleral show:
    - Results from excessive skin removal, scarring, or poor support
    - Prevent by conservative excision and performing canthopexy when needed
  - Lagophthalmos:
    - Inability to close eyelids due to over-resection or scarring
    - Prevent with careful tissue handling and pre-operative evaluation of eye closure

Figure 4. The above image demonstrates the effects of a lower blepharoplasty with fat pad resection. *From Miranda SG, Codner MA. Micro Free Orbital Fat Grafts to the Tear Trough Deformity During Lower Blepharoplasty. Plast Reconstr Surg. 2017 Jun;139(6):1335-1343.*

MIDDLE THIRD: MIDFACE AND CHEEK AESTHETICS

- Facelift: highly sought-after procedure for patients seeking surgical correction of facial aging, especially in the lower two-thirds of the face and neck
  - Common indications:
    - Jowling and loss of mandibular definition
    - Deep nasolabial folds and marionette lines
    - Laxity of the lower face and platysmal bands
    - Midface descent (may be addressed with extended SMAS or deep plane)
    - Redundant skin and fat in the neck

- Anatomy review:
    - Facial soft tissue layers (Mendelson's 5-layer model): skin, subcutaneous fat, SMAS (Superficial Musculoaponeurotic System), loose areolar tissue (glide plane for deep plane dissection), deep fascia and periosteum
    - Facial retaining ligaments:
        - Zygomatic, mandibular, and masseteric ligaments must be released to mobilize facial tissues
        - Ligaments anchor the soft tissues to deeper structures
    - Facial nerve branches:
        - At risk during deep dissections, especially the marginal mandibular (most common symptomatic motor nerve injury), buccal, and temporal branches
        - The facial nerve generally lies deep to the SMAS in early dissection zones
        - Knowledge of danger zones minimizes nerve injury
    - Vascular supply:
        - Preserve subdermal plexus and facial artery branches for flap viability
        - Avoid excessive tension and wide undermining to minimize hematoma and necrosis
- SMAS facelift (Fig. 5):
    - SMAS anatomy:
        - Organized fibrous network inclusive of the platysma muscle, parotid fascia, and fibromuscular layer overlying the cheek
        - Separates the deep and superficial adipose layers of the face.
        - Continuous with platysma (inferiorly) and temporoparietal fascia (superiorly)
        - Structural layer for lifting soft tissues in SMAS plication, imbrication, or extended flap techniques
    - SMAS manipulation:
        - SMAS plication: imbrication of the SMAS to itself or deeper fascia without formally elevating a separate SMAS flap
        - SMASectomy: resection of an oblique strip of SMAS (usually from posterior border of mandible to malar prominence) with primary approximation of SMAS edges; allows skin and SMAS to be manipulated along different vectors
    - Pearls/pitfalls:
        - Undermine adequately, but conservatively
        - Perform multivector SMAS elevation (vertical for midface, horizontal for jowls)
        - Avoid overdissection, which can devascularize the skin or increase seroma risk
        - Anchor the SMAS to strong, immobile structures (e.g., parotid fascia, zygomatic arch periosteum)
        - Avoid placing tension on the skin—lift on the SMAS, redrape the skin passively
        - Control hemostasis meticulously; hematoma is the most common complication
            - Check for bleeding before closure, especially in hypertensive patients
- Deep plane facelift:
    - Relevant anatomy:
        - Operates below the SMAS, in what is often referred to as the ‘gliding plane'
            - Dissection principally involves 1) mobilization of the deep fat compartments, and 2) release of the retaining ligaments
        - Deep fat compartments:
            - Deep medial cheek fat: key target for midface lift in deep plane
            - Mobilized with SMAS and skin en bloc
            - Releasing its tethering ligaments allows elevation of nasolabial fold and malar region
        - Retaining ligaments:
            - Zygomatic cutaneous ligament (McGregor's patch): tethers SMAS to zygomatic arch
            - Masseteric cutaneous ligament: over the anterior edge of the masseter

Figure 5. The above images demonstrate the postoperative changes seen in a SMAS facelift at 5 months and 11 years. *From Liu TS, Owsley JQ. Long-term results of face lift surgery: patient photographs compared with patient satisfaction ratings. Plast Reconstr Surg. 2012 Jan;129(1):253-262.*

        - Mandibular ligament: defines the jowl and lower border
        - Parotid cutaneous ligaments: limit lateral skin movement
    - Facial nerve branches
        - Buccal and zygomatic branches: travel within the deep plane, initially deep to the deep fascia and become more superficial as they traverse toward the mimetic muscles
        - Greatest nerve injury risk occurs near the malar region, where the zygomatic branch may course more superficially
        - Preserving deep plane (beneath SMAS) helps protect nerve branches, as they are typically deep to dissection plane in early portions of the surgery
- Key surgical steps:
    1. Lift skin and enter the deep plane
        - A small amount of skin is lifted to expose the layer under the facial muscles (SMAS), which is then entered to access the deep plane below
    2. Release ligaments and mobilize the tissue
        - Key retaining ligaments are released to free up the midface and jowls, allowing them to be lifted more naturally
    3. Lift and fix the tissue
        - SMAS and deep tissues (along with some overlying fat and skin) are lifted together and secured in a higher position to restore youthful contour
    4. Re-drape the skin and close the incisions
        - Excess skin is trimmed without tension, then the incisions are closed with care to hide scars and preserve natural anatomy

- Pearls/pitfalls:
    - Facial nerve injury is the most feared complication associated with deep plane facelifts; careful dissection is key to success
- Endoscopic facelift:
  - Indications:
    - Ideal in patients without significant skin redundancy
    - Brow ptosis (often combined with endoscopic brow lift)
    - Patients with good skin tone, minimal excess skin
    - Patients desiring midface rejuvenation without visible scars
  - Surgical approach:
    - Incisions: small (~1.5-2 cm) hidden incisions in the temporal hairline and preauricular/postauricular scalp
    - Endoscopic dissection: using a camera and instruments, subperiosteal or sub-SMAS dissection is performed
      - Focused on midface, brow, and malar fat pad
    - Ligament release: key retaining ligaments are released to allow tissue mobilization
    - Tissue suspension: elevation and fixation of soft tissues to the deep temporal fascia or bone using sutures, screws, or Endotines™
    - Closure: incisions are closed with minimal scarring
  - Pearls/pitfalls:
    - Ideal for younger patients with early midface descent and good skin elasticity
    - Allows precise lifting of the midface and brow with minimal scarring
    - Subperiosteal plane protects nerves and allows safe ligament release
    - Limited skin laxity correction — not ideal for older patients with excess skin
    - Technically demanding; requires specialized instrumentation and training
    - Risk of temporary nerve weakness, especially temporal branch injury if dissection is too superficial
    - Fixation failure can lead to loss of result if tissues aren't securely anchored

LOWER THIRD: JAWLINE AND NECK REJUVENATION

- Lower third aging patterns:
  - Jowls
    - Sagging of facial tissue below the mandibular border due to ptosis of the buccal fat pad and lower cheek soft tissues, creating a disrupted jawline and pre-jowl sulcus
    - Caused by loss of skin elasticity, weakening of mandibular retaining ligaments, and volume descent
  - Jawline descent
    - Progressive blunting and softening of the mandibular contour as tissues descend below the bony border
    - Aggravated by laxity of the SMAS, descent of deep fat compartments, and skin redundancy
  - Neck laxity
    - Combination of skin redundancy, platysmal banding, and accumulation of subcutaneous or subplatysmal fat, resulting in a "turkey neck" or obtuse cervicomental angle
    - Can be isolated or extend from facial aging and is central to neck rejuvenation goals
- Relevant neck anatomy:
  - Platysma: superficial neck muscle arising from the clavicle and inserting into the lower face (mandible, modiolus, SMAS)
    - With aging, its medial borders separate, forming visible platysmal bands; it is often manipulated or sutured during neck lift procedures (e.g., corset platysmaplasty) (Fig. 6)

- Subplatysmal fat: deep fat located beneath the platysma, distinct from superficial cervical fat; may contribute to fullness or blunting of the neck angle
    - Often requires direct excision during more invasive neck lifts; not accessible via liposuction
- Submandibular glands: paired salivary glands located beneath the mandible, just deep to the platysma and anterior digastric muscles
    - Prominent submandibular glands can impair neck contour, and in select cases may require partial excision or suspension during rejuvenation procedures

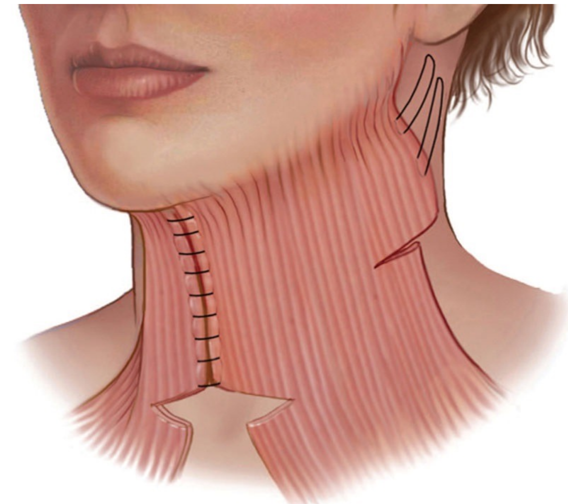

Figure 6. The above illustration demonstrates the platysma work that can be involved in a neck lift. *From Narasimham K, Stuzin JM, Rohrich RJ. Five-step neck lift: integrating anatomy with clinical practice to optimize results. Plast Reconstr Surg. 2013 Aug;132(2):339-350.*

- Surgical approaches to neck lift (Fig. 7):
    - Cervicoplasty (skin-only neck lift):
        - Excision of redundant neck skin without manipulation of platysma or fat
        - Indication: patients with skin laxity and good underlying muscle tone
        - Limitations: does not correct platysmal bands or deep submental fat
        - Incisions: often combined with facelift incisions or performed via a submental approach
    - Platysmaplasty (anterior neck lift):
        - Tightening or resection of medial platysmal bands, often via a submental incision
        - Can involve:
            - Midline approximation (corset platysmaplasty)
            - Partial resection of medial platysma
        - Indication: prominent platysmal banding, central neck laxity, or blunted cervicomental angle
    - Submental liposuction or lipectomy:
        - Suction or direct excision of subcutaneous and/or subplatysmal fat through a small submental incision
        - Indication: excess fat in the submental area with good skin elasticity
        - Often combined with platysmaplasty or skin tightening procedures
    - Lateral neck lift or lateral platysma suspension
        - Definition: tightening of lateral platysma and neck skin through preauricular and postauricular incisions
        - Indication: lower face and neck laxity, jawline softening, and jowling
        - Can be used as an isolated procedure or as part of lower facelift
    - Composite or deep plane neck lift:
        - Elevation of skin, platysma, and deep neck fat as a unit, often with ligament release
        - Indication: advanced neck aging, platysmal bands, deep fat compartments, and skeletal deficiency
        - Often includes digastric muscle contouring, subplatysmal fat resection, and submandibular gland management
        - May involve a deep cervical dissection for full contour restoration
    - Extended neck lift with submandibular gland contouring:
        - Traditional neck lift techniques plus exposure, partial excision, or suspension of submandibular glands
        - Indication: patients with bulky or low-positioned submandibular glands causing contour deformity
        - Requires careful planning due to bleeding and salivary complications

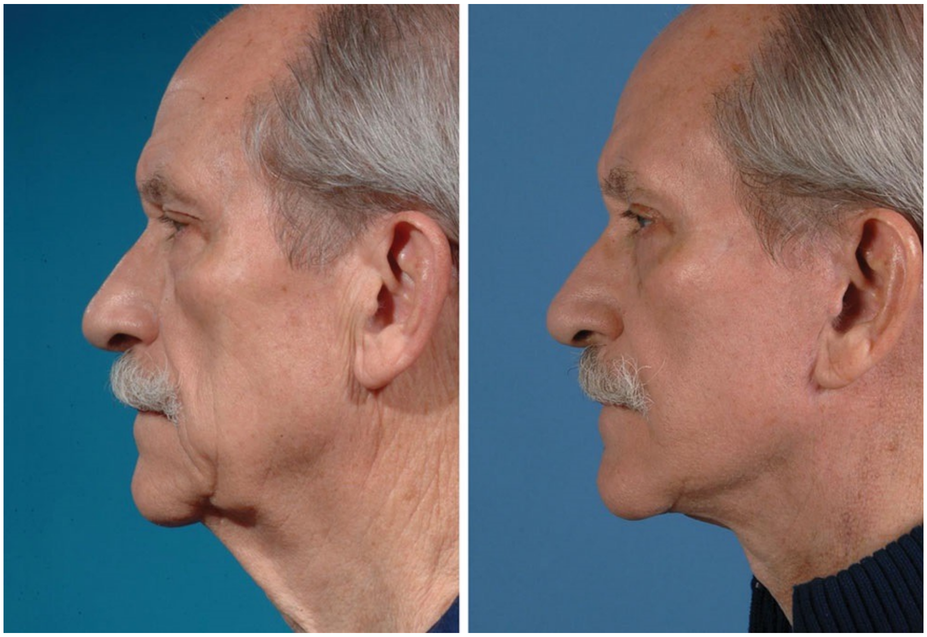

Figure 7. The above images depict before and 2.5 years after a neck lift procedure. *From Narasimham K, Stuzin JM, Rohrich RJ. Five-step neck lift: integrating anatomy with clinical practice to optimize results. Plast Reconstr Surg. 2013 Aug;132(2):339-350.*

- Non-surgical options/adjuncts (described in more detail in Chapter 24):
    - Deoxycholic acid (Kybella®): injectable treatment that permanently reduces submental fat by lysing fat cells; best for patients with mild to moderate fullness and good skin elasticity
    - RF and ultrasound-based skin tightening: devices like Thermage®, FaceTite®, and Ultherapy® use thermal energy to stimulate collagen production and skin contraction, offering subtle improvement in mild skin laxity
    - Jawline contouring with fillers and neuromodulators: dermal fillers enhance jawline definition and neuromodulators (e.g., Botox®) reduce platysmal banding, providing temporary, non-invasive refinement of the lower face and neck contour

RHINOPLASTY

- Goals:
    - Aesthetic: improve nasal shape, size, and symmetry in harmony with the face; refining the dorsum, tip, and overall proportions
    - Functional: preserve or improve nasal airflow by maintaining valve patency, septal alignment, and internal nasal structure integrity
    - Successful rhinoplasty balances beauty and breathing
- Surface analysis and facial proportions:
    - Facial analysis evaluates how the nose fits into vertical facial thirds and horizontal fifths, and its proportions to key landmarks (Fig. 8):
        - Ideal nasofrontal angle: 115-130°
        - Ideal nasolabial angle: ~90-105° (men more acute angle vs. women)
        - Ideal nasal length: ~0.67 × midface height
        - Surface exam includes dorsal contour, tip definition, alar base width, columellar show
- Nasal anatomy:
    - Upper third: nasal bones and radix
        - Nasal bones form the upper bony vault; over-resection may cause inverted-V deformity (when upper lateral cartilage becomes detached from nasal bones)
        - Radix is the nasion’s soft tissue depth; adjusting it alters dorsal profile and nasal root harmony

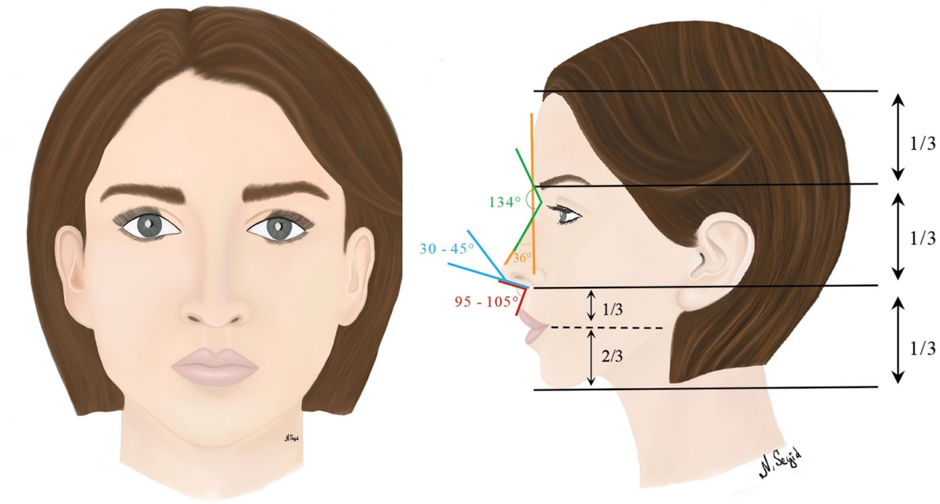

Figure 8. The above image demonstrates the relationship of the nose to the face in aesthetic facial proportions. *From Boustany AN, et al. Cosmetic Rhinoplasty. Plast Reconstr Surg. 2023 Feb 1;151(2):315e-329e.*

- Middle third: upper lateral cartilages, internal valve
  - Upper lateral cartilages articulate with the nasal bones and septum
  - Internal nasal valve is the narrowest segment (between septum and ULCs at ~10-15°)
    - Collapse here is a major cause of nasal obstruction; spreader grafts help restore patency
- Lower third: tip cartilages, external valve
  - Lower lateral (alar) cartilages divided into medial, intermediate, and lateral crura
  - External valve includes the alar rim and nostril opening; key for airflow and tip shape
  - Precise control of tip projection, rotation, and support depends on these structures

- Septum and turbinates:
  - Nasal septum is both a structural support and source of graft material
  - Septal deviation can cause airflow obstruction and tip asymmetry
  - Inferior turbinates modulate airflow and humidification; reduction may be needed in select patients
  - Septoplasty is often combined with cosmetic rhinoplasty to improve function
- Nasal subunits:
  - Nine anatomic subunits of distinct contour, skin quality, and aesthetic boundary; help guide reconstructive planning, especially in skin cancer surgery and scar placement
    - Nasal dorsum
    - Right and left nasal sidewalls
    - Nasal tip
    - Columella
    - Right and left alae
    - Right and left soft triangles
  - If >50% of a subunit is lost, complete subunit reconstruction is preferred to camouflage scars in natural borders
    - This principle ensures that contour and shadow are restored and avoids a patchwork appearance
- Surgical approaches:
  - Open (external):
    - Definition: involves a transcolumellar incision with full elevation of the nasal skin to expose underlying cartilage and bone
    - Indications: precise tip work, complex revision cases, grafting, asymmetry correction

    - Advantages: direct visualization of anatomy; facilitates complex maneuvers and structural grafting
    - Disadvantages: small visible scar; longer postoperative edema
- Closed (endonasal):
    - Definition: all incisions are made within the nostrils, without external scarring
    - Indications: minor dorsal hump removal, subtle tip refinement, primary cases with good anatomy
    - Advantages: no external scar; faster recovery; less swelling.
    - Disadvantages: limited exposure; more difficult for complex or revision cases
- Preservation rhinoplasty (emerging technique):
    - Definition: seeks to preserve native dorsal lines, ligamentous attachments, and septal support, rather than resecting and rebuilding
    - Techniques: dorsal preservation, subdorsal septal strip, push-down or let-down maneuvers
    - Advantages: more natural aesthetic; less postoperative swelling
    - Disadvantages:
        - Limited indications – not ideal for severely deviated or revision noses
        - Technical complexity – steep learning curve and precise anatomical demands
        - Unpredictable dorsal outcome – risk of residual hump or contour irregularities
        - Restricted tip modification – less flexibility for major changes in tip projection or rotation
        - Graft placement limitations – difficult to perform structural grafting without disrupting preserved dorsum
- Septoplasty:
    - Purpose: corrects deviations of the nasal septum to improve airflow and provide structural support for cosmetic work
    - Technique: involves mucoperichondrial flap elevation, excision or scoring of deviated cartilage, and preservation of the L-strut (1 cm dorsal and caudal)
    - Relevance: often performed with rhinoplasty to address both functional obstruction and to harvest cartilage for grafting
- Osteotomies:
    - Performed to mobilize and reposition the nasal bones – typically after dorsal hump reduction or to correct bony deviation or excess width
    - “Low-low,” “low-high,” and “double-level” terminology refers to the trajectory and positioning of the lateral osteotomies
        - Terminology is related to the relative dorsal position of the start and end of the osteotomy
    - Low-low osteotomy
        - Pathway: begins low at the piriform aperture and stays low along the nasofacial groove, close to the maxilla
        - Effect: allows maximum medialization of the nasal bones, effective for broad bony dorsum or flattened nasal sidewalls
        - Risks: can increase the risk of bony instability or inward collapse if overdone
        - Best for: wide nasal bones or aggressive narrowing
    - Low-high osteotomy
        - Pathway: begins low near the piriform aperture, then curves high toward the dorsal aspect of the nasal bone
        - Effect: preserves the upper lateral nasal wall, allowing more controlled narrowing with better dorsal aesthetic lines
        - Advantages: lower risk of inverted-V deformity and preserves dorsal support
        - Best for: mild-moderate narrowing or when preservation of the upper bony vault is desired

- Double-level (or double) osteotomy
    - Pathway: involves two cuts – a low lateral cut and a second, higher cut, typically along the ascending process of the maxilla
    - Effect: used for very thick or convex nasal bones that resist movement with a single osteotomy
    - Advantages: improves bony mobilization and reduces the risk of greenstick fractures or incomplete narrowing
    - Best for: thick or S-shaped nasal bones, revision cases, or major bony deviation
- Grafts:
  - Cartilage grafts are frequently utilized in rhinoplasty to help create a durable, aesthetic nose
  - Typically, multiple grafts will be used in one procedure, with the specific type of graft(s) utilizing depending on the needs of the patient
  - Spreader graft: cartilage placed between the septum and upper lateral cartilages to restore or maintain the internal nasal valve angle and dorsal aesthetic lines
  - Columellar strut graft: a structural graft placed between the medial crura of the lower lateral cartilages to support tip projection and rotation
  - Shield graft: a tip-defining graft shaped like a shield to enhance projection and definition of the nasal tip
  - Alar batten graft: a graft placed over the lateral crura or alar rim to correct or prevent external nasal valve collapse
  - Septal extension graft: a graft fixed to the caudal septum to provide a rigid framework for precise control of tip projection and rotation
  - Onlay dorsal graft: a dorsal augmentation graft placed over the nasal dorsum to increase height or correct saddle nose deformity
  - Rim graft: a small graft placed along the alar rim to reinforce the external valve or smooth contour irregularities
  - Spreader flap: an autologous flap created by folding the upper lateral cartilage medially, mimicking the function of spreader grafts without requiring additional graft material
  - Alar rim strut: a thin graft placed along the caudal margin of the lower lateral cartilage to prevent alar retraction or notching
- Allograft vs. autologous rib cartilage
  - Allograft (irradiated cadaveric cartilage): readily available, avoids donor-site morbidity, and is often used for dorsal augmentation or minor structural grafting
    - Higher resorption and warping risk compared to autologous grafts
  - Rib cartilage (autologous costal cartilage): robust, abundant source of graft material for major structural needs in revision or reconstructive rhinoplasty
    - Associated with donor-site morbidity and a risk of warping if not carved precisely
- Revision rhinoplasty (Fig. 9):
  - About 5-15% of rhinoplasty patients seek revision
  - Indications:
    - Persistent aesthetic deformity (e.g., pollybeak, crooked nose, asymmetry)
    - Functional issues (e.g., nasal obstruction, valve collapse)
    - Graft visibility, warping, or displacement
  - Timing:
    - Wait at least 12 months post-primary surgery before performing revision
    - Allows swelling to resolve and scar tissue to mature
  - Common deformities:
    - Pollybeak (supratip fullness due to under-resected cartilage or scar)
    - Inverted-V (middle vault collapse from dorsal over-resection)
    - Alar retraction, pinched tip, asymmetric nostrils, columellar show
  - Grafting is often required

Figure 9. The above images demonstrate the benefits of a well-performed revision rhinoplasty to correct nare deformity, provide tip support, allow tip refinement, and improve breathing. *From Datta S, et al. Nasal Tip Deprojection in Rhinoplasty. Plast Reconstr Surg. 2025 Mar 1;155(3):439-444.*

        - Septal cartilage may no longer be available
            - Alternatives: conchal cartilage, costal cartilage, or irradiated homologous grafts (allograft)
        - Spreader grafts, columellar struts, alar batten grafts, and tip grafts are commonly used
    - Approach:
        - Often requires open rhinoplasty for exposure and precision
        - Careful dissection through scar tissue is critical
        - Must reconstruct support structures, not just reshape the nose
    - Risks:
        - Higher risk of poor healing, infection, scar contracture, or persistent deformity
        - Outcomes may be limited by scar tissue, thin skin, or prior graft failure
    - Pearls:
        - Always assess both functional and aesthetic issues
        - Be conservative in primary cases to reduce need for revision
        - Master nasal anatomy and structural grafting principles
        - Set realistic expectations: revision is more complex and less predictable
- Complications and prevention:
    - Airway compromise
        - Cause: over-resection of the septum, upper lateral cartilages, or inadequate support of the internal nasal valve
        - Prevention:
            - Preserve at least 10 mm of dorsal and caudal septum
            - Use spreader grafts to maintain internal valve angle (~10-15°)
            - Avoid aggressive cephalic trimming of alar cartilages
    - Tip over-reduction:
        - Cause: excessive resection of the lower lateral cartilages, especially the intermediate and lateral crura
        - Results in loss of projection, poor support, bossae, or pinched tip deformity
        - Prevention:
            - Preserve adequate medial and lateral crural length
            - Consider columellar strut, lateral crural strut, or shield grafts for structural support

- Graft warping
    - Cause: autologous costal cartilage undergoing intrinsic tension remodeling after harvest
    - Prevention:
        - Use balanced carving techniques and centered grafts
        - Let grafts "rest" in saline before implantation
        - Consider diced cartilage in fascia (e.g., DCF technique) for dorsal augmentation

COMPREHENSIVE REJUVENATION STRATEGIES

- Combining procedures: sequence, synergy, and safety
    - Sequencing is critical to surgical planning
        - Typically, procedures are performed deep to superficial: e.g., facelift first, then eyelids, followed by skin resurfacing
    - Combining procedures (e.g., facelift + blepharoplasty + fat grafting) can create synergistic results, enhancing global harmony and rejuvenation
    - Safety must be prioritized: cumulative operative time (ideally less than 6-8 h), anesthetic risk, and bleeding potential must be assessed
    - Common combinations:
        - Facelift + neck lift + fat grafting (Fig. 10)
        - Blepharoplasty + brow lift
        - Rhinoplasty + chin augmentation
        - Multimodal approaches often yield more natural and balanced outcomes

Figure 10. The above figure demonstrates the synergistic effect of a face lift with fat grafting. *From Strong AL, et al. Technical Precision with Autologous Fat Grafting for Facial Rejuvenation: A Review of the Evolving Science. Plast Reconstr Surg. 2024 Feb 1;153(2):360-377.*

- Staging versus single-session treatment:
    - Single-session:
        - Advantages: one anesthesia event, unified recovery, patient convenience

        - Disadvantages: longer OR time, increased perioperative risk, less flexibility in managing tissue response
    - Staged approach:
        - Useful in high-risk patients, complex anatomy, or when combining energy-based treatments (e.g., laser resurfacing) with structural surgery
        - Allows tissue healing and objective reassessment before secondary refinement
        - Decision should be individualized based on patient goals, comorbidities, and procedural complexity
- Long-term maintenance and follow-up care:
    - Aesthetic surgery results evolve; follow-up includes:
        - Monitoring for healing, symmetry, scar quality, and recurrence of laxity
        - Discussion of adjunctive nonsurgical maintenance (e.g., neuromodulators, fillers, skincare)
        - Photography at standardized intervals aids in tracking outcomes and setting expectations
    - Patient education on UV protection, weight stability, and aging processes supports long-term results
- Role of photography and documentation
    - Pre-operative and postoperative photographs are essential for:
        - Surgical planning and patient counseling
        - Medico-legal documentation
        - Tracking outcomes over time
    - Should be performed using standardized views, lighting, and positioning.
    - Digital morphing tools may be used to help set expectations, though should be framed with caution

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Chapter 22
Aesthetic Surgery of the Breast

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Aesthetic surgery of the breast aims to create a youthful, pleasing-appearing breast in addition to alteration of size, ptosis, and shape. Techniques include breast reduction, breast augmentation, and mastopexy. Important considerations for all patients include an assessment of their breast history (such as history of breast cancer and mammographic history) and measurements of the breast/chest wall (sternal-notch to nipple, nipple to inframammary fold, inter-nipple distances, breast width, and areolar diameter).

MASTOPEXY

- Goals:
    - Correct breast ptosis through skin re-draping and parenchymal remodeling of the breast to reduce the mismatch between skin and breast tissue
        - Generally minimal volume is removed but can result in a decrease in cup size
    - Place the nipple-areolar complex (NAC) into a more youthful more superior position (Fig. 1)
- Regnault classification of breast ptosis based on two important anatomic landmarks: (1) inframammary fold (IMF) and (2) nipple position
    - Grade I: nipple at level of the IMF
    - Grade II: entire nipple below the level of IMF but not at the lowest point of the breast
    - Grade III: nipple at the lowest point of the breast
    - Pseudoptosis: nipple at the level of IMF but majority of glandular tissue below the level of the IMF (results in increased nipple to IMF distance)

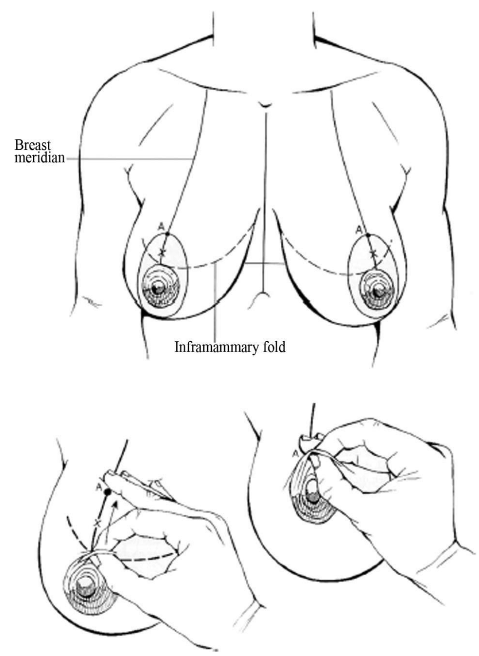

Figure 1. Ideal nipple position is based on its relationship to the inframammary fold. *From Nahabedian MY. Breast deformities & mastopexy. Plast Reconstr Surg 2011 Apr;127(4):91e-102e.*

- Patient concerns:
    - Usually bothered by the "shape" of the breast or size and position of NAC
    - Often report deflation and sagging of breasts.
    - Commonly seen in patients with history of massive weight loss
- Types of mastopexy:
    - Periareolar (circle scar) (Fig. 2)
        - Incision made around areola as an eccentric oval
        - Can be used to raise the nipple up to 2 cm
        - Generally only used for mild ptosis (grade I)
        - Disadvantages: often results in widened periareolar scar, can flatten and de-project the central portion of the breast
    - Circumvertical or vertical (lollipop scar) (Fig. 3)
        - Incision made around the areola, extending down the meridian of the breast towards the IMF
        - Ideal for moderate to severe ptosis without much horizontal skin excess (grade II, III)
        - Usually involves removal of breast skin and underlying tissue from the lower pole of the breast with sutures to bring the medial and lateral pillars of the breast together, supporting the new, elevated position of the NAC

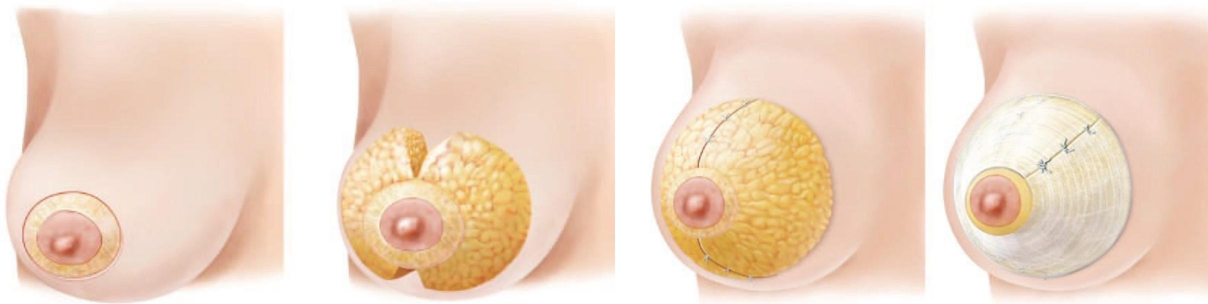

Figure 2. Periareolar mastopexy with mesh support. *From Hidalgo D, Spector J. Mastopexy. Plast Reconst Surg 2013 Oct;132(4)642e-656e.*

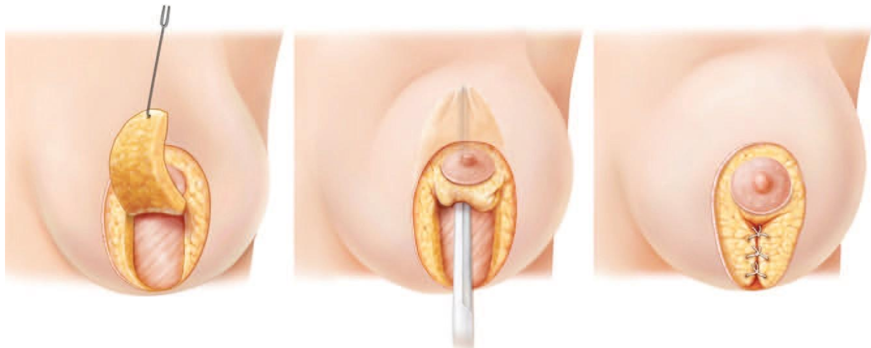

Figure 3. Vertical mastopexy. *From Hidalgo D, Spector J. Mastopexy. Plast Reconst Surg 2013 Oct;132(4)642e-656e.*

    - Disadvantages: may require additional horizontal skin excision if redundant skin does not retract and can result in long nipple to IMF distance
- Wise-pattern (anchor scar) (Fig. 4)
    - Incision made in an "inverted T" shape around the areola, vertically down the breast meridian, and along the IMF towards the medial and lateral edges of the breast
    - Ideal for severe ptosis (grade II, III), patients with significant excess skin or poor skin quality (e.g., massive weight loss patients)
    - Inferior wedge of breast parenchyma can often be sutured under pedicle to pectoralis fascia or used as sling for extra lower pole support
    - Disadvantages: largest scar burden of any mastopexy technique, can lead to "bottoming out" or recurrent ptosis of glandular tissue when used with inferior pedicle

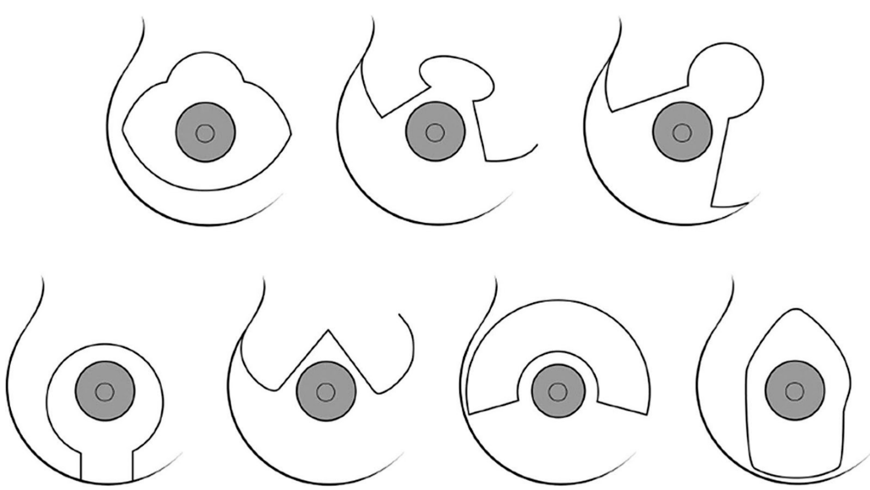

Figure 4. Wise pattern or inverted T mastopexy incision types. *From Nahabedian M. Breast deformities and mastopexy. Plast Reconstr Surg 2011 Apr;127(4):91e-102e.*

AUGMENTATION

- Goals:
    - Increase the size of the breast parenchyma either using the patient's own tissue (autologous) or a prosthetic device (saline or silicone implant)
    - Improve upper breast pole fullness
- Patient concerns:
    - Usually bothered by the size of the breasts or lack of "cleavage" (i.e., sloping of upper pole of breast in clothing, bras)
- Important parameters in pre-operative evaluation:
    - Base width: width of the breast parenchyma on the chest wall
    - Pinch thickness of the upper pole breast skin and subcutaneous tissue
    - Elasticity of skin
    - Baseline chest wall or breast asymmetries (e.g., pectus carinatum, tuberous breast deformity)
- Augmentation with an implant:
    - Implants: can be round or anatomic, smooth or textured, saline or silicone
        - Silicone (more common)
            - Only FDA approved for women 22 years of age and older unless used in reconstruction after mastectomy for cancer
            - More "natural" feel and appearance, come in set sizes and projection profiles, ruptures are difficult to detect
        - Saline
            - FDA approved for women 18 years of age and older
            - Size is more customizable, implants are more prone to rippling, breast deflates with rupture/leak
    - Planes of implant placement: implant should be covered with durable soft tissue, which can include any combination of skin, parenchyma, and muscle.
        - Subglandular: implant placed beneath the breast tissue but above the pectoralis muscle fascia
            - More prone to implant visibility
        - Subfascial: implant placed beneath the pectoralis fascia but above the pectoralis muscle fibers
        - Total subpectoral: implant placed entirely beneath the pectoralis major muscle (Fig. 5)
            - More prone to animation deformity (implant lateralizes during activation of pectoralis muscle)

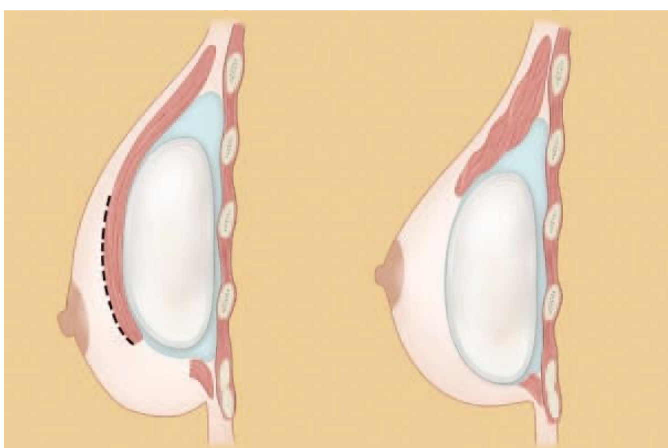

Figure 5. Subpectoral implant placement. Release of pectoralis muscle allows the muscle to rise above the implant. *From Hidalgo D, Spector J. Breast augmentation. Plast Reconst Surg 2014 Apr;133(4):567e-83e.*

        - Dual plane: the upper pole of the implant sits below pectoralis major, while the lower pole of the implant sits in the subglandular plane
            - Achieved through release of the inferior attachments of pectoralis major while preserving medial attachments and release of the glandular tissue from the muscle to varying degrees (type I-III)
    - Incision choices: IMF (most common), periareolar, transaxillary, transumbilical
    - Breast implant-associated anaplastic large cell lymphoma (BIA-ALCL):
        - Associated with textured breast implants
        - An area of evolving research
        - Prevalence estimated to be 30.54 per 100,000 implanted patients with textured implants and 6.70 per 100,000 implanted patients with any type of implant
        - Presents with a delayed seroma
        - Cytology: CD30+ and ALK-
        - Treatment: implant removal and total capsulectomy, possible need for adjuvant treatments such as chemotherapy
            - Requires multidisciplinary team approach including medical oncologist involvement
- Augmentation with autologous tissue:
    - Fat can be harvested through liposuction from another part of the body (i.e., abdomen or thighs) and injected in the various planes of the breast to increase the size of the breast
    - Auto-augmentation:
        - Various flaps can be designed on lateral axillary tissue or adjacent tissue and rotated, advanced or folded onto the existing breast mound to reshape and increase the size of the breast
        - Commonly performed in massive weight loss patients
    - Free tissue transfer: DIEP or msTRAM flaps most common and had traditionally been used in reconstruction after cancer surgery, though still an emerging technique for cosmetic breast surgery
- Mastopexy-augmentation:
    - Combined procedure to both increase the size, improve ptosis, and improve breast shape
    - Very high revision rates (up to 30%)
    - Can be performed in one or two stages
        - Higher rates of revision and malpractice claims for single-stage procedures
- “Internal bra”:
    - Some surgeons use synthetic mesh or acellular dermal matrix during mastopexies and augmentations to provide increased support of the implant in the lower pole of the breast
    - Types of synthetic mesh include P4HB and polydioxanone

BREAST REDUCTION

- Goals:
    - Decrease the size of the breast (has highest rate of patient satisfaction among all plastic surgical procedures)
    - Restore NAC location to a more youthful position
- Patient concerns:
    - Macromastia symptoms: neck, shoulder, or mid-thoracic back pain that has not improved with medications or physical therapy, erythema intertrigo (rashes, moisture, redness) underneath the breasts, hygiene complaints, bra strap grooving, difficulty finding clothing that fits, occasionally hand numbness/tingling
    - Reductions can be performed in asymptomatic patients for cosmetic reasons
- Skin incision patterns and pedicles (portion of breast parenchyma providing blood supply to the nipple areola complex) are the two main considerations in breast reduction and should be determined prior to surgery

- Skin incisions: vertical or Wise pattern (inverted T)
- Basis of pedicles for blood supply to the NAC (Fig. 6):
    - Inferior: 4th intercostal perforator
    - Superior: 1st and 2nd intercostal perforators
    - Superomedial: 2nd intercostal perforator
    - Medial: 2nd or 3rd intercostal perforator
    - Lateral: lateral intercostal perforators
    - Central: musculocutaneous perforators from thoracoacromial artery

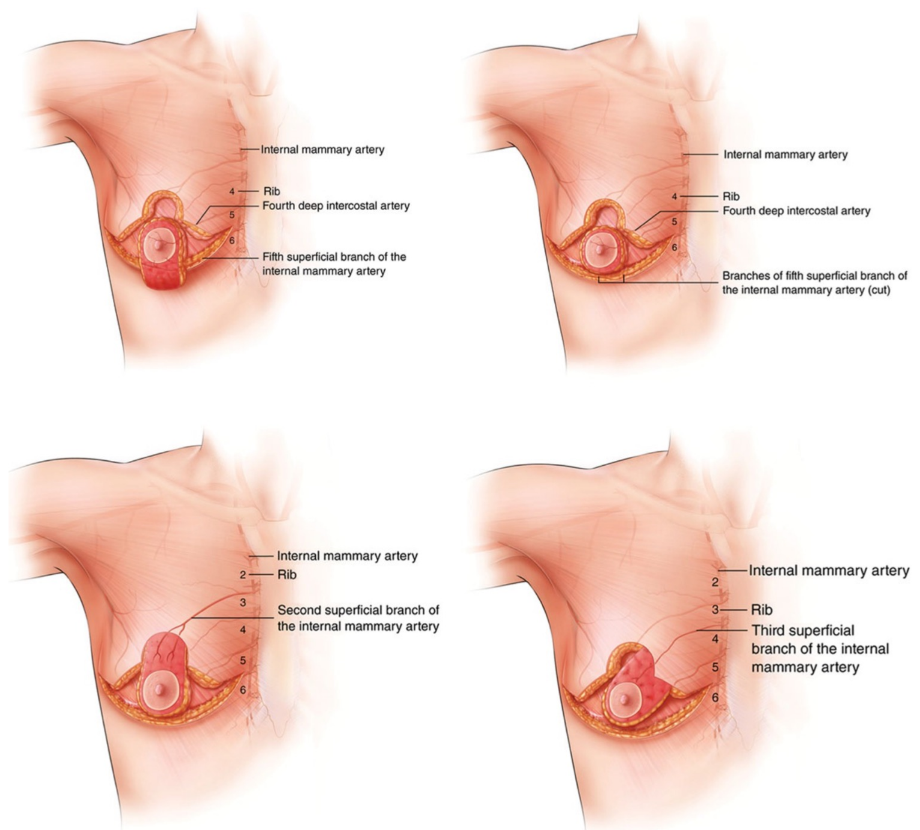

Figure 6. Breast reduction pedicles and their blood supply. *From Hall-Findlay E, Shestak K. Breast Reduction. Plast Reconst Surg 2015 Oct;136(4):531e-44e.*

- Other techniques:
    - Breast amputation with free nipple grafting: for very large and ptotic breasts requiring significant reductions
    - Liposuction: for a small to moderate decrease in breast size in patients with minimal ptosis
- Complications:
    - Loss in ability to breast feed
    - Changes in nipple sensation
    - Hypersensitivity, decreased sensitivity, or no change in sensation
    - NAC necrosis due to inadequate blood supply
        - If a change in color is noted, must release sutures, assess pedicle, etc.
        - If remains ischemic or congested despite intraoperative maneuvers, an option includes converting the nipple to a free nipple graft with similar principles to skin grafting for survival
        - Medications such as nitropaste can help in cases of venous congestion, but can systemic effects for the patient (hypotension, syncope, headache)

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Chapter 23
Body Contouring

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Omar E. Beidas, MD

Body contouring refers to a comprehensive category of aesthetic procedures designed to reshape and refine the body's silhouette. It encompasses both surgical and non-surgical interventions targeting the trunk and extremities. While traditionally associated with cosmetic enhancement, body contouring is increasingly recognized for its role in individuals who have undergone massive weight loss.

Procedures can be done in isolation or in combination. Procedures include skin excision, liposuction, and an expanding array of non-invasive technologies such as cryolipolysis and dermal tightening. Together, these tools are used to restore proportionality, reduce excess tissue, and help patients achieve functional and aesthetic balance in alignment with their personal goals.

PRINCIPLES OF BODY CONTOURING AFTER MASSIVE WEIGHT LOSS (MWL)

- MWL: commonly defined as a loss of 50% or more of excess body weight.
    - Typically seen following bariatric surgery, sustained lifestyle interventions, or with the help of GLP-1 medications. Clinically, MWL is associated with significant changes in skin elasticity, subcutaneous tissue volume, and musculoskeletal support, often leading to functional impairments and aesthetic deformities that require surgical correction.
- Physiology of skin and fat after MWL: Loss of dermal elasticity and subcutaneous fat leads to deflated, inelastic skin with poor recoil
- Patterns of skin redundancy: predictable zones of excess skin develop based on weight loss trajectory — common areas include face, arms, breasts, abdomen, flanks, and thighs
- Psychosocial and quality of life considerations: excess skin can impair mobility, body image, intimacy, and contribute to depression or social withdrawal
- Insurance coverage and criteria for medical necessity: coverage often requires documentation of rashes, infections, or functional interference, with stable weight thresholds
- Comorbidities: array of comorbidities to be mindful of when assessing MWL patient for body contouring procedures; most common conditions and associated investigations/recommendations listed below
    - Obesity/weight stability: BMI (target ≤32 kg/m²), history of weight regain
    - Diabetes: glycemic control (HbA1c), infection and wound-healing risk
    - Nutritional deficiencies: evaluate protein, micronutrients (A, D, B12, iron, zinc), supplement history
    - Cardiovascular/COPD: frailty index, mFI-5 score, METS, pulmonary/cardiac clearance
    - Clotting history/disorders: assess risk of DVT/PE; implement VTE prophylaxis
    - Nicotine use status: nicotine increases infection/wound dehiscence risk; advise cessation
    - Psychosocial health: screen for depression, body dysmorphia, unrealistic expectations

PRE-OPERATIVE EVALUATION AND PLANNING

- History and physical exam:
    - Assess prior weight loss method, stability, and comorbidities.
    - On exam, evaluate skin quality (elasticity, striae), fat distribution, presence of surgical scars, and check for hernias or abdominal wall defects that may require repair
- Pre-operative markings and photography:
    - Detailed markings are made in standing position to guide incision planning and symmetry
    - Standardized pre-op photography documents baseline deformity and supports insurance authorization

- Nutritional optimization (albumin, smoking cessation):
  - Ensure serum albumin >3.5 g/dL for wound healing
  - Screen for micronutrient deficiencies
  - Nicotine cessation is essential for at least 4-6 weeks pre-op to reduce flap necrosis and wound dehiscence risk
- Multidisciplinary coordination:
  - Coordinate with PCP, nutrition, bariatric surgery and mental health providers to confirm medical stability, optimize metabolic status, and ensure realistic expectations and psychological readiness for body image changes
- Risk stratification:
  - Use tools like the Caprini score to assess VTE risk
  - Develop a DVT prophylaxis plan, including sequential compression devices (SCDs), chemoprophylaxis (e.g., heparin), and early ambulation strategies tailored to the patient's score and comorbidities

NONINVASIVE BODY CONTOURING TECHNIQUES

There exist several noninvasive procedures that may be utilized in helping patients achieve an aesthetic result when seeking body contouring. These techniques are described in more detail in Chapter 24.

LIPOSUCTION

Classic liposuction utilizes a cannula and vacuum to remove subcutaneous fat. It's widely used for localized fat removal in 'stubborn' areas. Desirable results require good skin elasticity and patient selection.

- Cannulas and technologies
  - Cannula types by tip design:
    - Mercedes: triple hole along the circumference of the cannula
    - Triport: triple hole along one side of the cannula
    - Basket tip: blunt, rounded tip with multiple circumferential fenestrations
    - Spatula tip: blunt tip for delicate areas (face, neck)
    - Exploded tip: most aggressive
  - Cannula diameter:
    - Microcannulas (≤2 mm): for superficial contouring or facial liposuction
    - Standard (3-4 mm): used in body contouring procedures
    - Large bore (≥5 mm): for bulk removal in non-aesthetic zones (less common today)
  - Cannula shape:
    - Straight: most common; suitable for uniform fat planes
    - Curved/angled: useful for access under the inframammary fold, flanks, or submental area
  - Power types:
    - Power-assisted liposuction (PAL): vibrating cannula facilitates faster fat removal, reduces surgeon fatigue
    - Ultrasound-assisted liposuction (UAL): utilizes ultrasound-induced cavitation to emulsify fat; effective in fibrous areas, may reduce blood loss
    - LASER-assisted lipolysis (LAL): uses laser to liquefy fat and stimulate collagen; improves skin tightening but may carry higher burn or scarring risk
- Safety and fluid management:
  - Tumescent
    - Infiltration of large volumes of epinephrine solution with or without lidocaine
    - Provides anesthesia and vasoconstriction; enhances safety, minimizes blood loss
    - Considered the gold standard for large-volume liposuction under local anesthesia

    - Below is a table outlining the various degrees of fluid infiltration that can be pursued, with tumescent the most common for large body contouring procedures and dry ill-advisable due to otherwise avoidable blood loss (Table 1)

Table 1. Liposuction technique		
Technique	Ratio of infiltrate to lipoaspirate	Risks/complications
Dry	No fluid	Heavy bleeding; not advised
Wet	100-300 cc per site	Blood loss
Superwet	1:1	Lidocaine toxicity (low risk)
Tumescent	3:1	Lidocaine toxicity Fluid overload/pulmonary edema in large-volume cases

  - Lidocaine dosing and toxicity:
    - Safe tumescent lidocaine doses: up to 35 mg/kg, with low systemic toxicity; peak plasma levels depend on infiltration rate.
    - Monitoring required; rare systemic toxicity if guidelines are followed
    - If performing > 5L of lipoaspirate, special formulas are used for IV resuscitation
    - Overnight monitoring is recommended when more than 5 L of lipoaspirate is retrieved
- Indications and limitations:
  - Optimal for localized fat in patients with good skin elasticity and near-ideal body weight
  - Not indicated for treating skin redundancy—does not remove excess skin
  - Adjunctive technologies (UAL, LAL, PAL) can enhance outcomes but still require proper skin tone
- Technique:
  - Patient preparation and marking:
    - Pre-operative markings are performed with the patient standing to define areas of contour irregularity, fat accumulation, and planned aspiration zones
    - Markings should consider natural fat compartments, aesthetic units, and danger zones (e.g., lateral femoral cutaneous nerve path)
    - Infiltration of tumescent solution is typically performed using a peristaltic or pressure pump, and care is taken to allow sufficient time for vasoconstriction prior to suction
  - Incisions and access sites:
    - Small stab incisions (~2-3 mm) are placed in hidden areas to allow multiple trajectories for the cannula, minimizing visible scarring
    - A skin protector may be inserted at each incision site to reduce friction and trauma
  - Cannula insertion:
    - Cannulas are introduced through access sites using a cross-tunneling technique to ensure even fat removal and prevent step-offs or contour irregularities
  - Fan pattern movement:
    - Cannula is moved in a radial "fan-shaped" pattern from each incision point, with smooth reciprocating motions
    - Liposuction is performed in layers, beginning in the deep plane, progressing toward the superficial subcutaneous layer, avoiding injury to dermis or muscle fascia
  - End-point determination:
    - Surgeons judge adequacy of fat removal by observing skin pliability, resistance, and contour symmetry, supplemented by intraoperative palpation and visualization
- High-definition liposuction (Fig. 1):
  - Targets both deep and superficial fat layers to sculpt muscular contours and enhance definition, such as the “six-pack” abs or the V-shaped torso

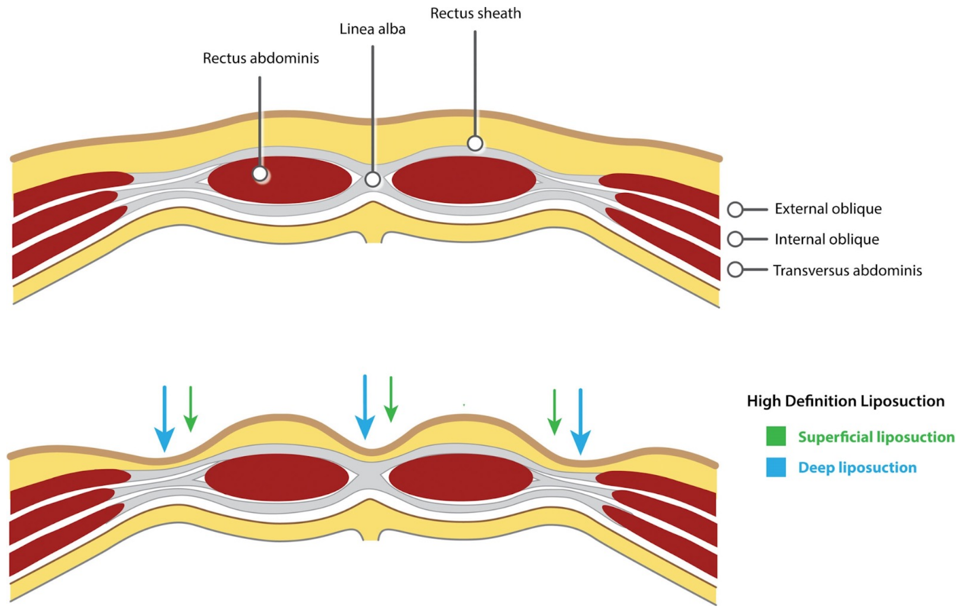

Figure 1. Cross-section of abdomen demonstrating the effect of HDL on linea semilunaris and linea alba. Similar effects can be achieved in areas of tendinous intersection to create muscle definition. *From Willet JW, et al. A Systematic Review of Efficacy and Complications of High-Definition Liposuction. Plast Reconstr Surg. 2023 Jul 1;152(1):57-63.*

        - Often incorporates energy-assisted modalities (e.g., VASER ultrasound) and fat grafting for volume restoration in specific areas
    - Ideal candidates: BMI <30, good skin elasticity, realistic expectations.
    - Operative technique:
        - Pre-operative markings to delineate zones for deep debulking ("negative spaces") and superficial definition
        - Multi-layered liposuction: deep first, then superficial to sculpt fine detail
        - Optional fat grafting to enhance muscular contours (e.g., pecs, deltoids, gluteals)
        - Often performed using VASER or other energy-assisted devices for precision and reduced trauma
- Complications:
    - Contour irregularities and asymmetry: common in areas with fibrous attachments; precise technique essential
    - Seroma formation: fluid accumulation managed with drainage or compression; leaving incision slightly open may aid drainage
    - Fat embolism: rare but life-threatening; more common in large-volume procedures or gluteal augmentation
    - Other risks: burns (especially with UAL/LAL), fluid overload or imbalance, infection, skin necrosis, sensory changes
- Post-op care essentials:
    - Compression garments: reduce swelling, promote contour.
    - Drainage/incision management: leave small openings or suction to prevent seromas
    - Monitor fluid balance: vital in high-volume sessions
    - Follow-up appointments: early detection of complications like embolism or hematoma
    - Patient education: emphasize realistic expectations, skin tone limitations, and wound care

EXCISIONAL PROCEDURES BY ANATOMIC REGION

I. Trunk

- Variety of body contouring procedures available to patients depending on the distribution of their excess skin and aesthetic goals

- Panniculectomy: excision of the pannus (overhanging abdominal skin and fat)
    - Indications: symptomatic pannus (e.g., intertrigo, hygiene issues, immobility); often covered by insurance
    - Operative steps: transverse elliptical skin excision below the umbilicus; umbilicus may be preserved or removed; no rectus plication or aesthetic contouring
    - Recovery: 2–4 weeks; longer if pannus was large; compression garment use encouraged
    - Complications: wound dehiscence, seroma, infection, delayed healing
    - Pearls: ideal for functional improvement, not aesthetics; stable weight (≥6 months) and BMI <35 improve outcomes
- Abdominoplasty: removal of excess abdominal skin with rectus plication and umbilical transposition for aesthetic contouring (Fig. 2)
    - Indications: abdominal laxity, diastasis recti, and excess skin/fat in patients with good general health and weight stability.
    - Operative steps: low transverse incision, flap elevation to xiphoid, rectus muscle plication, umbilical repositioning, skin re-draping
    - Recovery: 2–4 weeks; earlier ambulation encouraged; no lifting for 4–6 weeks
    - Complications: seroma, hematoma, umbilical necrosis, contour irregularity
    - Pearls: drainless approaches use progressive tension sutures; good skin quality = better result

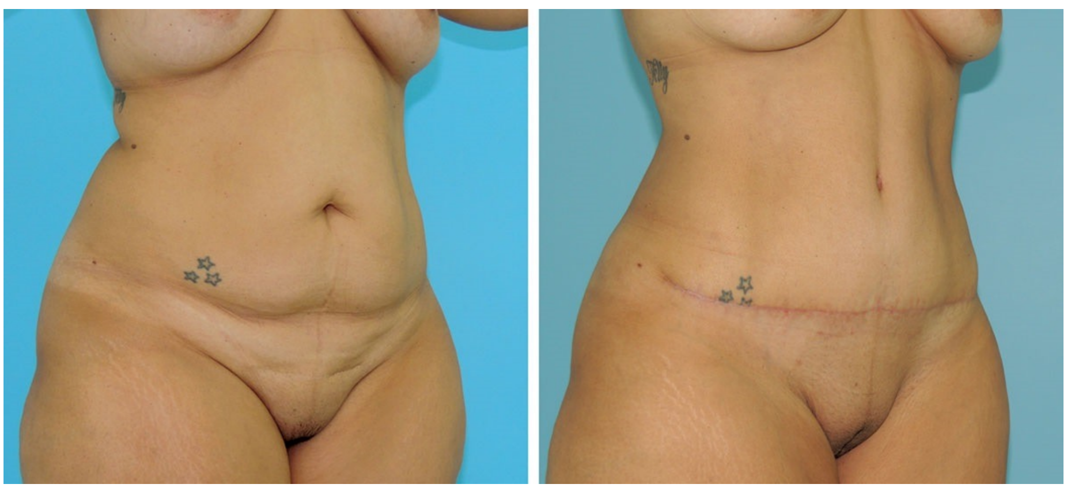

Figure 2. The above image demonstrates a classic abdominoplasty before and after, with noticeable improvement in waist contour and flattening of the abdomen with plication of the rectus abdominus muscle. *From Saldanha O, et al. Lipoabdominoplasty with Anatomical Definition. Plast Reconstr Surg. 2020 Oct;146(4):766-777.*

- Reverse abdominoplasty: removal of excess skin from the upper abdomen
    - Indications: excess skin of upper abdomen
    - Operative steps: incision in inframammary fold of breast, often connects across midline sternum, skin lifted and excised
    - Recovery: 2-4 weeks
    - Complications: seroma, hematoma, upwards pull of belly button
    - Pearls: cannot be combined with traditional tummy tuck in same stage due to risk of vascular compromise
- Fleur-de-lis panniculectomy/abdominoplasty (Fig. 3):
    - Indications: excess vertical laxity in the abdomen that would not be sufficiently addressed with a transverse-only incision; serves as a modification to the traditional panniculectomy/abdominoplasty
    - Operative steps: elevation of lateral skin flaps with elliptical incision of medial excess tissue

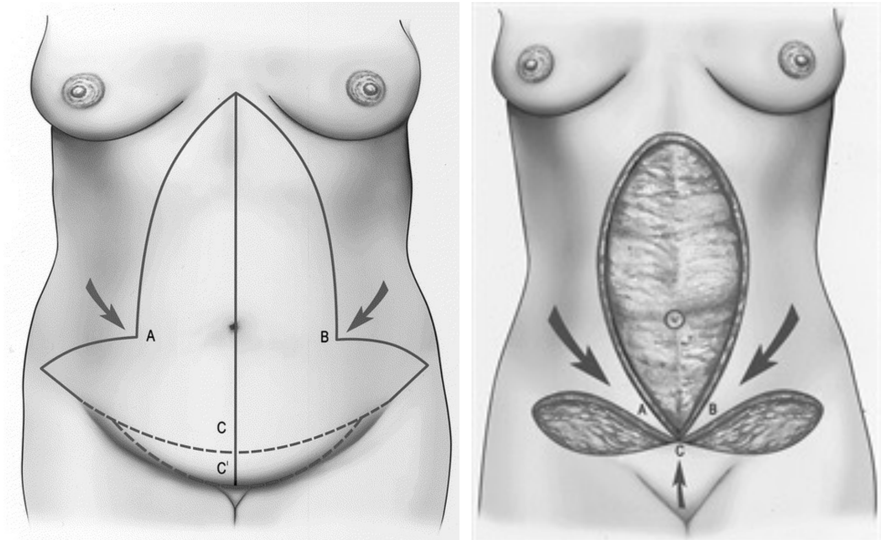

Figure 3. The above schematics demonstrates the markings and subsequent skin excision for an FDL abdominoplasty. *From Fernando da Costa L, Landecker A, Marinho Manta A. Optimizing Body Contour in Massive Weight Loss Patients: The Modified Vertical Abdominoplasty. Plast Reconstr Surg. 2004 Dec;114(7):1917-23.*

        - May also require release of fascial bands in cases of 'double apron' belly where thick fascial attachments disallow a smooth contour after skin resection
    - Recovery and complications are similar to abdominoplasty
    - Pearls: careful pre-operative markings and conservative skin flap undermining are key to a successful operation
        - In the case of umbilicus preservation, minimize tension on the closure to prevent vertical distortion along the vertical scar
- Monsplasty: elevation and excision of redundant mons pubis tissue
    - Indication: ptotic mons pubis is often unmasked or worsened after abdominal pannus removal
    - Operative steps: after appropriate excision of excess skin/adiposity, the mons is lifted
        - Securing the skin flap to the rectus fascia or pubic symphysis periosteum using sutures ensures cephalad repositioning and tension-free closure
    - Complications: similar to those in an abdominoplasty, most notably scar widening, wound dehiscence, or skin necrosis if too much undermining or closure under excessive tension
    - Pearls: often incorporated into abdominoplasty for a complete result
- Circumferential lower body lift: 360° excision of skin and fat from abdomen, flanks, outer thighs, back, and buttocks; repositions tissues both anteriorly and posteriorly
    - Indications: global truncal skin laxity following massive weight loss; redundant lower back, outer thigh, and buttock skin
    - Operative steps: posterior and anterior incisions connected laterally; abdominoplasty, lateral thigh lift, and buttock reshaping; performed prone-to-supine (can be staged)
    - Recovery: 2-4 weeks; increased pain and wound burden; limited sitting initially
    - Complications: wound breakdown, seroma, posterior scar tension, buttock flattening
    - Pearls: preserve and reshape buttock projection; address scar placement to avoid visible high-riding scars
- Upper back lift: resection of upper back rolls, bra-line folds, and lateral chest wall skin
    - Also known as 'bra lift', as scar is hidden in bra line in women
    - Indications: lateral thoracic or upper back skin redundancy
    - Operative steps: excision along bra line; direct closure with tension re-distributed
    - Recovery: 2–3 weeks; avoid heavy lifting; compression garment recommended.
    - Complications: scar visibility, tension-related dehiscence, hypertrophic scars

        - Pearls: proper pre-op marking in upright position critical; align scar with bra line or desired garment concealment
    - Buttock lift: elevation and reshaping of the gluteal region via skin excision and re-draping; often included in lower body lift
        - Indications: sagging buttocks, skin laxity over gluteal region, often after MWL
        - Operative steps: crescent or elliptical excision over superior buttocks; deep fixation to fascia; preserve fat pads to avoid flattening
        - Recovery: 3-4 weeks; avoid prolonged sitting; scar across upper buttock may be visible in swimwear
        - Complications: buttock flattening, wide scars, delayed wound healing
        - Pearls: consider fat grafting or flap preservation techniques to maintain volume and contour

II. Breast

A detailed review on aesthetic breast surgery can be found in Chapter 22. While these breast procedures are also classified as body contouring procedures, in this chapter we will describe them as they relate to the MWL patient population, who often experience unique challenges in achieving a satisfying aesthetic result.

- Evaluation of the MWL breast:
    - Patients will have:
        - Loss of parenchymal volume
        - Severe ptosis (Grade II-III)
        - Deflated upper pole with stretched skin envelope
        - Lateral chest wall rolls
        - Lack of IMF support
        - Medialized nipple
    - Goals include restoring shape, projection, symmetry, and volume – often requiring combinatorial techniques
    - Patient history:
        - Weight loss history: degree of loss, time since weight stabilization (ideally ≥6 months), bariatric surgery history, nutritional supplementation
        - Breast history: prior surgery, radiation, breastfeeding, or trauma
        - Symptoms: physical discomfort (e.g., neck/back pain), intertrigo under the breasts, dissatisfaction with shape or volume
    - Physical examination:
        - Skin quality:
            - Evaluate for elasticity, striae, thinness, and redundancy
            - MWL skin is often inelastic and prone to poor recoil – impacts longevity of results
        - Volume assessment:
            - Is there true hypertrophy or parenchymal deflation?
            - Palpate for residual breast tissue vs. fat; consider imaging if needed
        - Degree of ptosis (NAC position):
            - Grade I–III ptosis (Regnault classification)
            - Measure sternal notch to nipple distance, inframammary fold (IMF) position, and nipple to IMF distance
        - Breast footprint and shape:
            - Note base width, projection, and upper vs. lower pole fullness
            - Identify lateral chest wall rolls or axillary excess that may require additional excision
        - Asymmetry:
            - Document pre-existing asymmetry in size, shape, or nipple position

- Mastopexy (breast lift):
    - Indication: moderate-to-severe ptosis with adequate native volume
    - Technique: skin envelope reshaping via vertical, Wise-pattern, or crescent/lollipop incisions, with parenchymal reshaping
    - MWL consideration:
        - Skin often lacks elasticity; high recurrence of ptosis without internal support
        - Consider dermal suspension or mesh reinforcement
- Augmentation-mastopexy:
    - Indication: ptosis + volume loss (especially upper pole fullness)
    - Technique: combines mastopexy with implant placement; may be staged or performed in one operation
    - MWL consideration:
        - Thin tissue envelope increases implant visibility and risk of complications
        - Staging (mastopexy first, augmentation later) may reduce risks in severe cases
        - Reinforcement (e.g., mesh) helpful
- Dermal suspension auto-augmentation (Fig. 4):
    - Indication: deflated ptotic breast with sufficient inferior pole tissue
    - Technique: central flap of breast tissue is deepithelialized and folded to auto-augment volume, anchored to the chest wall (e.g., Dr. Peter Rubin's technique, autologous internal bra techniques)
    - MWL consideration:
        - Excellent option to avoid implants
        - Allows auto-projection with durable result if skin quality is adequate
        - May need to combine with lateral chest wall excision or bra-line lift

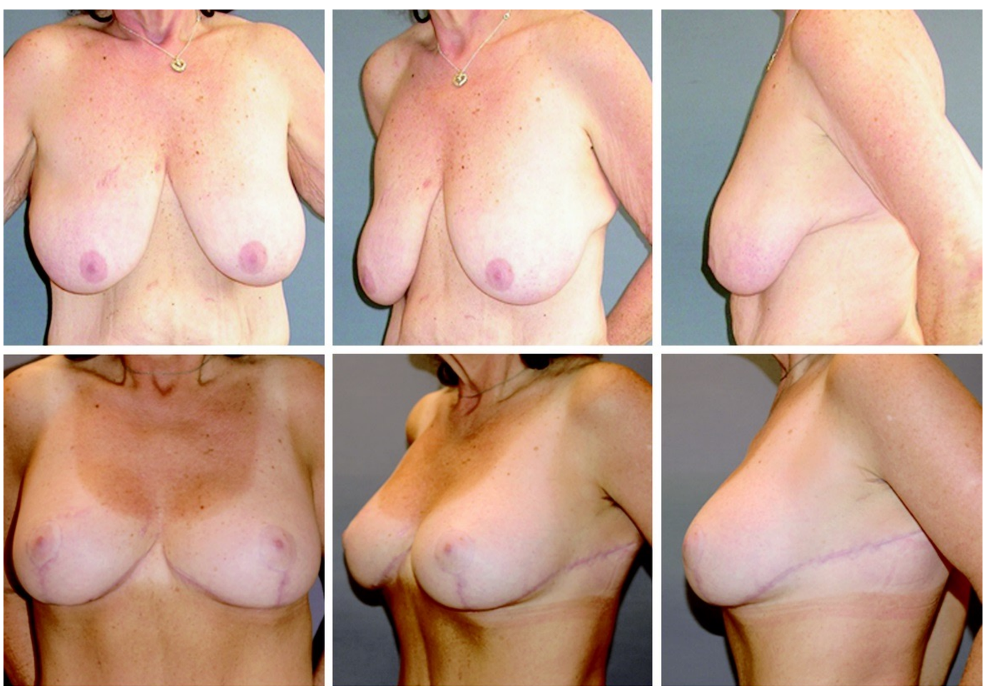

Figure 4. The above patient underwent a dermal suspension auto-augmentation after a 130-lb weight loss. *From Rubin JP, Gusenoff JA, Coon D. Dermal suspension and parenchymal reshaping mastopexy after massive weight loss: statistical analysis with concomitant procedures from a prospective registry. Plast Reconstr Surg. 2009 Mar;123(3):782-789.*

- Reduction mammaplasty:
    - Indication: macromastia, desires smaller breast size
    - Technique: removal of glandular tissue and skin; reshaping of parenchyma and repositioning of nipple

- MWL consideration:
    - Patients may have deflated tissue, not true hypertrophy—assess carefully
    - May require volume preservation rather than reduction
    - Lateral extensions or rolls may need separate excision (axilloplasty or bra-line lift)

III. Arms

MWL patients may have excess skin in the upper extremity. This excess skin can be bothersome and unsightly. There are several incision patterns for skin excision of the upper extremity, each with a unique target patient demographic.

- Standard medial brachioplasty:
    - Indications:
        - Moderate to severe upper arm skin laxity, commonly seen after MWL
        - Redundant tissue in the upper third to half of the arm
        - Patients typically willing to “trade skin for scar”
    - Basic steps:
        - Medial incision from axilla to medial epicondyle
        - Skin and subcutaneous tissue excised en bloc or via skin flaps
        - Deep dermal sutures and layered closure
        - Optional liposuction for contouring before or after skin excision
    - Drain:
        - May be used or avoided (surgeon preference)
        - Used more often in MWL patients or high-volume resections, although surgeons are trending away from them
        - Not necessary in small cases with hemostasis and progressive tension sutures.
    - Recovery:
        - 2–3 weeks for return to light activity; full healing over 6 weeks
        - Compression garment recommended for 3-6 weeks
        - Avoid heavy lifting initially
    - Pearls:
        - Mark with patient standing and arms abducted 90°
        - Keep incision along medial bicipital groove to reduce visible scarring
        - Preserve medial antebrachial cutaneous nerve (MABC) – injury can cause sensory deficits
        - Avoid aggressive undermining to reduce seroma risk
- Posterior brachioplasty (Fig. 5):
    - Indications: moderate to severe laxity with preference for scar hidden in posterior arm position
    - Basic steps:
        - Incision placed along posterior arm (over triceps groove)
        - Skin and soft tissue resected as per medial approach, but plane shifted posteriorly
        - Closure and management as per medial technique
    - Pearls:
        - Scar can be visible from behind patient in arms-down posture
        - Careful positioning during closure is important to avoid dog-ears or lateral bunching
        - Avoid over-resection that may tether posterior deltoid area
- Extended brachioplasty:
    - Indications:
        - Severe skin laxity of upper arm and lateral chest wall (bra roll, axillary fold)
        - MWL patients with extensive upper torso skin excess

Figure 5. A 46-year-old patient with a body mass index 24.4 kg/m2 (48-kg weight loss following sleeve gastrectomy). (Left) Pre-operative views. (Right) One-year postoperative views. *From Simone P, et al. Postbariatric Brachioplasty with Posteromedial Scar: Physical Model, Technical Refinements, and Clinical Outcomes. Plast Reconstr Surg. 2018 Feb;141(2):344-353.*

- Basic steps:
    - Incision begins at elbow, traverses medial or posterior upper arm, and extends across axilla to lateral chest wall
    - May include back or breast contouring procedures in combination
    - Wide undermining often required laterally
- Pearls:
    - Must address lateral chest fold in continuity to avoid dog-ear and contour distortion
    - Carefully position lateral scar to fall beneath bra line or natural skin fold
    - Higher risk of delayed wound healing, particularly in axilla
    - Scar burden is greater—patient counseling is key
    - Watch for lymphatic disruption in axillary region

- Short-scar brachioplasty (crescent or transverse axillary):
    - Indications:
        - Mild skin laxity confined to proximal upper arm
        - Good candidates with localized axillary excess and excellent skin quality
    - Basic steps:
        - Crescent-shaped or transverse excision confined to axillary fold
        - Limited undermining; skin re-draped and closed with suspension sutures to axillary fascia
    - Pearls:
        - Less dramatic improvement; not appropriate for MWL patients
        - Good option for younger, fit patients concerned about visible scars
        - Watch for scar migration or hypertrophy in axilla

IV. Thighs

MWL patients often suffer from excess skin in the thighs that is best addressed with a thighplasty (sometimes referred to as 'thigh lifts' colloquially). Thighplasty must be tailored to the pattern and severity of skin excess (vertical, horizontal, circumferential) and may involve medial, spiral, lateral, or combined approaches. Proper patient selection and expectation management are key due to the relatively high complication and scar burden.

- Thighplasties carry a high visible scar burden with a range of aesthetic improvements, but are nonetheless commonly performed and praised for the following benefits:
    - Restores proportion and silhouette: balances lower body aesthetics with concurrent trunk or upper body procedures
    - Improves function and hygiene: reduces friction, moisture retention, and intertrigo in the medial thigh
    - Enhances mobility: removes bulky, pendulous skin that may impair walking or exercise
    - Complements global reshaping: often performed after or with lower body lift, abdominoplasty, or buttock lift to achieve cohesive results
    - Addresses psychosocial concerns: improves body image, clothing fit, and self-esteem in post-MWL patients
- Horizontal (inguinal crescent) thighplasty:
    - Indications: mild to moderate excess in upper third of medial thigh
    - Technique: crescent excision placed in inguinal crease, with fixation to Colles' fascia to prevent scar migration
    - Pearls:
        - Best for patients with vertical skin laxity only
        - Anchor flap to deep fascia to prevent labial distortion or scar descent
        - Risk of wound dehiscence if tension is high or anchoring inadequate
- Vertical medial thighplasty (Fig. 6):
    - Indications: moderate to severe horizontal laxity along inner thigh, often extending to the knee
    - Technique: longitudinal excision from groin to above knee, usually along medial thigh
    - Pearls:
        - Good for MWL patients with "curtain-like" vertical redundancy
        - Scar is visible; patient counseling is key
        - Avoid femoral triangle to preserve lymphatics and prevent lymphedema

Figure 6. The above photos depict intraoperative markings, skin resection, and closure for a medial vertical thighplasty. *From Schmidt M, et al. Concomitant Liposuction Reduces Complications of Vertical Medial Thigh Lift in Massive Weight Loss Patients. Plast Reconstr Surg. 2016 Jun;137(6):1748-1757.*

- Combined (T- or L-Shaped) medial thighplasty
    - Indications: combined horizontal and vertical skin excess (common in MWL)
    - Technique: combines horizontal (inguinal) and vertical (medial thigh) excisions; forms T or L shape
    - Pearls:
        - T-pattern preferred for more symmetric tension distribution
        - Increased scar burden, but better contour in severe deformities
        - May combine with liposuction for improved outcome
- Spiral thighplasty:
    - Indications: circumferential thigh skin laxity, including anterior, posterior, and lateral thigh; especially in MWL patients

- Technique: oblique spiral excision that lifts the thigh circumferentially, often integrated with buttock or lower body lift
    - Pearls:
        - Targets 360° laxity, not just the medial aspect
        - Often part of posterior body lift procedures
        - Requires experience in flap tension control and scar placement over visible areas (posterolateral thigh)
- Lateral thighplasty:
    - Indications: significant lateral thigh and hip skin laxity, often in MWL patients
    - Technique: incision along the iliac crest or lateral thigh, often extending from the buttock or posterior lift incision
    - Pearls:
        - Often performed with circumferential body lift or extended abdominoplasty
        - Improves outer thigh contour and buttock lift synergy
        - Scar placement should follow natural gluteal-lateral crease to minimize visibility

LIPEDEMA

Lipoedema is a chronic, progressive adipofascial disorder characterized by the symmetrical deposition of pathologic adipose tissue predominantly affecting the lower extremities and, in some cases, the arms. Unlike generalized obesity, lipedema spares the hands and feet, and is often resistant to diet and exercise. The condition primarily affects women and may be hormonally mediated, with onset frequently around puberty, pregnancy, or menopause.

Lipedema remains significantly underdiagnosed and is frequently misclassified as simple obesity or lymphedema, leading to delays in appropriate treatment; ongoing research aims to clarify its distinct pathophysiology, diagnostic criteria, and optimal management strategies.

- Diagnosis: clinical diagnosis based on history and physical examination
    - Symmetrical enlargement of the lower extremities, sparing the feet
    - Tenderness to palpation, easy bruising, negative Stemmer sign (unlike lymphedema)
    - Disproportion between trunk and limb girth (Fig. 7)

Figure 7. Contour deformity of the ankle in lipedema. The excess subcutaneous fat seen in the lower leg ceases abruptly at the level of the malleoli, sparing the feet and leading to a ring-like appearance of the ankle. *From Warren AG, et al. Evaluation and management of the fat leg syndrome. Plast Reconstr Surg. 2007 Jan;119(1):9e-15e.*

    - Progressive nature, with worsening pain, mobility issues, and secondary lymphedema in advanced stages
- Staging: typically based on cutaneous and fascial changes
    I. Smooth skin surface, thickened subcutaneous tissue with palpable nodules
    II. Uneven skin surface, larger nodules and lobules, fibrosis begins
    III. Significant deformity, lipomas, and redundant overhanging tissue
    IV. Lipo-lymphedema: Coexisting secondary lymphedema and fibrosis
- Treatment:
    - Conservative management:
        - Compression therapy

- Manual lymphatic drainage (MLD)
- Exercise and anti-inflammatory nutrition
- Does not reduce the pathologic adipose tissue; for patients with significant symptom burden or deformity, liposuction is the only evidence-supported intervention to reduce limb volume and improve quality of life

- Surgical management:
  - Tumescent liposuction (particularly power-assisted and water-assisted variants) is the most studied and preferred method for surgical treatment (Fig. 8)
    - Compared to traditional liposuction, these modalities preserve lymphatic structures and reduce long-term complications

Figure 8. Before and after photos of multi-stage liposuction for advanced stage lipedema. *From Kruppa P, et al. A 10-Year Retrospective before-and-after Study of Lipedema Surgery: Patient-Reported Lipedema-Associated Symptom Improvement after Multistage Liposuction. Plast Reconstr Surg. 2022 Mar 1;149(3):529e-541e.*

  - Indications: pain, limited mobility, cosmetic deformity, psychosocial distress
  - Contraindications: uncontrolled comorbidities, active infection, or unrealistic expectations
  - Operative considerations:
    - Staged procedures are common due to the extensive surface are
    - General or tumescent local anesthesia may be used
    - In advanced-stage lipedema (particularly Stage III-IV) or in patients with significant skin redundancy following prior liposuction or weight loss, adjunctive skin excision procedures may be required to optimize functional and aesthetic outcomes
    - Long-term compression garments are recommended postoperatively
    - Avoid energy-based liposuction (e.g., ultrasound, laser) which may increase lymphatic injury risk
  - Outcomes and complications
    - Numerous studies report improvement in pain, function, and cosmetic appearance with a low complication rate when lymphatic-sparing techniques are employed
    - Risks include seroma, infection, skin laxity, and transient sensory changes
  - Pearls
    - Distinguish from obesity and lymphedema; misdiagnosis is common
    - Psychological support is critical; many patients report prior medical dismissal
    - Lipedema is often under-recognized – early intervention improves outcomes

STAGING AND COMBINING PROCEDURES

- In cases of massive weight loss or situations where patients otherwise have various areas they'd like addressed, staging body contouring may be necessary
- Many surgeons follow the principle of only operating on either the upper or lower extremities at any given time
- Timing between procedures is ultimately at the discretion of the operating surgeon, but generally speaking, it is wise to wait until the scars from the first stage are well-healing, at a minimum of 3 months post-operatively
- The decision to stage a procedure should take into consideration the anticipated time under anesthesia and the necessity of an overnight stay

POST-OPERATIVE CARE AND COMPLICATIONS

The below guidelines are generic and should be tailored according to the procedure(s) being performed, as well as the specific needs of the patient.

- Compression garments:
    - Purpose: reduce edema, support tissues, minimize seroma, and improve contour adherence
    - Duration: typically worn 24/7 for 4-6 weeks, then tapered
    - Pearl: should be snug but not cause skin folds, ischemia, or nerve compression
- Wound care and seroma prevention:
    - Wound care: keep incisions clean and dry; remove sutures/drains per protocol; monitor for signs of infection or dehiscence
    - Seroma prevention:
        - Use progressive tension sutures and limited undermining to obliterate dead space
        - Closed suction drains may be placed; typically removed when output is <30 mL/24 hrs for 2 consecutive days
        - Liposuction-assisted techniques reduce seroma risk in thighplasty and abdominoplasty
- DVT prophylaxis and early ambulation:
    - Risk stratification: use Caprini score to guide prophylaxis
    - Pharmacologic prophylaxis: LMWH or heparin for moderate-high risk patients (especially in MWL)
    - Mechanical measures: SCDs during and after surgery
    - Ambulation: Initiate within 12-24 hours post-op to reduce VTE risk
- Scar management:
    - Typically should start at 3 weeks postoperatively
    - Silicone gel/sheets to reduce hypertrophy
    - Sun protection for at least 6-12 months
    - Massage to improve pliability
    - Hypertrophic risk is higher in MWL patients, with the exact etiology not fully elucidated but often attributed to tension, scar positioning, or skin quality
- Patient education: expectations and healing
    - Timeline: major swelling resolves in 6 weeks; full results take 3-6 months, scars mature over years
    - Realistic outcomes: emphasize function over perfection, and potential need for revisions
    - Early concerns: numbness, firmness, asymmetry are common and often improve
    - Follow-up: regular visits for wound check, drain removal, scar monitoring, and reassurance

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Chapter 24
Injectables, Lasers, and Non-Invasive Procedures

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FOUNDATIONS OF NON-SURGICAL AESTHETIC MEDICINE

Interest and pursuit of aesthetic noninvasive procedures has steadily increased as patients seek more holistic and longitudinal means to achieving a youthful, healthy look. Patient evaluation is key to selecting the appropriate treatments for patients, noting that both surgical and non-surgical options exist, and some patients may benefit from just one, while others may benefit from both. Patient evaluation should include ethnic, gender, and age-specific considerations. All patients should undergo standardized photography and expectation management as a part of their evaluation.

SKIN CARE

- While initially thought to be outside the world of plastic surgery practice, skincare is of growing interest to plastic surgeons for many reasons, including:
  - Improved skin quality in the perioperative/peri-procedure period
  - Addressing patient concerns that are mistakenly identified as helped by more invasive procedures
- Commonly recommended skincare products
  - Cleansers
    - Ingredients: gentle, non-soap surfactants
    - Purpose: cleanse without disrupting skin barrier
  - Exfoliants
    - Ingredients: AHAs (glycolic, lactic), BHAs (salicylic)
    - Purpose: improve skin texture and unclog pores
  - Retinoids
    - Ingredients: retinol (OTC), tretinoin (rx), adapalene
    - Purpose: boost collagen, reduce fine lines and pigmentation
  - Antioxidants
    - Ingredients: vitamin C (L-ascorbic acid), ferulic acid
    - Purpose: neutralize free radicals, brighten complexion
  - Pigment regulators
    - Ingredients: hydroquinone (rx), tranexamic acid, niacinamide
    - Purpose: treat melasma, post-inflammatory hyperpigmentation (PIH), uneven skin tone
  - Moisturizers
    - Ingredients: ceramides, hyaluronic acid, glycerin
    - Purpose: repair skin barrier, maintain hydration
  - Sunscreens (broad-spectrum)
    - Ingredients: zinc oxide, titanium dioxide, Mexoryl SX
    - Purpose: protect against UV-induced aging and pigmentation
- While the individual needs of patients will vary, it is generally agreed upon that some combination of the above skincare will help promote healthy, youthful skin and improved procedural outcomes when pursued
- Skin care is a crucial step in a patient's facial aesthetics and is key to optimizing outcomes in both non-surgical and surgical facial procedures

NEUROMODULATORS

- Purpose: to paralyze specific muscles, resulting in decreased rhytids (wrinkles)

- Mechanism of action: botulinum toxin A inhibits acetylcholine release at the NMJ, resulting in flaccid paralysis of the targeted muscle due to impaired neuromuscular transmission
- Number of units needed will vary depending on the patient
- FDA-approved uses and injection patterns:
  - Glabella ("11" lines): 5-point pattern: procerus (1), corrugators (2 each side); deep intramuscular injection
  - Forehead rhytids: superficial intramuscular or subdermal injections in frontalis; dose adjusted to preserve brow position
  - Lateral canthal lines: 3-point fan lateral to orbital rim; superficial injection; avoid zygomatic muscles
- Off-label uses and injection patterns with average doses:
  - Masseter hypertrophy: 2–3 deep injections into masseter body per side; avoid parotid duct and facial artery (Fig. 1)

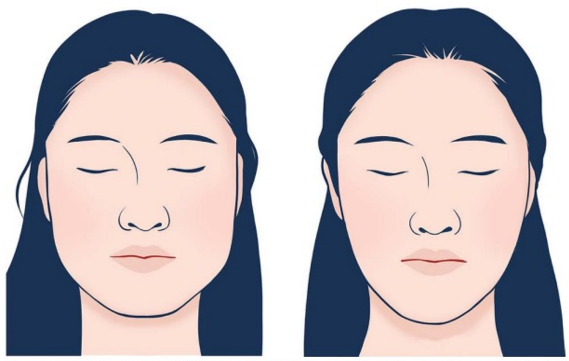

Figure 1. Left, hypertrophied temporalis and masseter muscles. Right, contoured facial line after botulinum neurotoxin treatment. *From Yi K, et al. Guidelines for Botulinum Neurotoxin Injection for Facial Contouring. Plast Reconstr Surg. 2022 Sep 1;150(3):562e-571e.*

  - Gummy smile: 1-2 units per side to levator labii superioris alaeque nasi; superficial injection.
  - Platysmal banding: multiple small aliquots injected directly into visible bands; avoid diffusion into deeper neck structures
  - Bunny lines: 1-2 units per side into nasalis muscle; superficial along upper nasal sidewall
  - Perioral lines: 0.5–1 unit per site intradermally around upper/lower vermilion border; avoid lip incompetence.
  - Brow lift/asymmetry: small dose (1-2 units) in lateral frontalis just above brow peak; avoid overt ptosis
  - Nasal tip rotation: 1-2 units into depressor septi nasi at columellar base; may aid tip elevation
  - Nefertiti lift: series of injections along lower jawline and upper platysma; targets downward pull and defines mandibular border
- Various neuromodulator agents on the market (Table 1)
- Individual results will vary, with it being well-understood that those individuals receiving long-term neuromodulator treatment will likely have increased tolerance requiring higher doses to achieve a similar effect
  - Men tend to require higher doses to achieve the same therapeutic effect as women, as do those who are more 'expressive' than others
  - Best practice dictates that patients are counselled and closely monitored for therapeutic effect, with changes in dose occurring slowly over time to accommodate for desired mobility
- Emerging trends:
  - "Microbotox" or "baby Botox": involves multiple microdroplet injections of highly diluted botulinum toxin into the superficial dermis, targeting fine lines, pore size, and skin texture without compromising facial movement

Table 1. Available neuromodulator agents					
Agent	Onset	Full Effect	Duration	Diffusion	Special characteristics
Botox™	3–5 days	7-14 days	3-4 months	Moderate (reference standard)	Longest established formulation with broad FDA approvals
Dysport™	2-3 days	7-10 days	3-4 months	High (greater than Botox)	Dose conversion Dysport:Botox is ~4:1U
Xeomin™	3–5 days	7-14 days	3-4 months	Moderate	Free of accessory proteins ("naked toxin"), potentially lowering antibody/immune response risk
Jeuveau™	3-5 days	7-14 days	3-4 months	Moderate	Launched in 2019 as a "modern cosmetic" alternative; FDA-approved for glabellar (frown) lines
Daxxify™	1-2 days	2 days	6 months	Low (less than Botox)	Vegan, free of animal/human serum proteins

    - Ideal for patients seeking subtle, natural-looking results with preserved expression.
- Sebaceous suppression: intradermal microinjections of diluted botulinum toxin ("microbotox") have been shown to reduce sebum production by inhibiting acetylcholine-mediated stimulation of sebaceous glands
    - Can lead to smaller pores, less oiliness, and improved skin texture, especially in patients with oily or acne-prone skin
- Rosacea and flushing: may help modulate neurovascular signaling and reduce vasodilation, leading to decreased facial flushing, erythema, and burning sensations
    - Studies have shown that low-dose intradermal doses can calm inflammatory responses in erythematotelangiectatic rosacea
- Scars: when injected early in the healing process, can reduce tension across a wound, inhibit myofibroblast contraction, and limit hypertrophic scarring
    - May also help improve the appearance of existing scars by relaxing surrounding muscle pull and enhancing remodeling

SOFT-TISSUE FILLERS

- Dermal fillers can be categorized into four main types:
    1. Hyaluronic acid (HA) fillers: provide immediate, reversible volumization
    2. Biostimulatory fillers: stimulate collagen production for gradual, long-lasting results
    3. Autologous fillers: fat grafting, derived from the patient's own tissue (i.e., fat grafting)
    4. Allogeneic/homologous fillers: offer structural support and tissue integration from donor-derived materials (i.e., acellular dermal matrices)
- Filler science:
    - Rheology: flow and mechanical behavior of filler in tissue
    - G' (elastic modulus): measures stiffness or ability to resist deformation
        - High G′ fillers are ideal for deep support (e.g., cheeks, jawline)
        - Low G′ for mobile or superficial areas (e.g., lips, perioral lines)
    - Cohesivity: degree to which filler molecules stick together
        - High cohesivity helps maintain shape and resist spreading; important in rhinoplasty or deep bolus areas
    - Viscosity: thickness/resistance to flow through tissue
        - High viscosity aids in volumization; low viscosity spreads easily, suited for fine lines
- Longevity: varies by filler type, crosslinking, injection site, and metabolism:
    - HA fillers: 6-24 months
    - Biostimulatory fillers: 12-36 months
    - Fat grafting: variable, partially permanent

- Reversibility:
    - HA fillers are reversible with hyaluronidase
    - Biostimulatory, autologous, and allogeneic fillers are not reversible; require observation, steroids, or excision for complications
- HA fillers: Juvederm™, Restylane™, Belotero™, RHA™(Table 2)
    - Indications: principally volume replacement, nonsurgical rejuvenation
        - Specific indications depend on the treatment area(s) of interest
    - Mechanism of action: cross-linked HA gel is injected into soft tissue → attracts water and volumizes tissue, supports collagen matrix, and integrates into the dermal or subdermal layers for contour and lift
    - Duration: typically 6-24 months, depending on product properties (e.g., crosslinking, viscosity), treatment area, and individual metabolism
        - Shorter duration in dynamic, mobile areas (e.g., lips)
        - Longer duration in deep structural areas (e.g., cheeks, jawline)

Table 2. Hyaluronic acid filler types

Feature	*Juvederm™*	*Restylane™*	*Belotero Balance™*	*RHA Collection™*
Manufacturer	Allergan (AbbVie)	Galderma	Merz Aesthetics	Revance Aesthetics
Longevity	9-24 months (depending on product)	6-18 months (depending on product)	~6-12 months	~12-15 months
FDA-approved areas	Lips, cheeks, nasolabial folds, chin, under eyes (off-label), jawline	Similar range; Kysse FDA-approved for lips	Moderate lines, tear troughs, perioral lines	Dynamic wrinkles, nasolabial folds, perioral lines
Best known for	Volumizing (e.g., Voluma for cheeks), lip enhancement	Versatile use and natural-looking results	Very fine lines and superficial injections	Natural movement in high-expression areas
Key advantages	Long-lasting with less swelling (Vycross line)	Broad product range; flexible gels	Excellent for superficial fine lines	Designed for dynamic facial movement; resilient
Notable considerations	Can cause more swelling/bruising (Vycross)	Stiffer products can be harder to mold	Best for superficial dermis, less volumizing	Slightly higher cost; newer to U.S. market

- Biostimulatory fillers: Sculptra™ (PLLA), Radiesse™ (CaHA) (Table 3)
    - Indications: volume restoration and collagen induction
    - Mechanism of action: injected particles (PLLA or CaHA) act as foreign-body stimulants, triggering fibroblast activation → neocollagenesis (primarily Type I collagen)
        - Carrier gel provides initial volume (esp. with CaHA), while long-term correction results from endogenous collagen deposition
    - Duration:
        - Sculptra™ (PLLA): ~2-3 years (after a series of treatments)
        - Radiesse™ (CaHA): ~12-18 months for volume; longer-lasting collagen stimulation
            - Results are progressive, peaking over several months
- Autologous: fat grafting (structural fat, nanofat)
    - Structural fat: harvested via liposuction, processed (e.g., centrifuged), and injected in larger particles into deep planes for volume restoration (e.g., cheeks, buttocks, hands)
    - Nanofat: emulsified and filtered fat – no volume effect – used superficially to improve skin quality via stromal vascular fraction (SVF) and growth factors
    - Indications: volume loss, contouring, skin rejuvenation
    - Recovery: variable swelling, bruising; resorption 20-50%
    - Complications: fat necrosis, nodules, overcorrection, oil cysts

Table 3. Biostimulatory filler types		
Feature	Sculptra™ (PLLA)	Radiesse™ (CaHA)
Manufacturer	Galderma	Merz Aesthetics
Active Ingredient	Poly-L-lactic acid (PLLA) *A synthetic polymer that triggers a delayed inflammatory response and collagen synthesis.*	Calcium hydroxylapatite (CaHA) microspheres *Naturally occurring mineral-based microspheres that provide scaffold and stimulate fibroblasts.*
Mechanism of Action	Stimulates fibroblasts to produce new collagen (Type I)	Immediate volumization + collagen stimulation
Onset of Effect	Delayed — results develop gradually over weeks to months	Immediate volume correction + delayed collagen stimulation
Duration	~2-3 years	~12-18 months
Texture / Viscosity	Thin suspension; reconstituted with sterile water; distributes well in large areas	Thick, creamy consistency; suitable for deep structural injection
FDA-Approved Areas	Cheeks, temples, nasolabial folds (not lips or periorbital)	Lower face, nasolabial folds, hands; off-label: cheeks, jawline
Best Known For	Subtle, natural-looking, gradual panfacial volume restoration and collagen boost	Structural contouring (e.g., jawline), hand rejuvenation, and deep volumizing
Key Advantages	Longest-lasting collagen stimulator; excellent for large-volume restoration with natural results	Instant lift with secondary collagen stimulation; provides structure and volume
Notable Considerations	Requires multiple sessions; results not immediate; massage post-treatment essential; risk of nodules	Cannot be used in dynamic/superficial/lip areas; not reversible; risk of lumps if placed superficially

- Allogeneic/homologous:
    - Acellular dermal matrix (ADM)(Alloderm™)
        - Derived from cadaveric human dermis; decellularized to remove antigenic components
        - Used for soft tissue support in facial, breast, and reconstructive surgery (e.g., deep nasolabial folds, lip augmentation, periorbital hollows)
        - Provides a scaffold for cellular ingrowth and tissue integration
        - Implanted surgically or via a tunneling technique
    - Micronized/injectable ECM Products (e.g., Renuva™, micronized Alloderm)
        - Processed to fine particles or injectable suspension
        - Intended to stimulate native fat regeneration and soft tissue fill without donor site morbidity
        - May be used for small volume contour correction or skin quality improvement
        - Recovery: minimal downtime; swelling possible
        - Complications: rare rejection, cost, variable longevity
        - Pearls: Alloderm must be placed deep to avoid palpability; micronized forms are more versatile but do not produce immediate volumization like HA or fat
- Injection techniques
    - Planes of injection of filler will depend on several factors, including:
        - Anatomic area/condition being treated (e.g., midface volume loss may require deep structural support (supraperiosteal), while fine perioral lines need superficial placement (intradermal)
        - Desired effect
            - Lifting and projection → deeper planes
            - Line filling or hydration → more superficial planes
        - Type of filler

        - High G’ fillers (e.g., Voluma™, Lyft™): better suited for deep support
        - Low G’ fillers (e.g., Belotero Balance™, Volbella™): ideal for superficial correction
- Layers of the skin subject to injection:
    - Supraperiosteal: directly on bone, beneath muscle/fat
        - Useful for structural support (e.g., cheeks, chin, jawline)
        - Use high-viscosity filler; low mobility; aspirate to avoid vessels
    - Subcutaneous: between dermis and SMAS layer
        - Useful for moderate-depth volume (e.g., lips, nasolabial folds)
        - Good for contouring and soft volume; beware of vascular anatomy
    - Intradermal: within the dermis (papillary or reticular)
        - Useful for fine lines, skin hydration (e.g., perioral, forehead)
        - Risk of Tyndall effect with improper product choice or technique
- Use of a cannula vs. needle
    - Cannulas have a blunt and rounded tip. They are also longer and more flexible. Their benefit in dermal fillers to minimize bruising and swelling.
    - Needles have sharp and rigid tips. They allow for precise placement of fillers, but carry a higher risk of bruising and potential injury to blood vessels
- Must be mindful of branches of facial artery when injecting into temporal and frontal regions of the face (Fig. 2)

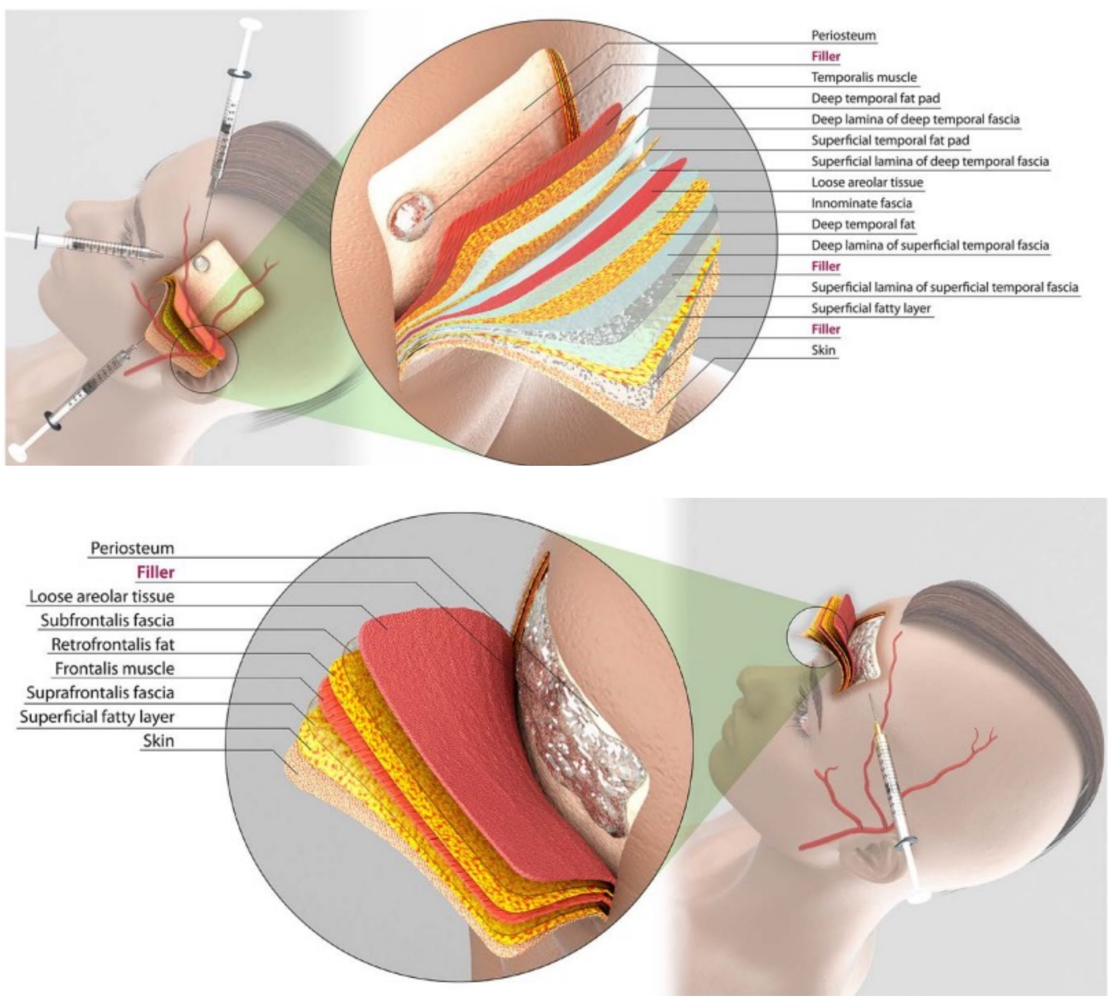

Figure 2. Skin access points for temporal (above) and frontal (below) filler injection techniques. *From Colucci L, Rengifo J. Hyaluronic Acid Filler Usage and Technique for the Facial Upper Third: A Comprehensive Review. Plast Reconstr Surg Glob Open. 2025 Apr 28;13(4):e6668.*

- Common indications for HA filler by facial subunit:
  - Temples: fills hollowing from fat/volume loss; softens contour transition between forehead and lateral face;
    - Inject deep (preferably supraperiosteal) to avoid vascular injury
  - Tear troughs: improves hollowness and shadowing; requires low-viscosity filler with deep supraperiosteal placement
    - High risk of Tyndall effect and swelling
  - Nose: non-surgical rhinoplasty; improves dorsum contour, camouflages humps, refines tip
    - High-risk area; precise technique and aspiration critical to avoid vascular occlusion (esp. dorsal nasal artery)
  - Nasolabial folds: softens static folds by restoring volume in the fold or adjacent cheek; may be treated secondarily after midface support
    - Avoid overfilling to prevent unnatural look
  - Midface/cheeks: restores youthful contour, improves malar projection, supports lower lid and nasolabial fold
    - Deep bolus or layered techniques often used
  - Lips: enhances volume, defines vermilion border, improves symmetry, softens perioral lines
    - Risk of overfilling, migration, and vascular compromise (e.g., labial artery)
  - Chin: enhances projection and length, balances facial thirds, can smooth cleft or dimpling
    - Inject deep on bone, watch for mentalis strain.
  - Jawline: defines mandibular border, improves jowling and contour; high G' fillers placed deep along mandible and gonial angle
    - Avoid parotid duct and marginal mandibular nerve
- Complications and management:
  - Vascular occlusion
    - Inadvertent intravascular injection → arterial blockage → ischemia or necrosis.
    - Early signs: blanching, pain, livedo, reticulated skin.
    - Treatment:
      - Immediate hyaluronidase (150-450 IU per site); repeat hourly if needed; consider ultrasound guidance
    - Warm compress
    - Massage
    - Aspirin
    - Topical nitroglycerin
  - Tyndall effect: from superficial injection, causing bluish discoloration due to light refraction through gel. Common under thin skin (e.g., tear trough).
    - Prevention: correct plane and product selection.
    - Treatment: low-dose hyaluronidase (10-20 IU) or aspiration/removal
  - Granuloma: firm, persistent, delayed nodules due to chronic foreign body reaction (weeks–months later); rare
    - Treatment:
      - Rule out biofilm
    - Hyaluronidase, intralesional steroid (e.g., triamcinolone), ± oral doxycycline or 5-FU
    - Consider biopsy if persistent
  - Delayed hypersensitivity: swelling, erythema, and induration weeks to months later; possibly immune-mediated or triggered by illness/vaccine
    - Treatment:
      - Oral steroids (e.g., prednisone taper), antihistamines
      - May require hyaluronidase in severe cases
      - Rule out infection.
  - Hyaluronidase
    - Function: Enzyme that breaks down hyaluronic acid (both native and filler-derived)
    - Indications: vascular occlusion, overcorrection, nodules, Tyndall effect, uneven results

    - Dosage: ranges from 10 IU (Tyndall) to 450+ IU (vascular compromise); titrated to effect
    - Brands: Vitrase™, Hylenex™, Hyalase™ (regional differences)
    - Contraindications: known allergy to ovine/bovine proteins (some formulations); skin testing optional
    - Caution: may dissolve native HA in surrounding tissue; always consent patient
- Ultrasound-guided safety
    - High-resolution ultrasound is increasingly used in aesthetic practice for:
        - Vessel mapping: to avoid key arteries (e.g., angular, supratrochlear, facial)
        - Real-time guidance: during injection to ensure proper filler plane and avoid vasculature
        - Complication management: localize and target hyaluronidase precisely during vascular events or nodules
    - Benefits:
        - Increases safety in high-risk areas (glabella, nose, tear troughs)
        - Helps visualize vascular occlusion sites for targeted reversal
        - Valuable tool for training and complication management

LASER AND ENERGY-BASED DEVICES

Laser and energy-based devices (EBDs) are used in skin rejuvenation to target chromophores like water, melanin, and hemoglobin, delivering controlled thermal injury that stimulates collagen remodeling, improves texture, and treats pigment or vascular irregularities. They include modalities such as ablative and non-ablative lasers, IPL, RF microneedling, and ultrasound-based tightening, each tailored to specific skin concerns and downtime tolerances.

I. Lasers

- Laser physics simplified
    - Chromophores: molecular targets that absorb specific wavelengths of laser light, converting it into heat for selective photothermolysis.water, melanin, hemoglobin
        - Water:
            - >1,300 nm (esp. 2,940 nm Er:YAG, 10,600 nm CO_2)
            - Dominant in ablative resurfacing; vaporizes tissue, tightens skin
        - Melanin:
            - 400–1,060 nm (e.g., 755 nm Alexandrite, 810 nm Diode)
            - Target for hair removal, lentigines, melasma; caution in darker skin types
        - Hemoglobin:
            - 532 nm (KTP), 585–595 nm (PDL), 1,064 nm (Nd:YAG)
            - Used for vascular lesions (e.g., telangiectasias, rosacea, hemangiomas)
    - Ablative vs. non-ablative; fractional vs. non-fractional (Table 4)

Table 4. Types of laser and energy-based devices

Type	Mechanism	Effect	Recovery
Ablative	Vaporizes epidermis and dermis (targets water)	Resurfacing, collagen remodeling	Moderate to long downtime (5–14+ days)
Nonablative	Heats dermis without breaking skin barrier	Stimulates collagen without ablation	Minimal downtime (0–3 days)
Fractional	Laser delivered in microthermal zones, leaving surrounding tissue intact	Faster healing, fewer complications	Shorter downtime, multiple sessions needed
Nonfractional	Laser delivered to entire skin surface uniformly	More dramatic results, full-field effect	Longer downtime, higher risk of PIH/scarring

- Ablative lasers (Table 5)
  - Target both the epidermis and dermis, using water as the primary chromophore
  - Vaporize superficial skin layers, creating controlled wounds that stimulate a robust healing response
  - Mechanism of action: precise removal of epidermis and partial dermis → collagen remodeling and re-epithelialization
  - Downtime is typically 5–10+ days due to open wounds, crusting, and peeling
  - Often requires topical anesthetic, nerve blocks, or sedation depending on depth
  - Typically 1–2 sessions may achieve substantial results in wrinkle reduction, texture improvement, scarring, and skin tightening
  - Results tend to be more dramatic and longer-lasting than non-ablative options, but with increased risk
  - Higher risk of post-inflammatory hyperpigmentation, especially in Fitzpatrick IV–VI
  - Infection, delayed healing, and scarring are also possible with improper care or technique

Table 5. Ablative lasers

Feature	CO_2 Laser (10,600 nm)	Er:YAG Laser (2,940 nm)	Fractional CO_2	Fractional Er:YAG	Hybrid Laser(e.g., HALO™)
Indications	Deep rhytids, acne scarring, laxity	Fine lines, periorbital/perioral aging	Moderate wrinkles, acne scars	Superficial texture, early signs of aging	Pigment, texture, pores, early laxity
Ideal Patient	Deep photoaging, thick skin	Mild-moderate aging, thin/sensitive skin	Acne scars, photodamage, wrinkles	Light resurfacing, sensitive areas	Early aging signs, pigment + texture combo
Mechanism	Full ablative + thermal coagulation	Full ablative, minimal coagulation	Ablative microcolumns + thermal zones	Ablative microcolumns, minimal heat	Ablative Er:YAG + non-ablative 1470 nm
Recovery Time	7–14 days+ weeks of erythema	3–7 days	3–10 days depending on settings	2–6 days	3–5 days; faster return to makeup and activity
Skin Tightening	Yes – strong collagen remodeling	Mild	Moderate	Mild to moderate	Mild to moderate collagen stimulation
PIH Risk	High (esp. in Fitzpatrick IV–VI)	Low	Moderate	Low	Low; safe in skin types III–IV with caution
Common Brands	*UltraPulse™, SmartXide™, MiXto™*	*Sciton Contour™, Fotona SP Dynamis*	*Fraxel Re:pair™, Alma Pixel CO_2™*	*Sciton ProFractional™, Fotona SP*	*Sciton HALO™, BBL+ combo with Moxi™ optional*

- Non-ablative lasers (Table 6)
  - Target the dermis (water or pigmented structures)
  - No epidermal disruption, so the skin surface remains intact
  - Mechanism of action: controlled thermal injury to dermis → neocollagenesis
  - Downtime is typically minimal (1–3 days of redness or swelling)
  - These procedures are usually well-tolerated with local anesthetic.
  - Typically require multiple sessions (3–6+) for optimal results, which are gradual and include improved tone, texture, and mild tightening over time
  - Risk of PIH is lower in non-ablative than ablative lasers, making it safer for darker skin types

Table 6. Non-ablative lasers			
Laser type	Wavelength	Common devices	Main indications
Diode Laser	1450 nm	SmoothBeam™	Acne, sebaceous glands, fine lines
Nd:YAG (Long Pulse)	1064 nm	Cutera Genesis™, Excel V™, Cynosure Elite	Rosacea, vessels, collagen remodeling
Thulium Laser	1927 nm	Moxi™, Fraxel DUAL™ (fractional)	Pigment, melasma, texture, photoaging
Pulsed Dye Laser (PDL)	585-595 nm	Vbeam Perfecta™	Redness, telangiectasias, post-op erythema
IPL (Not laser)	Broadband light	Lumecca™, BBL™, Icon MaxG	Dyschromia, photorejuvenation, redness

II. Energy-based technologies

- RF Microneedling (Morpheus8™, Profound™)
    - Mechanism of action: delivers radiofrequency energy via insulated or semi-insulated microneedles into the dermis/subdermis → causes controlled thermal injury → neocollagenesis, elastin formation (Fig. 3), dermal remodeling

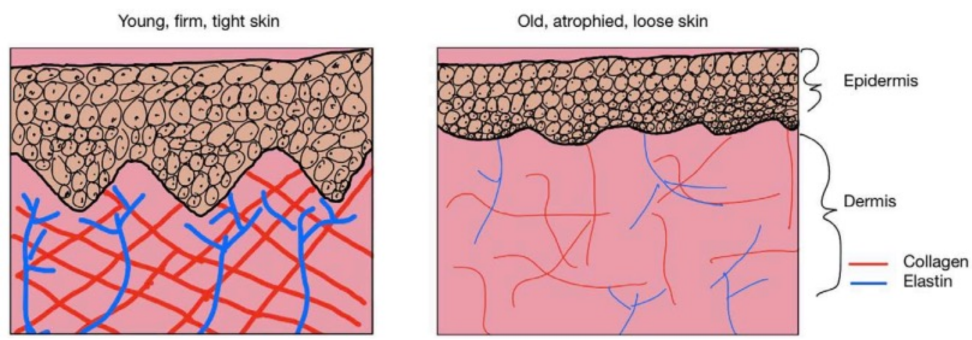

Figure 3. Illustration of atrophy of the extracellular matrix during the aging process and the effect it has on skin. *From Shridharani SM, Ribaudo JG, Kennedy ML. Skin Tightening Technologies in Body Contouring. Plast Reconstr Surg. 2025 May 1;155(5):935e-946e.* .

    - Indications: skin laxity, jowls, acne scars, wrinkles, enlarged pores, stretch marks, early submental fullness
    - Recovery: mild erythema, swelling, pinpoint crusting for 2-4 days; makeup typically allowed after 48 hours
    - Complications/pearls:
        - Risk of PIH (esp. Fitzpatrick IV—to prevent burns or post-treatment texture changes
        - Depth and pulse duration matter (Profound™ targets SMAS level for more lift; Morpheus8 has adjustable depths)
        - Deeper energy delivery may cause facial hollowing as the energy delivered may target deeper subcutaneous tissue
        - Avoid use over implants, keloid-prone areas
- Ultrasound-based (Ultherapy™)
    - Mechanism of Action: Uses microfocused ultrasound with visualization (MFU-V) to deliver heat at precise depths (1.5, 3.0, 4.5 mm) → coagulation zones in SMAS, deep dermis → triggers collagen contraction and neocollagenesis

    - Indications: mild to moderate skin laxity (brow lift, jawline, neck), non-surgical lifting, fine lines, décolletage wrinkles
    - Recovery: no visible downtime; mild tenderness, tingling, or edema for 1–3 days
    - Complications/pearls:
        - Painful during treatment → topical + oral analgesia helpful
        - Deep delivery requires precise visualization to avoid fat atrophy
        - Results are gradual (3–6 months) and best in younger patients with mild laxity
        - May cause transient nerve irritation if improperly delivered
- Intense Pulsed Light (IPL)
    - Mechanism of action: emits broad-spectrum light (500–1,200 nm) absorbed by chromophores: melanin, hemoglobin → heats pigment or vessels → photothermolysis → destruction and gradual clearance
    - Indications: sunspots, lentigines, telangiectasias, rosacea, photodamage, uneven tone; off-label: acne and hair reduction
    - Recovery:
        - 1-2 days: erythema and mild swelling
        - 3-7 days: darkening/sloughing of pigmented spots
    - Complications/pearls:
        - Not a true laser (broadband light, not collimated)
        - Risk of burns or hyperpigmentation in darker skin tones → lower fluence, use with caution
        - Multiple sessions needed (3-5) for best results
        - No tanning pre/post procedure to minimize PIH risk
- Treatment planning
    - Device selection based on indication (wrinkles, pigment, scars, vascular lesions)
    - Downtime, risks, and contraindications

CHEMICAL PEELS

Chemical peels are topical treatments that use acids—such as glycolic, salicylic, TCA, or phenol—to exfoliate the skin at varying depths, stimulating cell turnover and improving texture, tone, fine lines, and pigmentation. They are classified as superficial, medium, or deep peels based on how deeply they penetrate the epidermis and dermis.

- Indications: dyschromia, photoaging, acne scars, melasma
- Mechanism of action: protein denaturation → exfoliation and regeneration
- Peel depths and agents
    - Superficial: glycolic acid, salicylic acid, Jessner's solution
    - Medium: TCA (10-35%)
    - Deep: Phenol (Baker-Gordon, Hetter's)
- Pretreatment care (priming protocol)
    - Purpose: prepares skin for even penetration of peel, reduces risk of PIH, and enhances efficacy.
    - Common agents:
        - Retinoids (e.g., tretinoin): promote epidermal turnover and thin the stratum corneum
        - Hydroquinone (2-4%): suppresses melanogenesis to reduce risk of PIH
    - Timing: begin 2-4 weeks before peel (unless contraindicated); discontinue 3-5 days before the procedure.
    - Pearl: for deep peels or in those patients with a history of herpes infection, prescribe prophylactic antivirals (e.g., valacyclovir)
        - Treat active infections promptly with antibiotics or antivirals
- Post-treatment care (wound healing support)
    - Cleansing: use a gentle, non-foaming cleanser to avoid irritation
    - Moisturization: keep skin hydrated with petrolatum-based or non-comedogenic ointments

- Sun protection: broad-spectrum sunscreen is critical; strict sun avoidance for 2-4 weeks post-procedure
- Avoidance: no picking, exfoliating, or active skincare (retinoids, acids) during recovery

OTHER MINIMALLY INVASIVE SKIN TREATMENTS

- Dermabrasion vs. microdermabrasion (Table 7)
    - Dermabrasion: surgical, ablative procedure best for deep scarring, with significant recovery and pigmentation risk
    - Microdermabrasion: superficial cosmetic treatment for brightening and smoothing, with minimal risk and downtime

Table 7. Dermabrasion versus microdermabrasion

	Dermabrasion	Microdermabrasion
Indications	• Deep acne scars • Surgical/traumatic scars • Rhinophyma • Deep perioral rhytids	• Dull skin • Fine lines • Superficial pigment • Mild texture irregularities
Depth of treatment	Papillary to reticular dermis (manual/mechanical removal of epidermis + dermis)	Stratum corneum only (superficial exfoliation)
Recovery	7-14 days with oozing, crusting, and erythema; prolonged redness possible	Minimal downtime; mild erythema for 24-48 hrs; return to activities same day
Pigmentation risks	High risk of PIH and hypopigmentation, especially in Fitzpatrick IV-VI	Low risk; caution in melasma or inflamed skin

- Microneedling
    - Mechanism of action: controlled micro-injury using fine needles stimulates collagen and elastin production
        - Often combined with PRP or RF
    - Technique: manual or motorized pen with adjustable depth; often repeated in series
    - Applications: acne scars, fine lines, enlarged pores, under-eye crepiness, stretch marks, and skin texture
- PRP and biologic injectables
    - Mechanism of action: autologous platelets release growth factors that promote tissue regeneration and vascularization.
    - Technique: blood draw → centrifuge → injection into skin/scalp or applied post-treatment
    - Applications: hair loss (especially androgenetic alopecia), dark circles, fine lines, skin tone, and wound/scar healing
- Threads
    - Mechanism of action: polydioxanone (PDO) or other biocompatible threads inserted subdermally to provide mechanical lift and stimulate collagen production via foreign-body reaction
    - Technique: threads placed with blunt or sharp cannulas in vectors tailored to lift (barbed threads) or rejuvenate (smooth threads)
    - Applications: mild lifting of jawline, cheeks, brows, and skin tightening.
    - Results are modest at best and temporary; outcomes are technique- and patient-dependent
- Micro-coring devices (Ellacor®)
    - Novel, minimally invasive skin-tightening modality that mechanically removes full-thickness cores of dermal and epidermal tissue without the use of thermal energy
    - Device employs hollow needles to excise micro-cores – typically 0.5 mm in diameter – in a fractional, grid-like pattern, which induces tissue contraction and neocollagenesis during the healing process

    - Mechanism of action: full-thickness removal of micro-columns of skin, resulting in immediate skin contraction due to reduced surface area and gradual dermal remodeling and collagen deposition over weeks to months
    - Indications:
        - Mild to moderate age-related skin laxity
        - Perioral rhytids
        - Jowling and lower face laxity
        - Patients desiring minimal downtime and no thermal injury
- Combined modalities
    - Oftentimes, multiple synergistic treatments can/should be used to address different components of facial aging (volume loss, wrinkles, laxity, texture) (Fig. 4)
    - Approach:
        - Filler → restores volume
        - Neurotoxin → softens dynamic lines
        - Energy-based device → stimulates collagen and improves tone
    - Delivery: can be sequential (e.g., RF first, filler later) or simultaneous, depending on safety and indication
    - Applications: comprehensive facial rejuvenation, neck and periorbital aging

Figure 4. Left, preintervention photograph. Center, photograph following rhytidectomy alone. Right, A 60% phenol peel was performed 12 months after rhytidectomy (photograph taken 18 months after phenol peel and 30 months after rhytidectomy). *From Weissler JM, et al. The Evolution of Chemical Peeling and Modern-Day Applications. Plast Reconstr Surg. 2017 Nov;140(5):920-929.*

NON-SURGICAL AND MINIMALLY INVASIVE BODY CONTOURING TECHNIQUES

The techniques described below help surgeons comprehensively address the sometimes complex and diverse needs of body contouring patients. They offer safe, gradual improvements and can serve as stand-alone treatments or adjuncts to surgical body contouring.

- Cryolipolysis (CoolSculpting™)
    - Non-invasive fat reduction technique that uses controlled cooling to selectively induce apoptosis in subcutaneous adipocytes without damaging surrounding tissues; crystallized fat cells are gradually cleared through the lymphatic system over several weeks
    - Patient selection: ideal candidates are healthy individuals near their goal weight with localized pockets of diet- and exercise-resistant fat (e.g., flanks, abdomen, thighs)
        - Not a weight loss treatment and is contraindicated in patients with cold-induced disorders (e.g., cryoglobulinemia, cold urticaria)
    - Outcomes and limitations:
    - Patients may experience a reduction in adiposity of 20-25% per treatment area
    - Visible results in typically present at 2-3 months

        - Some adverse effects may include: transient numbness, erythema, rare paradoxical adipose hyperplasia
        - Results are modest compared to surgical excision, and multiple sessions may be required for optimal contouring
        - Cryolipolysis cannot address skin laxity or visceral fat
- High-intensity focused ultrasound (HIFU) (UltraShape™, Liposonix™)
    - Delivers focused ultrasound energy deep into subcutaneous tissue, causing thermal coagulative necrosis of adipocytes and stimulating collagen remodeling
    - Bypasses the epidermis, minimizing surface damage
    - Patient selection:
        - Mild to moderate skin laxity and small areas of unwanted fat particularly in the lower face, jawline, and neck
        - Not intended for significant fat reduction or large body areas
    - Outcomes and limitations:
        - Modest fat reduction and skin tightening over several weeks to months
        - Non-invasive, with minimal downtime, but its effects are variable and often subtle.
        - Not appropriate for patients seeking dramatic contour changes or with extensive skin redundancy
- Radiofrequency (RF) & LASER-assisted lipolysis (Vanquish™, SculpSure™)
    - Work by delivering thermal energy to subcutaneous fat
        - RF heats tissue through electromagnetic waves, stimulating adipocyte disruption and dermal collagen contraction
        - LASER lipolysis uses targeted laser wavelengths (e.g., 1064-1440 nm) to liquefy fat and promote dermal tightening via neocollagenesis
    - Patient selection:
        - Localized fat deposits and mild skin laxity
        - Often as an adjunct to traditional liposuction
    - Outcomes and limitations:
        - Offer improved contour and skin firmness with less downtime than conventional liposuction
        - Results depend on device type, operator skill, and patient factors
        - Risks include burns, fibrosis, and seroma
        - Efficacy decreases with severe laxity or inelastic skin
- Injectable fat-dissolving agents
    - Deoxycholic acid (e.g., Kybella™): bile salt that emulsifies and destroys fat cell membranes via cytolysis
        - FDA-approved for submental fat and sometimes used off-label in small body areas (Fig. 5)
        - Patient selection: patients with discrete, well-defined fat deposits in the chin or jowls and good overlying skin tone (Fig. 6)
        - Outcomes and limitations:
            - Results emerge after 2-4 sessions, spaced ~1 month apart
            - Once destroyed, fat cells are permanently eliminated
            - Common side effects include swelling, bruising, tenderness, and numbness; rare risks include nerve injury
            - Unsuitable for large-volume reduction or areas with loose skin

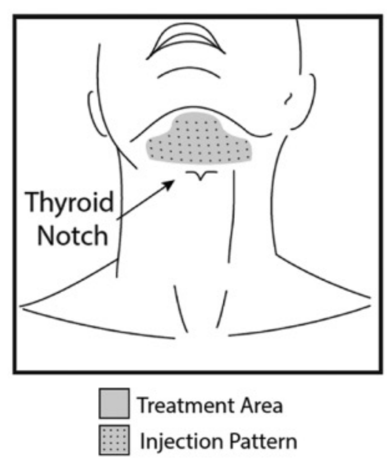

Figure 5. Injection area for deoxycholic acid. *From Shridharani SM, Chandawakar AA. Novel Expanded Safe Zone for Reduction of Submental Fullness with ATX-101 Injection. Plast Reconstr Surg. 2019 Dec;144(6):995e-1001e.*

Figure 6. Before and after treatment with deoxycholic acid. *From Shridharani SM, Chandawakar AA. Novel Expanded Safe Zone for Reduction of Submental Fullness with ATX-101 Injection. Plast Reconstr Surg. 2019 Dec;144(6):995e-1001e.*

- Electromagnetic Muscle Stimulation (Emsculpt™)
    - FDA 510(k) clearance since 2017 for muscle toning of the abdomen, buttocks, and longer clearance in 2019 for noninvasive lipolysis of the abdomen
    - Mechanism of action: inducing supramaximal involuntary contractions (~20,000 in 30 minutes) and generating localized hypermetabolism that may stimulate both muscle hypertrophy and fat apoptosis
    - Most studies review modest numeric changes – approximately 5 mm fat reduction and 2 mm muscle increase – with high variability in outcomes
    - While safe, evidence for its efficacy is still tenuous; many studies lack neutral control and publish bias toward positive results

COMPLICATIONS AND MEDICO-LEGAL CONSIDERATIONS

It is essential to have an informed discussion with patients regarding the potential risks associated with non-surgical treatments. Every intervention carries some degree of risk, and these should be thoroughly reviewed with the patient prior to initiating therapy. While some complications may be mild and manageable with supportive care, others can be serious and require urgent medical attention. A clear understanding of these potential outcomes is crucial before proceeding with any noninvasive procedure.

- Filler embolization
    - Prevention:
        - Use blunt cannulas in high-risk zones
        - Inject slowly, aspirate when appropriate
        - Avoid bolus injections in danger zones (glabella, nose, nasolabial folds)
    - Recognition:
        - Immediate blanching, pain, coolness, livedo reticularis, vision changes
    - Management:
        - Stop injection immediately
        - High-dose hyaluronidase in pulses
        - Warm compress, massage, nitropaste
        - Urgent ophthalmology referral if vision changes

- Burns from lasers
    - Prevention:
        - Use appropriate settings for skin type
        - Perform test spots on darker skin
        - Avoid overlapping passes or treating inflamed skin
    - Recognition:
        - Pain, blistering, excessive erythema, crusting
    - Management:
        - Cool compresses, topical steroids, non-adherent dressings
        - Antibiotics for secondary infection
        - Delay further treatments until healed
- Dyschromia from lasers
    - Prevention:
        - Use conservative settings on Fitzpatrick IV-VI
        - Pre-treat with hydroquinone and avoid sun exposure
    - Recognition:
        - Hyperpigmentation appears 1-3 weeks post-treatment; hypopigmentation may be delayed
    - Management:
        - For PIH: hydroquinone, retinoids, sunscreen
        - For hypopigmentation: often irreversible – sun protection and camouflage
- Lid ptosis
    - Prevention:
        - Avoid injecting <1 cm above orbital rim
        - Do not cross mid-pupil line in forehead
    - Recognition:
        - Drooping upper eyelid within 2-5 days post-injection
    - Management:
        - Apraclonidine 0.5% eye drops (2-3 times daily)
        - Reassurance—resolves in 2-6 weeks
- Asymmetry from neurotoxin
    - Prevention:
        - Symmetrical dosing and precise anatomic injection
        - Adjust for pre-existing asymmetries
    - Recognition:
        - Uneven brow position, smile deviation, lip pull
    - Management:
        - Add corrective units to opposite side if appropriate
        - Reassure—effects are temporary
- Documentation and informed consent
    - Document treatment plan, product used (lot, site, amount), pre- and post-photos, and patient education.
    - Consent must include:
        - Risks, benefits, alternatives
        - Off-label use disclosures
        - Expected onset and duration
        - Potential complications and recovery timelines
- Off-label use and scope of practice issues
    - Many uses of injectables and energy devices (e.g., neurotoxin for platysma, PRP for hair loss) are off-label
    - Providers must:
        - Use scientific rationale and peer-reviewed support
        - Clearly disclose off-label status in consent

        - Practice within licensure and training scope, especially for non-physician injectors

PATIENT-CENTERED REJUVENATION PLANNING

- Creating a treatment plan
    - Panfacial vs. regional intervention:
        - Panfacial approach addresses overall harmony and aging patterns
        - Regional treatments target specific concerns (e.g., lips, tear troughs) but may require more sessions for balance
    - Patient budget, downtime tolerance, event planning:
        - Plans should align with the patient's financial resources, recovery tolerance, and timeline (e.g., upcoming events), prioritizing staged treatments if needed
- Aesthetic maintenance
    - Recommended follow-up and maintenance intervals: common maintenance includes neurotoxins every 3-4 months, HA fillers annually, and energy-based treatments semi-annually
    - Home skincare regimens and adjunctive topical therapies: daily regimens with sunscreen, antioxidants, retinoids, and pigment modulators enhance and prolong in-office results

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Chapter 25
Gender Surgery

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GENDER IDENTITY DISORDER

- Gender dysphoria is defined as a marked incongruence between one's experienced gender identity and biologic sex
- Prevalence
    - 1.6 million people >13 years old identify as transgender in the US (~0.5% of the population)
    - 39% are transgender women
    - 36% are transgender men
    - 25% are gender nonconforming
- Distinct entity from those individuals with congenital disorders of sexual development/ambiguous genitalia
- Surgery is hypothesized to play a role in relieving their psychological discomfort
    - There is overall uncertainty in the evidence as to how gender surgery may impact quality of life, patient satisfaction, and reduction of gender dysphoria
    - Transgender males are twice as likely to seek surgical correction
- DSM-5 criteria for diagnosis:
    - Marked incongruence between one's experienced/expressed gender and primary and/or secondary sex characteristics (or in young adolescents, anticipated secondary sex characteristics)
    - A strong desire to be rid of one's primary and/or secondary sex characteristics because of a marked incongruence with one's experienced/expressed gender (or in young adolescents, a desire to prevent the development of the anticipated secondary sex characteristics)
    - A strong desire for the primary and/or secondary sex characteristics of the other gender
    - A strong desire to be of the other gender (or some alternative gender different from one's designated gender)
    - A strong desire to be treated as the other gender (or some alternative gender)
    - A strong conviction that one has the typical feelings and reactions of the other gender (or some alternative gender)
- Treatment of these individuals requires a multidisciplinary team
    - Primary care/internal medicine
    - Overall care coordination
    - Endocrinology: hormone therapy
        - Feminization via suppression of androgens and induction of female characteristics
            - GnRH antagonists
            - Estrogens: breast growth, redistribution of body fat, decreased body hair growth, decrease in testicular size and erectile function
        - Masculinization with testosterone induces clitoral hypertrophy, voice changes, hair growth, male-pattern baldness
    - Psychiatry/mental health
    - Surgery team: plastic surgery, otolaryngology (facial plastic surgery), urology
- General criteria for surgery:
    - One letter of readiness required for "top surgery," two letters for "bottom surgery"
    - No letters indicated at this time for facial feminizing or masculinizing procedures
    - Patients need to demonstrate that they have been living in their gender role for some time
        - Usually 12 months for bottom surgery

HISTORY

- Transsexualism is recorded throughout history, particularly in Greek and Roman literature
- 1923: Transsexualism term coined by Magnus Hirschfeld, a German physician
- 1931: Dr. Felix Abraham, a German surgeon, first to report staged vaginoplasty
- 1940s: evolution of the modern use of the word transsexual
- 1973: "gender dysphoria syndrome" coined to describe individuals who had a conflict between their natal and desired gender
- Current term is "gender identity disorder"
    - Needs to be contrasted from transvestitism, which describes those who like to dress as the opposite gender but have no desire to change their gender
    - Does not relate to sexual orientation or homosexualism
- 1978: the Harry Benjamin International Gender Dysphoria Association was founded
    - Plays a major role in research and treatment of these patients
    - Now known as the World Professional Association for Transgender Health (WPATH)
    - Publishes "Standards of Care for the Health of Transsexual, Transgender, and Gender Nonconforming People," which is now in its 8th edition
- 1983: Dr. Douglas Ousterhout performed the first facial feminization surgery in San Francisco
- 2014: Medicare lifts the 30-year ban on coverage for gender surgery
    - Number of surgeries tripled from 2016 to 2020

MALE-TO-FEMALE

I. Facial surgery (facial feminization)

- Frontonasal-orbital complex is greatest defining feature of male vs. female face
- Male face (Fig. 1, 2):
    - Larger in all dimensions than female face
    - Increased supraorbital bossing, prominent forehead/glabella, forehead more angled
    - Hairline with frontotemporal and overall recession (M-shaped)
    - Malar area flatter but larger
    - Squarer chin and jaw, mandible is larger and thicker with greater body height
    - More muscle bulk
    - Prominent thyroid cartilage
- Female face (Fig. 1, 2):
    - Smaller overall than male, about four-fifths the size
    - Curved forehead
    - O-shaped rounded hairline
    - Orbits are higher, more rounded, and larger
    - Less acute glabellar angle
    - Smaller nose
    - More prominent malar region
    - Pointed chin, heart-shaped face
- Typical procedures:
    - Brow lift
    - Frontal sinus setback
    - Forehead/supraorbital bar reduction
    - Frontal hairline advancement/hair transplant
    - Feminizing rhinoplasty
    - Genioplasty
        - Masseter resection/mandibular contouring with gonial angle reduction
        - Malar implants
    - Thyroid cartilage reduction, tracheal shave
    - Vocal cord shortening
    - Fat grafting

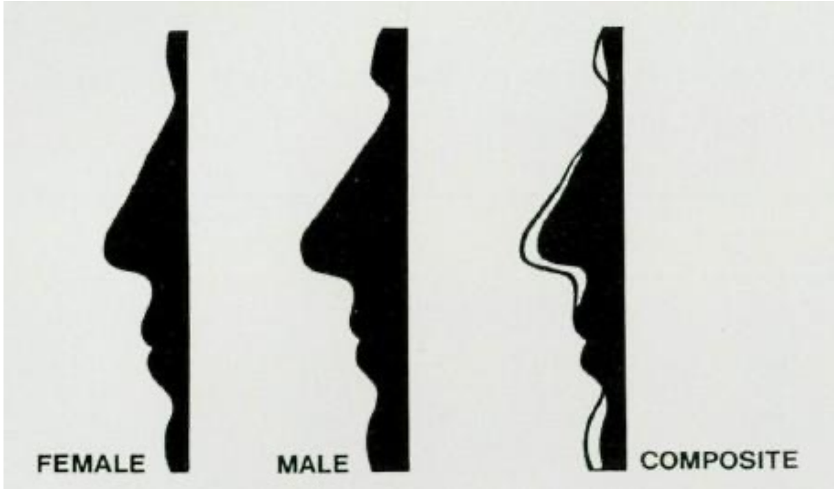

Figure 1. A more acute glabellar angle, a more acute nasal tip angle, a less open nasolabial angle, and a more pronounced chin are preferred in males. *From Hage J, et al. Gender-confirming facial surgery: considerations on the masculinity and femininity of faces. Plast Reconstr Surg. 1997;99(7):1799-1807.*

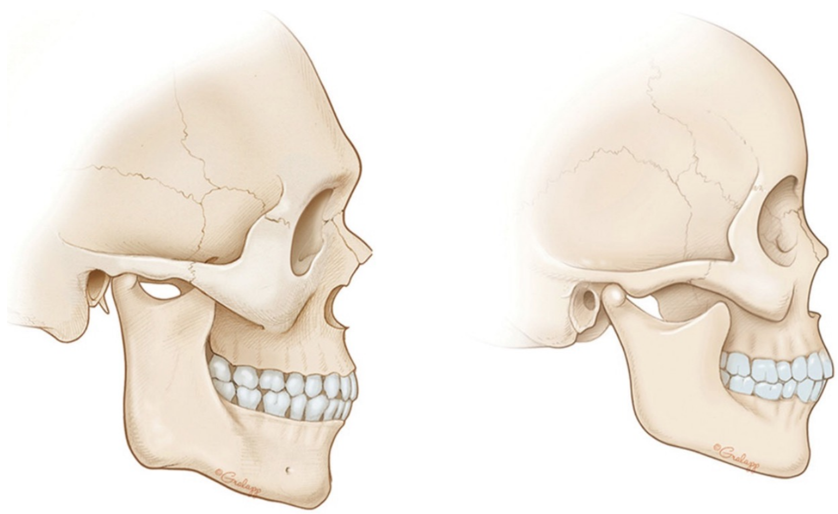

Figure 2. Differences in skeletal anatomy between males and females. The female skull has a more round, smooth forehead with a shorter tapered lowered jaw. *From Safa B, Lin WC, Salim AM, Deschamps-Braly JC, Poh MM. Current Concepts in Feminizing Gender Surgery. Plast Reconstr Surg.* 2019;143(5*):1081e-1091e. doi:10.1097/prs.0000000000005595*

II. Feminizing chest surgery ("top surgery" or breast augmentation)

- Some breast growth from hormones, about ½ to 1 cup size
- Transwomen should undergo feminizing hormone therapy for a minimum of one year for best aesthetic result
- Male chest different than natal female: chest is wider, nipple to IMF distance is less, areolae are smaller and lateralized, pectoralis major more developed
    - Implant can be placed pre- or sub-pectoral
    - Adjunct techniques include lowering of the IMF, lower pole parenchymal scoring, NAC repositioning

III. Feminizing genital surgery ("bottom surgery")

- Goals:
  - Create normal appearing vagina and mons pubis
  - Create a sensate neoclitoris
  - Create a large and deep enough neovagina for penetration (if desired by patient)
- Pre-operative considerations:
  - Hair removal from the base of the penis to the scrotum
  - Hormone therapy
  - Letters from mental health provider
  - Consider fertility preservation
  - Patient desire for canal for penetrative intercourse
- Types of feminizing genital reconstruction:
  - Vulvoplasty
    - “Zero depth vaginoplasty”
    - Only external genitalia, no vaginal canal
  - Penile inversion vaginoplasty (Fig. 3)
    - Most common operation
    - Neoclitoris created from the glans penis
      - W- shaped flap
      - Based off the dorsal penile neurovascular bundle
      - Placed at the level of the pubic symphysis
    - Labia minora from the prepuce or distal penile shaft skin
    - Labia majora from scrotal skin
    - Sutured in the groin crease
    - Vagina lined with inverted penile shaft skin
    - Pros: lined cavity, minimal shrinking, sensate
    - Cons: need for dilation, need for pre-op hair removal, may need revisions/labiaplasty for further feminization, stenosis

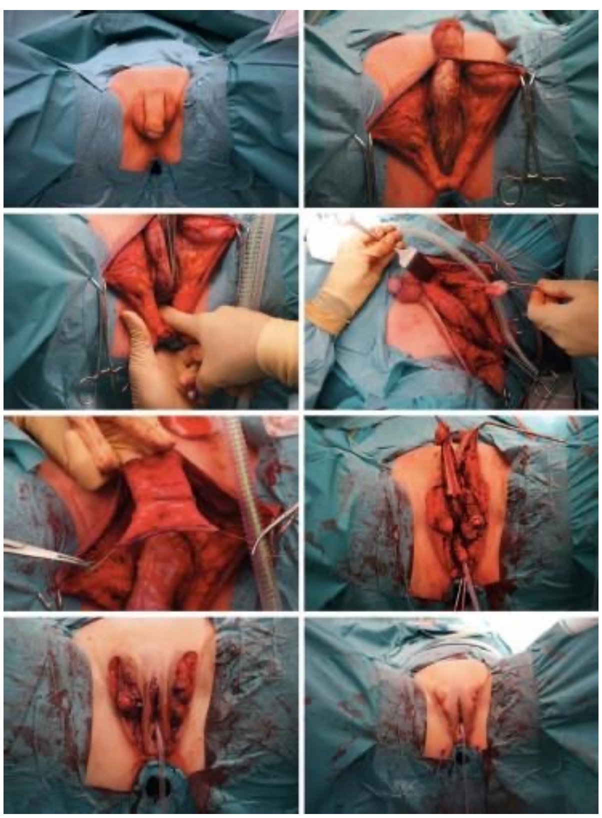

Figure 3. Penile inversion vaginoplasty performed in a 51- year-old transgender woman. (Above, left) erative genital area. (Above, right) An incision is made along the pre-operatively marked pattern. (Second row, left) Blunt dissection of the neovaginal cavity is performed. Caution is taken not to sever the rectum. This is checked by bimanual palpation. (Second row, right) Bilateral orchiectomy is performed. (Third row, left) Penile skin is separated from the penile shaft and closed at the distal end. (Third row, right) The dorsal neurovascular bundle is separated from the roof of the corpora cavernosa, and from a part of the glans penis, the preputium the neoclitoris and the labia minora are sculptured. (Below, left) A linear incision is made into the raphe of the penile skin, and the penoscrotal flap is imbedded. (Below, right) Postoperative genital area. *From Buncamper M, et al. Surgical Outcome after Penile Inversion Vaginoplasty: A Retrospective Study of 475 Transgender Women. Plast Reconstr Surg. 2016;138(5):999-1007.*

FEMALE-TO-MALE

I. Masculinizing chest surgery ("top surgery")

- Mastectomies in transmen are most commonly performed gender surgery
- Pre-operative considerations
  - Cosmetic operation, unlike cancer surgery, as some breast tissue is left behind
    - If patient has a significant family history of breast cancer:
      - Refer for genetics
      - Surgical oncology should perform risk-reducing mastectomies
- Chest wall contouring/mastectomy
  - Typically the first surgical procedure for FTM
  - Need to decrease breast/skin, obliterate IMF, reduce and lateralize nipple/areola
  - Incision choices depend on amount of ptosis
    - Subcutaneous keyhole or periareolar mastectomy for small breasts with minimal skin excess (Fig. 4, 5)
    - Double incision mastectomy with free nipple grafts for medium and large/ptotic breasts (Fig. 6)

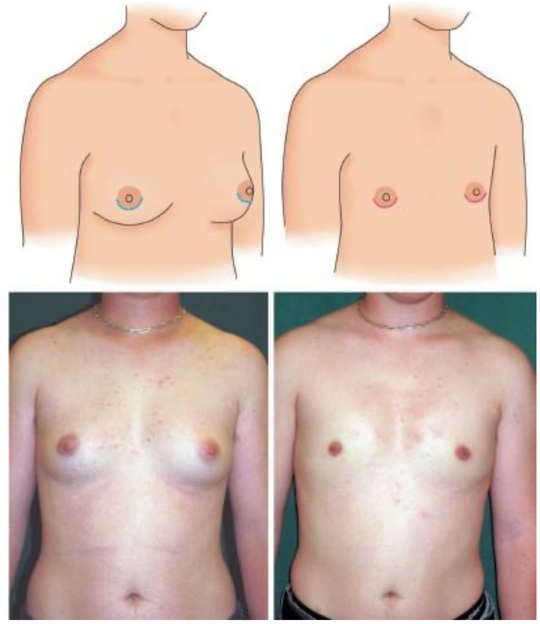

Figure 4. Semicircular technique. *From Monstrey S, et al. Chest-wall contouring surgery in female-to-male transsexuals: a new algorithm. Plast Reconstr Surg. 2008;121(3):849-859.*

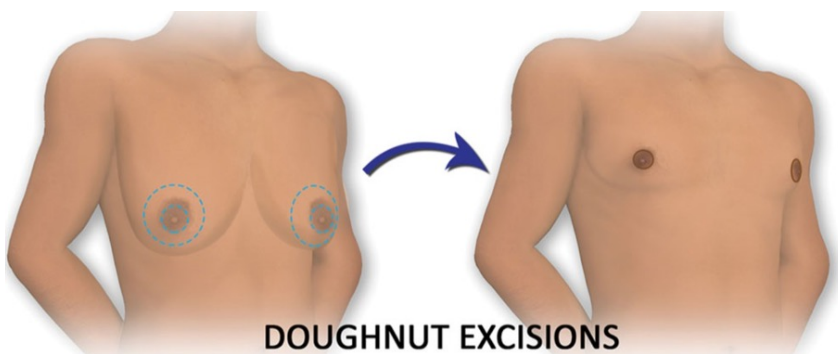

Figure 5. "Doughnut excision" technique. Best for patients who will require reduction of the NAC complex and skin followed by parenchymal reduction.

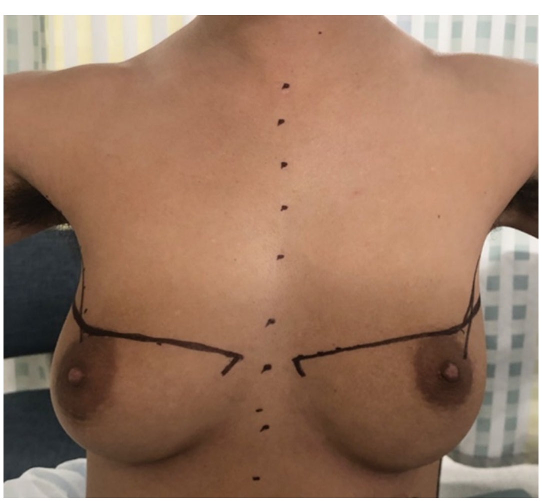

Figure 6. Pre-operative markings for double-incision mastectomy. The patient is marked in the standing position with arms raised to help accentuate the inferior and lateral borders of the pectoralis muscle. The superior incision is marked straight across the inferior border of the pectoralis major and is angled superiorly toward the axilla to follow the inferolateral border of the pectoralis muscle. *From Salibian AA, Gonzalez E, Frey JD, Bluebond-Langner R. Tips and Tricks in Gender-Affirming Mastectomy. Plast Reconstr Surg. 2021;147(6):1288-1296.*

II. Masculinizing genital surgery ("bottom surgery")

- Pre-operative considerations and goals:
  - Neourethra capable of voiding
  - Neophallus
  - Aesthetically pleasing
  - Staging
    - Hysterectomy, oophorectomy, and vaginectomy often performed before phalloplasty operations
    - Scrotal implants performed later
- Operations for phalloplasty:
  - Metoidioplasty (Fig. 7)
    - Stretching the hormonally hypertrophied clitoris, lengthening urethra with local flaps
    - Complications are usually urethral fistulas/strictures
    - Scrotoplasty from labia majora (can be concomitant or staged)
    - Pros: tactile and erogenously sensate clitoral tissue, sustained erectile rigidity without prostheses, minor donor site scarring, shorter hospitalization
    - Cons: very small phallus so unlikely to be able to provide penetration, impaired standing urination
  - Pedicled flaps: urethroplasties are via tube within a tube design
    - ALT (Fig. 8)
      - Pros: Reliable vascular supply, reduced total flap failure risk, hidden donor site, able to be innervated
      - Cons: donor site may be too thick

Figure 7. Result of metoidioplasty and scrotum reconstruction. *From Berli JU, Monstrey S, Safa B, Chen M. Neourethra Creation in Gender Phalloplasty: Differences in Techniques and Staging. Plast Reconstr Surg. 2021;147(5):801e-811e.*

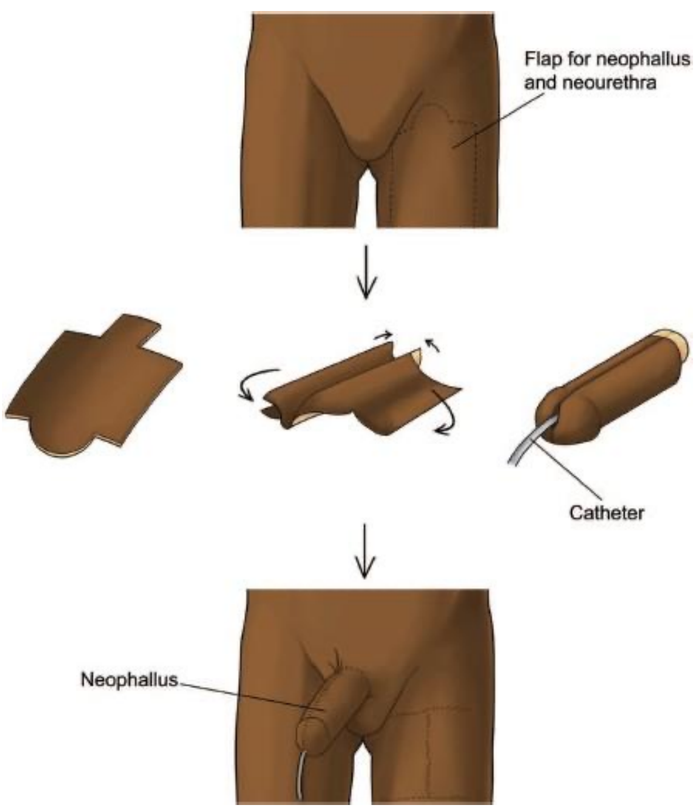

Figure 8. Illustration of the pedicled anterolateral thigh flap. A tube-within-a-tube design is used. The inner conduit becomes the neourethra, and the outer tubularized tissue represents the neophallus. The semicircular extension at the distal portion of the flap more accurately approximates the circumcised male phallus. *From Morrison S, et al. Phalloplasty: A Review of Techniques and Outcomes. Plast Reconstr Surg. 2016;138(3):594-615.*

- Inferiorly based abdominal flaps
    - Less aesthetic and higher complication rate
    - Easier to hide donor site scars
    - Diminished sensation
    - Variability in vascular pattern
    - Limited ability to void standing and unable to provide sexual penetration
- Pedicled groin flaps (Fig. 9)
    - Similar to abdominally based flaps
    - Insensate
    - Functional problems the same as abdominal flaps
- Gracilis flap (Fig. 10)
    - Bipedicled design with two flaps
    - Urethra made from skin graft

- Free flaps
    - Radial forearm (Fig. 11, 12)
        - Most commonly used
        - Tube within a tube neourethra
        - Can be sensate
        - Pros: aesthetic reconstruction, standing urination, tactile and erogenous sensation
        - Cons: donor site morbidity, urinary fistulas/strictures, requires prosthesis

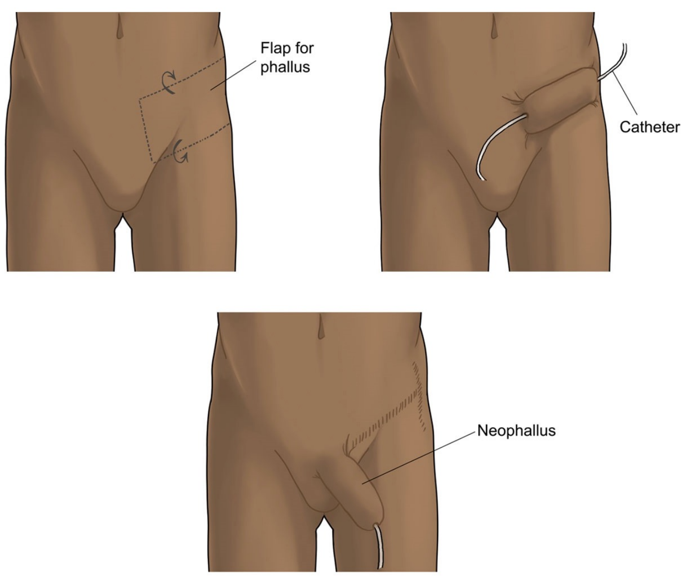

Figure 9. Illustration of groin flap. The groin flap with or without the iliac bone can be performed in either one or two stages. The two- stage procedure is based on the superficial circumflex iliac artery and the deep circumflex iliac artery. The lateral and medial skin edges of the flap are sutured together, constructing a tube still attached to the body. After some time, the flap is raised on its pedicle. The neourethra is reconstructed using a full thickness skin graft from the contralateral groin. *From Morrison S, et al. Phalloplasty: A Review of Techniques and Outcomes. Plast Reconstr Surg. 2016;138(3):594-615.*

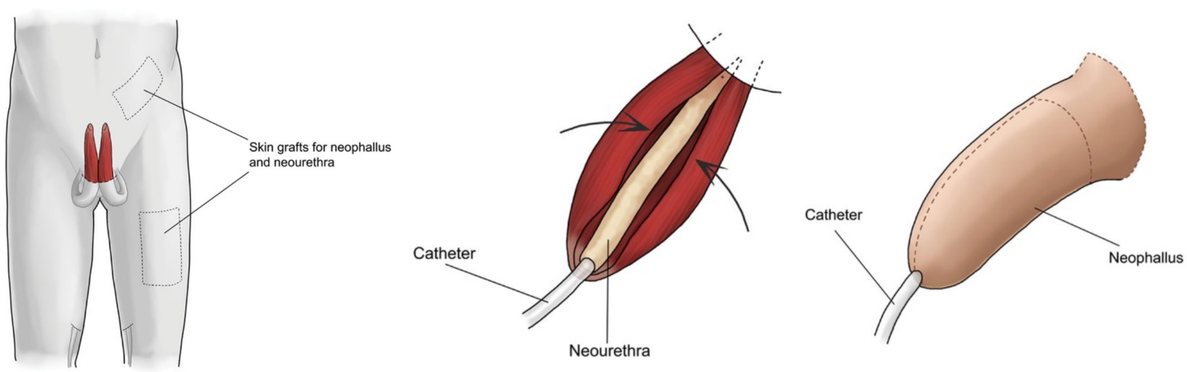

Figure 10. Illustration of the gracilis flap. A bipedicled gracilis muscle flap is harvested and pedicled into the groin. Once joined together around a skin graft used for the neourethra, another skin graft is placed around the muscle. *From Morrison S, et al. Phalloplasty: A Review of Techniques and Outcomes. Plast Reconstr Surg, 2016;138(3):594-615.*

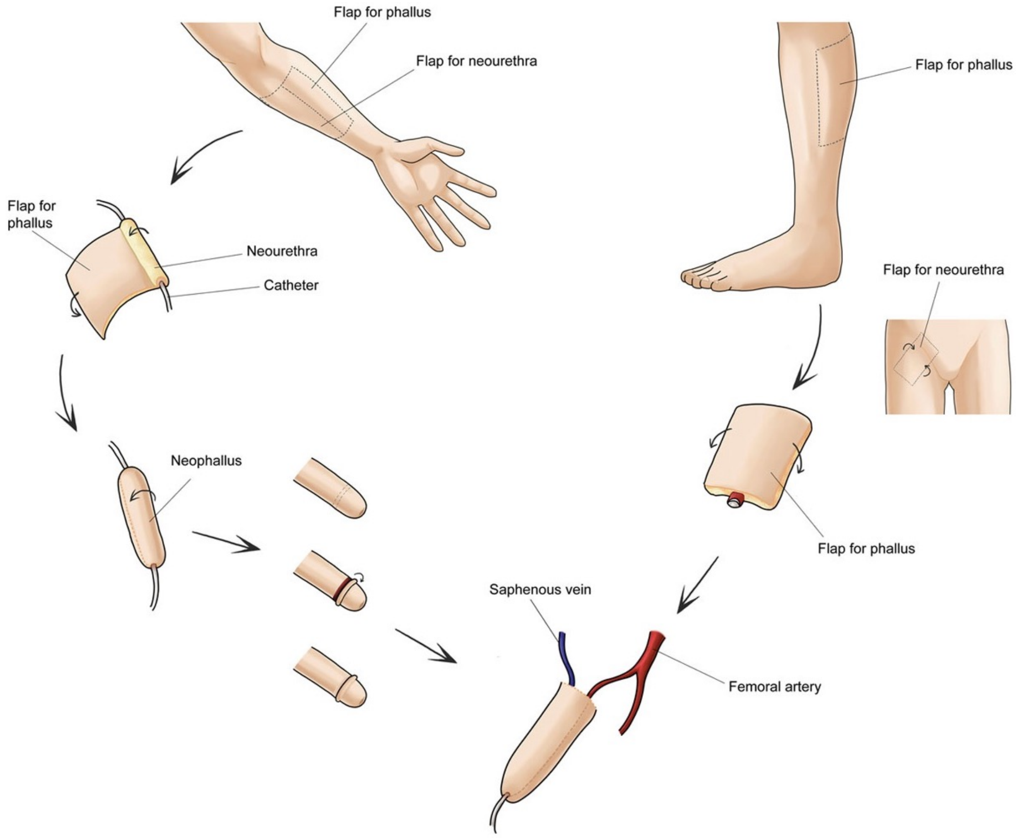

Figure 11. Illustration of the radial forearm free flap and the fibula osteocutaneous free flap. In the osteocutaneous free fibula flap, the fibula is harvested with a cuff of muscle, the peroneal artery, and either the lateral or posterior sural nerve to create the sensate phallus. The neourethra is created from a groin skin flap. In the radial forearm free flap, the tube-in-tube design is used to create a neophallus and neourethra in a single flap. The radial artery and the antebrachial nerves are harvested to create the sensate phallus. The Norfolk technique is used for the radial forearm free flap to create a glans. *From Morrison S, et al. Phalloplasty: A Review of Techniques and Outcomes. Plast Reconstr Surg. 2016;138(3):594-615.*

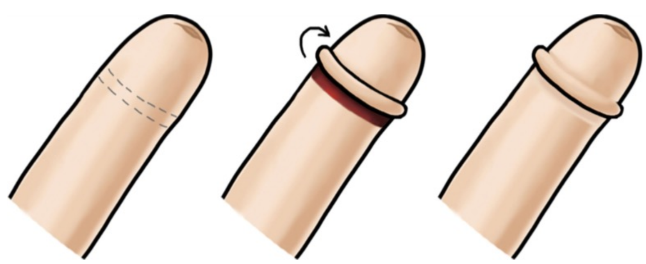

Figure 12. Illustration of the Norfolk technique. A distal circumferential portion of the neophallus shaft is elevated and rolled to create the corona. A split- or full- thickness skin graft is then placed over the defect on the shaft. *From Morrison S, et al. Phalloplasty: A Review of Techniques and Outcomes. Plast Reconstr Surg. 2016;138(3):594-615.*

- Osteocutaneous fibula (Fig. 10)
    - Can be made sensate
    - Does not require a prosthesis
    - Con: always erect
- ALT
- Latissimus flap: can be made functional with inclusion of muscle/nerve and may be able to have erectile function

- Penile epithesis
- Scrotoplasty with testicular prosthesis
    - Labia major flaps ± implants or tissue expanders
        - Good color and texture match
        - Embryologically from the same area
        - Have erogenous sensation
        - Can use pump for prosthesis to make one testicle

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Chapter 26
Composite Tissue Allotransplantation

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David A. Hill, MD

INTRODUCTION

- Also referred to as vascularized composite allotransplantation (VCA) or composite tissue allograft (CTA)
- Allograft (graft from cadaveric donor) composed of different tissue types (e.g. skin, muscle, bone, nerves, vessels)
- Introduced for major reconstruction of tissue defects from surgical excision of tumors, traumatic injury, and congenital malformations
    - Option for limb replacement and reconstruction of other non-reconstructible tissue defects including facial, abdominal wall, and others
- Couples the principles of microsurgical reconstruction with those of human organ transplantation
- Goal: improve function, quality of life, integration with society

HISTORY

- 348 AD: "The legend of the black leg" or the "Legend of Saints Cosmos and Damien"
    - Tale of twin brothers Cosmas and Damian who replaced the diseased leg of a man with that of a recently deceased person
- 1954: first successful human organ isograft, a kidney donated between identical twins; USA (Joseph E. Murray, John P. Merrill, and J. Hartwell Harrison)
- 1964: first case of hand CTA, failed due to rejection after 3 weeks; Ecuador (Robert Gilbert)
- 1990s: progress in immunosuppression → composite tissue renaissance
- 1998: first successful hand CTA; France (Jean-Michel Dubernard)
- 2000: first successful bilateral hand CTA; France (Jean-Michel Dubernard)
- 2005: first successful partial face transplantation; France (Devauchelle, Dubernard)

DONOR GRAFT PROCUREMENT

- In its first decade, approved largely by local or university committees as part of experimental/clinical research endeavors
- 1984: Congress passes the National Organ Transplant Act (NOTA), which establishes the legal framework for a national organ transplant system and prohibits the sale of human organs
- 1986: Organ Procurement and Transplantation Network (OPTN) is created, and UNOS is assigned to operate the OPTN
- 2014: VCA (face, hand) added to OPTN's jurisdiction
    - Treated similarly as solid organ transplantation
    - Additional donor permission may be required due to highly identifiable and sensitive nature of facial tissue
    - For organ donation (including face transplants), U.S. uses an "opt in" tissue donation model vs. Europe and other parts of the world use an "opt out" model (i.e., automatically considered a donor unless choosing otherwise)

ANATOMY/SURGICAL PLANNING

- Typically involves anastomosis of at least moderate to large arteries and veins (at least 1-4 mm in diameter) to supply the graft and nerve coaptation to preserve motor and sensory functions (Fig. 1)
- Involves meticulous tagging of important donor and recipient anatomic structures which need to be connected (i.e., nerves, tendons, and vessels in hand transplantations)

- Face transplants can be soft tissue only; can also include bone such as part of the maxilla or even part of the central nervous system (i.e. eye)
    - Virtual surgical planning can be a useful tool in pre-operative planning
    - Recent face transplant included whole eye transplant as part of composite graft
- In face transplantation, the facial nerve can be coapted at the trunk level or more commonly at each individual branch
- Bilateral hand transplant more common than unilateral hand transplant

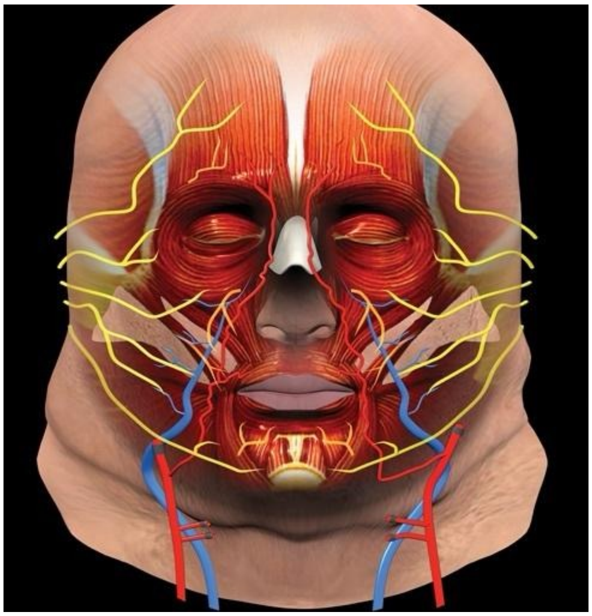

Figure 1. Full facial allograft containing all structures needed to be affixed and/or coapted in a transplantation procedure for a hypothetical patient lacking all nervous, vascular, and soft-tissue anatomy. *From Pomahac B et al. Novel Surgical Technique for Full Face Transplantation. Plast Reconstr Surg. 2012 Sep;130(3):549-555.*

INDICATIONS

- Most common mechanisms of injury:
    - Face: ballistic injuries, burns, neurofibromatosis
    - Hand: blunt trauma, blast injury, sepsis
    - Penis: blast injury
    - Abdominal wall: multi-visceral organ transplantation
    - Scalp: malignancy

CONTRAINDICATIONS

- Active cancer
- Active psychiatric disorders
- Poor social environment
- Inability to commit to lifelong immunosuppressants

MULTIDISCIPLINARY INVOLVEMENT/CARE

- A CTA program involves more than just plastic surgeons
- Other key members of the team include:
    - Psychiatry
    - Transplant surgery
    - Transplant nephrology
    - ENT (tracheostomy prior to transplant)
    - Social work
    - Long-term follow up with all different specialties likely for the rest of the patient's life

IMMUNOGENICITY

- CTAs are histologically heterogeneous, composed of different tissue types including skin, fat, muscle, nerves, lymph nodes, blood vessels, bone, cartilage, ligaments, and bone marrow
    - Each tissue has different antigenicity
        - Skin is most antigenic, likely owing to dendritic cell population and antigen variety
        - Immunogenicity of a CTA is not the sum of its different components
        - Whole limb allograft elicits a less intense immune response than does allografts of each of the individual components
- CTAs elicit a stronger immune response as compared to solid organ transplants
- Split tolerance phenomenon: simultaneous tolerance to one tissue and rejection of another from the same donor
- Some form of acute rejection seen in more than 50% of face transplant patients within first year

TYPES OF CTA PERFORMED TO DATE

- Hand/upper extremity:
    - Most common transplant
    - First 4 successful cases:
        - Right hand – transplanted in Lyon, France, on September 23, 1998
        - Left hand – transplanted in Louisville, KY on January 23, 1999
        - 2 right hands – transplanted to two individuals in Guangzhou, China, on September 21, 1999
    - >100 upper limb transplants reported to date
- Partial or total face:
    - First partial face transplant in 2005 in France
    - >50 cases reported to date
- Abdominal wall: typically in the setting of abdominal multi-organ transplant
- Knee
- Larynx
- Flexor tendon apparatus
- Peripheral nerve
- Tongue
- Trachea
- Esophagus
- Scalp: in the setting of active malignancy, and with simultaneous solid organ transplantation
- Penis (5-7 cases globally)
- Uterus: first successful pregnancy following uterus transplant in 2015

ADVANTAGES

- Replace "like with like"
- An option when standard reconstructive options are exhausted or autologous tissues are not available
- Can achieve structural, functional, esthetic, and psychological improvements
- Avoidance of any donor site morbidity
- Good functional outcomes
    - For example, for hand transplants:
        - Sensibility recovered in 6-12 months
        - Motor function allows return to most daily activities (eating, driving, grasping objects, riding a bicycle, shaving, using the telephone, and writing)
- Majority of patients are satisfied and report improved quality of life
- Positive long-term follow-ups

DISADVANTAGES/LIMITING FACTORS

- Need for lifetime immunosuppressants
  - Susceptible to opportunistic infections
- Similar to solid organ transplants, grafts not expected to last forever
  - One case of loss of facial graft requiring re-transplant
- Expensive and high expertise surgery
  - Only certain centers can afford programs with government-sponsored grants or institutional support

FUTURE DIRECTIONS

- Development of novel immunosuppression and donor-specific tolerance regimens to help decrease episodes of rejection
- Increasing application for a wider group of patients as surgery is streamlined, tolerance regimens are perfected, and outcomes are improved
- Pushing the boundaries of what other components can be included as part of the composite graft depending on the patient needs

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Chapter 27
Lymphedema

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DEFINITION

- Chronic, progressive soft tissue swelling due to insufficient drainage of interstitial fluid

EPIDEMIOLOGY

- Over 300 million cases worldwide
- Can be primary (1%) or secondary (99%)
    - Primary incidence is ~1.33:100,000
    - Most common cause of secondary lymphedema worldwide is lymphatic filariasis
- By location: 90% lower extremity, 10% upper extremity, <1% genitalia

ETIOLOGY

- Primary lymphedema: inherent lymphatic channel dysfunction due to abnormal lymphatic development
    - Lymphedema congenita (presents <1 year old)
        - Milroy disease: AD inheritance, associated with VEGF-R3 and VEGF-C mutations, bilateral lower limb involvement
    - Lymphedema praecox (presents 1-35 years old)
        - Meige disease: presents around puberty with lower limb involvement
    - Lymphedema tarda (presents >35 years old)
        - Rarest form; lower limb involvement
- Secondary lymphedema: acquired insult to lymphatic drainage
    - Cancer-related lymphedema: most common form in developed countries
        - Radiation therapy and surgical lymph node disruption (e.g. during axillary lymph node dissection for breast cancer) are most common causes
    - Most frequently seen with cancers of the breast, prostate, testis, uterus, cervix, ovary, and head and neck
- Infectious: most common form worldwide
    - Lymphatic filariasis
    - Most commonly the parasite, Wucheria bancrofti, which obstructs lymphatic vessels
- Obesity
- Trauma
- Vascular anomaly

PATHOPHYSIOLOGY

- Normal lymphatic flow: lymphatic capillaries absorb interstitial fluid from tissues → lymphatic vessels → venous circulation; lymph nodes filter lymphatic fluid along the way
- Mechanical disruption of lymphatic flow leads to:
    - Backup of lymphatic fluid
    - Accumulation of protein-rich fluid in interstitium
    - Pitting edema and chronic fluid stasis
    - Activation of inflammatory pathways
    - Fibroadipose tissue deposition in edematous regions
        - Non-pitting edema and chronic dermal inflammation
        - Skin changes (hyperkeratosis, skin infections)

DIFFERENTIAL DIAGNOSIS FOR LIMB ENLARGEMENT

- Edema
    - Cardiac insufficiency
    - Renal Insufficiency
    - Hepatic insufficiency
    - Venous insufficiency
    - Nutritional insufficiency (Starling forces)
- Deep venous thrombosis
- Thyroid disease
- Lipidema (a.k.a. Adiposis Dolorsa or Painful Fat Syndrome — abnormal fat accumulation that may be triggered by stress or hormonal changes)

CLINICAL PRESENTATION

I. History

- Swelling of affected body part
- Pain and/or heaviness
- Inability to find properly fitting clothing
- Decrease use of involved region
- Aesthetic concerns
- Speech concerns (head and neck lymphedema)
- Recurrent infections (cellulitis, erysipelas, lympangitis)

II. Physical exam

- Edema of affected region
    - Pitting in earlier stages, non-pitting in later stages (Fig. 1)
- Limb circumference measurements
- Limb volumetry
- Stemmer Sign: inability to pinch skin on the dorsum of the second toe
- Skin changes: hyperpigmentation, hyperkeratosis, acanthosis, skin ulcerations, plaques

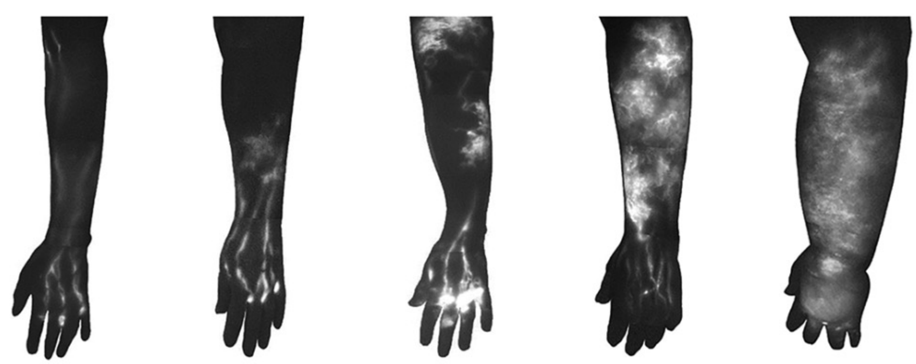
Figure 1. Finger pressure produces pitting edema in a patient with Stage 1 lymphedema. *From Kung, T, et al. Current concepts in the surgical management of lymphedema. Plast Reconstr Surg 2017;139(4):1003e-1013e.*

- Objective measurements
    - Limb circumference
        - Circumference measurements taken at standardized landmarkes along the length of the extremity
    - Limb volume
        - Truncated cone method (uses multiple circumference measurements to calculate the volume of each segment as a truncated cone)
        - Water displacement volumetry

CLASSIFICATION

- International Society of Lymphology (ISL) classification: clinical assessment (Table 1)
- Indocyanine Green (ICGN) staging: physiologic function via ICG angiography (Fig. 2)
- Campisi Score: also based on clinical assessment

Table 1. International Society of Lymphology (ISL) classification of lymphedema	
Stage 0 (or Ia)	Latent or subclinical condition where swelling is not evident despite impaired lymph transport. It may exist months or years before overt edema occurs (Stages I–III)
Stage I	Early accumulation of fluid relatively high in protein content that improves with limb elevation. Pitting may occur.
Stage II	Limb elevation alone rarely reduces tissue swelling and pitting is manifest.
Stage II (late)	Loss of pitting edema due to fibrosis and deposition of lymphadiposal tissue.
Stage III	Lymphostatic elephantiasis. Gross limb enlargement with absent pitting. Trophic skin changes develop, such as acanthosis, fat deposits, and warty overgrowths.



ICGN Stage	0	1	2	3	4
	• No dermal backflow	• Patchy discrete areas of dermal backflow	• Segmental dermal backflow in upper arm and forearm	• Confluent dermal backflow in upper arm and forearm	• Severe dermal backflow in entire extremity including hand
		• Many patent lymphatic vessels visualized	• Many patent lymphatic vessels visualized	• Few patent lymphatic vessels visualized distally	• No patent lymphatic vessels visualized
	• Normal contractility	• Mildly reduced contractility	• Moderately reduced contractility	• Severely reduced contractility	• No contractility

Figure 2. Indocyanine Green Staging Scale, modified from Chang et al. This scale evaluates the physiologic function of the lymphatic vessels within the limb, including the distribution and severity of dermal backflow, visualization of patent lymphatic vessels, and lymphatic vessel contractility. *From Schaverien et al. Surgical treatment of Lymphedema. Plast Reconstr Surg 2019;144(3):738-758.*

WORK-UP

- Radionuclide lymphoscintigraphy: gold standard diagnostic test; visualizes lymphatics and dermal backflow, though with low resolution
- Magnetic resonance lymphangiography (MRL): capable of generating three-dimensional renderings for pre-operative planning (Fig. 3a, b)
- ICG lymphography: good resolution for superficial structures, may be used intraoperatively (Fig. 3c)
- CT angiography: may assess extent of soft tissue involvement
- Venous duplex ultrasound: useful to rule out DVT

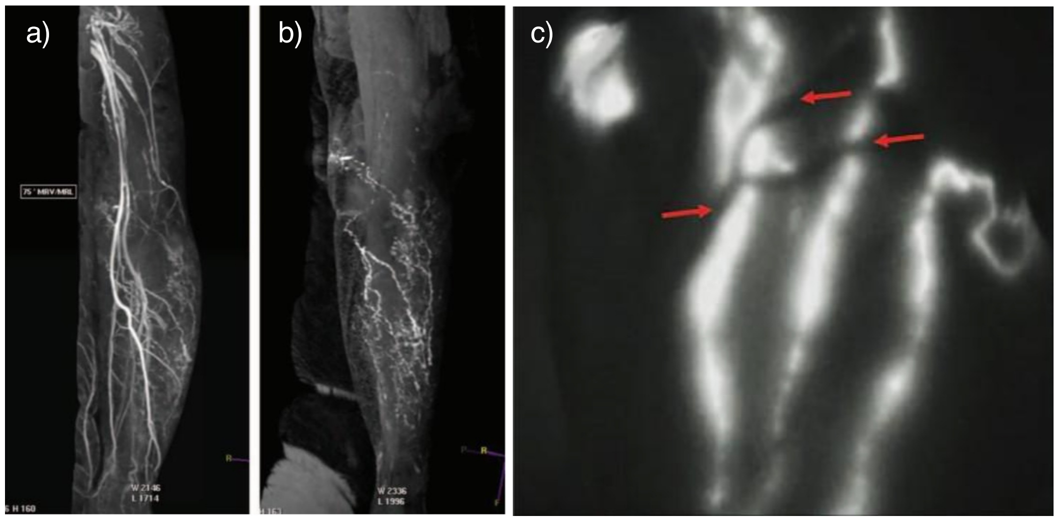


Figure 3. Imaging used to identify lymphatic channels. Magnetic resonance lymphangiogram showing (a) veins with a smoother appearance and (b) lymphatic channels with beadlike characteristics. Laser angiography with subdermal injection of indocyanine green (ICG) can also be used to observe lymphatic channels (c) that preferentially take up ICG in the interstitium. Arrows demonstrate shadow from an overlying vein that has not taken up ICG in this study. *From Kung, T, et al. Current concepts in the surgical management of lymphedema. Plast Reconstr Surg 2017;139(4):1003e-1013e.*

MANAGEMENT

In general, patients should undergo 3-6 months of conservative treatment for early to mid-stage lymphedema. Those who fail conservative management or have persistent cellulitis my be candidates for surgical intervention.

I. Non-surgical

- Complete decongestive therapy (CDT): a combination of non-surgical treatment modalities aimed at reducing disease burden and tailored to individual needs
    - Manual lymphatic drainage (MLD)
    - Sequential pneumatic compression
    - Compression garments
    - Weight loss
    - Skin care: hygiene, topical antifungals
    - Physical therapy/exercise
    - Acupuncture
    - Laser therapy, extracorporal shock wave therapy (ESWT)
- Anti-parasitics, if lymphatic filariasis present
    - Diethylcarbamazine (DEC): #1 choice in North America
    - Ivermectin
    - Albendazole
    - Doxycycline

II. **Surgical** (Fig. 4)

- Physiological procedures: restore lymphatic outflow with the goal of soft tissue volume reduction
    - Lymphaticovenular anastomosis/bypass (LVA/B)
        - Connection of lymphatic vessel to venule to restore lymphatic outflow tract – known as supermicrosurgery (connecting vessels <0.8 mm in diameter)
        - Indicated for early stages with intact venous flow
        - May be done prophylactically, commonly at the time of breast surgery to prevent breast-cancer related lymphedema
    - Vascularized lymph node transfer (VLNT)
        - Surgical transfer of lymph nodes on a vascular pedicle from an unaffected region; lymphangiogenesis bridges donor vessels with local lymphatic channels to restore flow
        - Common donor sites: axilla, supraclavicular, submental, groin, omentum
        - Recipient location may be orthotopic (i.e., anatomical) or heterotopic (distal to the anatomical location)
        - Indicated in later cases with significant dermal backflow (i.e., lymphatic vessels that are present are not working)
        - Of note, LVA and VLNT may be performed in combination for moderate-stage lymphedema
- Reductive procedures: remove excess adipose and fibrotic tissue
    - Liposuction: removes fibrous adipose tissue
    - Staged direct excision (Homan's procedure)
    - Charles procedure: radical excision of lymphedematous tissue and replacement of excised skin with circumferential skin grafts
        - Typically reserved for extreme cases
        - Post-operative compression and multidisciplinary follow-up is generally recommended

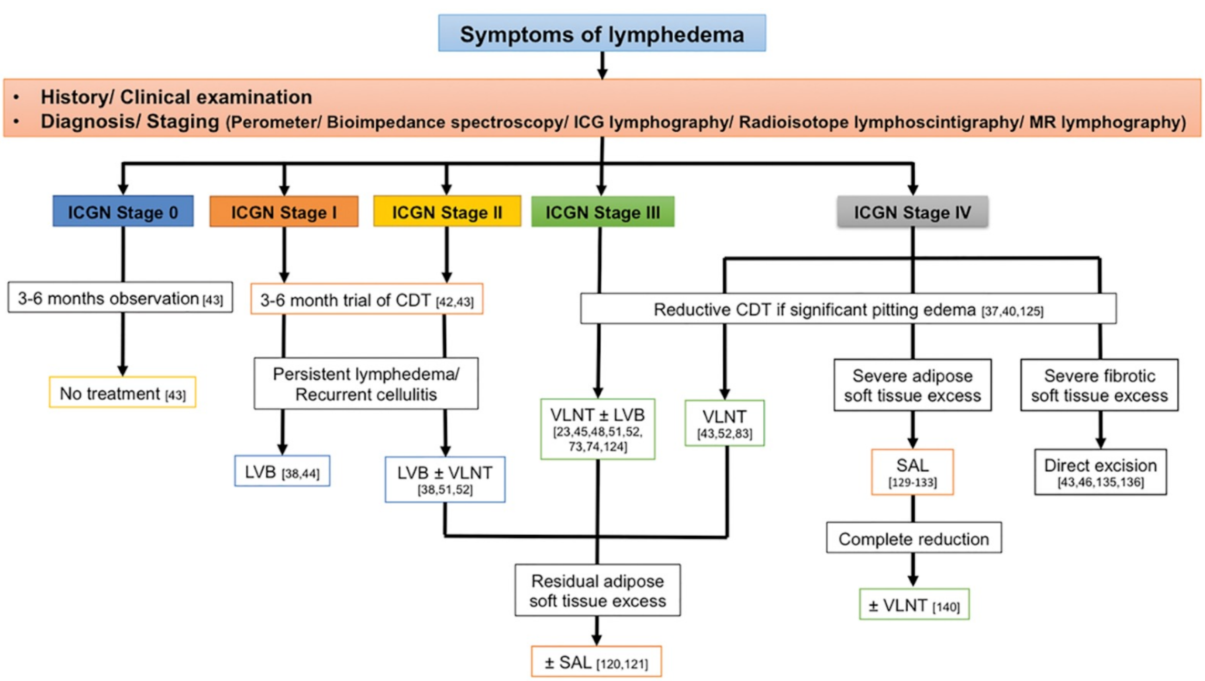


Figure 4. An evidence-based algorithm for surgical management of extremity lymphedema. *From Schaverien et al. Surgical treatment of Lymphedema. Plast Reconstr Surg 2019;144(3):738-758.*

COMPLICATIONS

- Disease complications:
    - Functional disability
    - Chronic wounds and cutaneous changes
    - Venous insufficiency, DVT
    - Recurrent infections (may be life-threatening)
    - Psychosocial morbidity
    - Stewart-Treves Syndrome: cutaneous angiosarcoma that develops in the setting of chronic lymphedema; best treated by wide local excision or amputation
- Surgical complications:
    - Failure to restore lymphatic flow
    - Donor-site lymphedema (VLNT)
    - Phrenic nerve injury or lymphatic leak (supraclavicular LN donor site)
    - Hematoma, seroma, infection, delayed wound healing

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Chapter 28
International Plastic Surgery

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INTRODUCTION

- Plastic surgery, while hailing from historically global influences, was formally organized and predominantly practiced in Western countries in modern times
    - The field has evolved into a global field once more that transcends borders, addressing the diverse needs of patients across the world
- With a broad international presence, plastic surgery has become essential in not only improving physical appearance but also restoring functionality and enhancing the quality of life for patients with life-altering injuries or conditions
- However, clinical and technological advancements in the past century have not benefited patients in the developing and developed world equally

GLOBAL PRACTICE IN PLASTIC SURGERY

- Plastic surgery practice in low- and middle-income countries (LMIC) focuses largely of chronic wound care, burn care, and congenital face and hand deformity reconstruction
- However, there is a growing demand for reconstructive surgery in post-conflict zones and disaster-stricken regions with limited access to specialized medical services in rural or underdeveloped areas
- Challenges in global practice in plastic surgery include economic and resource constraints, limited medical infrastructure, uneven access to education, and surgical burnout seen in surgeons working in resource-poor settings

INTERNATIONAL PLASTIC SURGERY OUTREACH

- Global collaboration through fellowships and exchange programs helps to address this gap by allowing surgeons from less developed regions to learn advanced techniques and gain exposure to global best practices
- Conferences, academic exchange programs, and global outreach initiatives have facilitated the transfer of knowledge, leading to greater standardization of surgical techniques and better patient outcomes across different regions
- Plastic surgical charities/NGOs such as Operation Smile, Smile Train, Resurge International (formerly Interplast), Hand Help, Rotaplast, Doctors Without Borders, Facing The World, and SHARE spearhead these efforts
- Volunteers in Plastic Surgery (an effort supported by the Plastic Surgery Foundation) plays a key role in coordinating efforts, standardizing guidelines, and supporting surgeons
- Plastic surgeons in the United States, smaller groups of surgeons, and even individuals have organized surgical missions to LMICs in the efforts to provide free surgical care
- Surgical missions provide numerous benefits to LMICs:
    - They can provide resources and improve manpower and training for local partners
    - They improve cost-conscious practice, cultural and clinical skills in volunteers
    - Promote sustainable medical practices and empower local healthcare systems to handle similar cases independently in the future
    - Walker et al. demonstrate that surgeon consultation in the mission setting can improve patient knowledge in populations being served
    - Attract attention and funding, leading to more partnerships with NGOs, government bodies, and international organizations

ETHICS IN GLOBAL PLASTIC SURGERY MISSIONS

- Providing care in resource-poor settings raises ethical questions worth considering
- For extremely vulnerable patients, whose healthcare rights and autonomy are at risk, upholding core ethical principles is essential to ensure safety and well-being
- Chikoti et al. describes core medical ethics in global plastic surgery as being analogous to Beauchamp and Childress' proposed set of four ethical principles: autonomy, beneficence, nonmaleficence, and justice
    - Advocates shifting from the paternalistic "white savior" model to training local physicians in LMICs, evaluating these strategies through the lens of medical ethics

EDUCATION

- The current cohort of residents and fellows represents the next generation of global surgeons
- Several residency programs have obtained approval from the Residency Review Committee of the ACGME to include global health or international rotations to LMICs as part of surgical training
- Such rotations benefit residents by exposing them to different pathologies and innovative operative and treatment approaches
- Global surgery fellowships focused on plastic surgery also provide post-residency clinical and research training for advanced trainees with a career interest in global surgery (Table 1)

Table 1. Global surgery fellowship list.

Plastic Surgery Focus in Global Surgery		
Fellowship (Web Site)	**Organization**	**Key Points**
Regan Fellowship http://bit.ly/2g6IN4g[49]	Operation Smile	The Regan Fellowship offers resident physicians the opportunity to participate in the life-changing work of Operation Smile. Made possible by invaluable donor support, residents in plastic surgery, pediatrics, and anesthesiology are invited to attend an international medical mission and work under the supervision and mentorship of veteran Operation Smile physicians. While on the medical mission, residents also participate in our research initiatives that will allow for better treatment and prevention of cleft lip and cleft palate. During this program, residents may network with one another and share their experiences at the annual conference of Regan Fellows.
Stryker International Fellows Program http://bit.ly/2g6IN4g[50]	Operation Smile	The Stryker International Fellows Program seeks to build a global team of international rising plastic surgeons who have had a unique exposure to the humanitarian programs of Operation Smile and to the surgical management of cleft lip and cleft palate.
Tsao Global Surgery Fellow http://bit.ly/2g5w0Rw[51]	Children's Hospital Los Angeles, Operation Smile, and the USC Institute of Global Health	Organized by Children's Hospital Los Angeles, Operation Smile, and the USC Institute for Global Health. The program's fellows develop academic, clinical, and administrative skills in global surgery, clinical and public health research, and humanitarian aid in resource-poor settings. In addition to gaining master's degrees in clinical and biomedical investigations, they conduct research and travel around the world to where Operation Smile carries out surgical care missions.
Sterling-Bunnell Fellowship http://www.assh.org/afsh/Grants-Awards-and-Programs/Education/Bunnell-Fellowship-Program [52]	American Society for Surgery of the Hand	American Society for Surgery of the Hand for a young hand surgeon to foster national and international relationships.
Jerome P Webster Fellowship http://bit.ly/2gnMw1K[53]	ReSurge International	The Webster Fellowship offers a newly trained, board-eligible plastic surgeon the opportunity to spend a year with Interplast's medical colleagues in developing countries such as Bangladesh, Bolivia, Brazil, China, Ecuador, Ghana, Myanmar, Nepal, Nicaragua, Peru, Sri Lanka, Vietnam, and Zambia—performing the highest form of medical citizenship through care of those in need.
The John D. Constable International Traveling Fellowship http://bit.ly/2f7X6ES[54]	American Association of Plastic Surgeons	The John D. Constable International Traveling Fellowship has been an integral part of the American Association of Plastic Surgeons since 2006 and has provided an opportunity for international plastic surgeons to work with leaders in American plastic surgery.

From Chung K. Plastic and Reconstructive Surgery in Global Health: Let's Reconstruct Global Surgery. Plast Reconstr Surg Glob Open. 2017 Apr 25;5(4):e1273.

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Chapter 29
Innovations and Emerging Technologies in Plastic Surgery

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As aspiring plastic surgeons, you are entering a dynamic field where innovation is not just a buzzword, but a daily reality. The future of plastic surgery will be shaped by groundbreaking technologies that enhance precision, expand capabilities, and improve patient outcomes. This chapter provides a brief overview of key emerging technologies that will redefine your practice.

ROBOTICS IN PLASTIC SURGERY

I. Enhanced precision and dexterity

A. Microsurgery: Robotics are revolutionizing delicate procedures like re-attaching tiny blood vessels and nerves in reconstructive surgery, overcoming human tremor and fatigue. This is particularly crucial in complex cases such as replantation of digits or advanced flap reconstructions, where vessel diameters can be less than 1 millimeter. The stable platform and fine motor control offered by robotic systems allow for sustained, high-magnification suturing with unparalleled accuracy.

B. Increased range of motion: Robotic arms can access confined spaces with greater articulation than the human hand, enabling less invasive approaches. This is evident in areas like transoral robotic surgery (TORS) for head and neck cancers, where traditional open approaches can be highly morbid. In plastic surgery, this translates to improved access in deep abdominal wall reconstructions or even certain types of breast reconstruction.

C. Example systems: Familiarize yourselves with systems like the da Vinci surgical system, which has seen widespread adoption in various surgical specialties, and newer platforms like the Symani surgical system, specifically designed for microsurgery (Fig. 1). The ongoing development of smaller, more specialized robotic instruments will further expand their utility in plastic surgery.

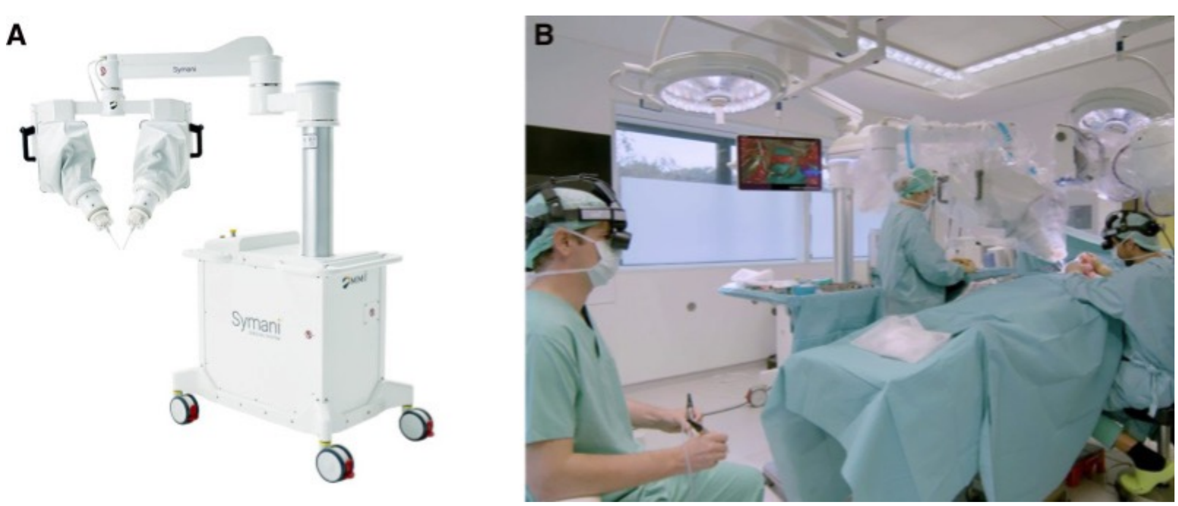

Figure 1. Symani surgical system. A, Image of the Symani surgical system highlights the system's ergonomic seating and dual-armed robot (image courtesy of MMI, Inc.). B, Image courtesy of MMI, Inc., showing a demonstration of the Symani's teleoperative capabilities and its use in vascular anastomosis. *From Brown HG, et al. Robotic-assisted Supermicrosurgery in Plastic Surgery and Reconstruction: A Systematic Review. Plast Recon Surg Glob Open. 2025 Jul 17;13(7):e6912.*

II. **Benefits for surgeons**

A. Ergonomics: Robotic platforms allow surgeons to operate in more comfortable positions, often seated at a console. This can significantly reduce physical strain, potentially extending career longevity and mitigating musculoskeletal injuries common in long, intricate, traditional surgeries.

B. Magnification and 3D visualization: Enhanced optics provide magnified, high-definition 3D views of the surgical field, improving visualization of intricate anatomy. This immersive visual feedback is critical for distinguishing fine structures and tissue planes, leading to more precise dissections and safer procedures.

III. **Current limitations and future directions**

A. Cost and setup time: High initial investment for robotic systems and the associated instruments, coupled with longer setup times for each case, remain significant hurdles to broader adoption, especially in smaller institutions or for less complex cases.

B. Tactile feedback: The absence of direct tactile feedback, or "haptics," is a major limitation. Surgeons rely heavily on touch to discern tissue tension, density, and texture. Research is actively focused on developing sophisticated haptic feedback systems that can simulate these sensations, allowing surgeons to "feel" the tissues through the robotic instruments.

C. Training and certification: The need for standardized robotic surgery training and certification within plastic surgery residencies and for practicing surgeons is critical to ensure safe and effective utilization of these complex systems. Establishing clear pathways for proficiency and credentialing will be vital.

AUGMENTED REALITY (AR) IN PLASTIC SURGERY

I. **Pre-operative planning and visualization**

A. 3D overlay: AR can overlay 3D models of patient anatomy, desired outcomes, and surgical plans directly onto the patient's body in real-time. Imagine projecting a patient's CT scan data directly onto their face during a rhinoplasty consultation, allowing both surgeon and patient to visualize precise bone and cartilage contours. This builds on current workflows employing virtual surgical planning and 3D printed guides and plates (Fig. 2).

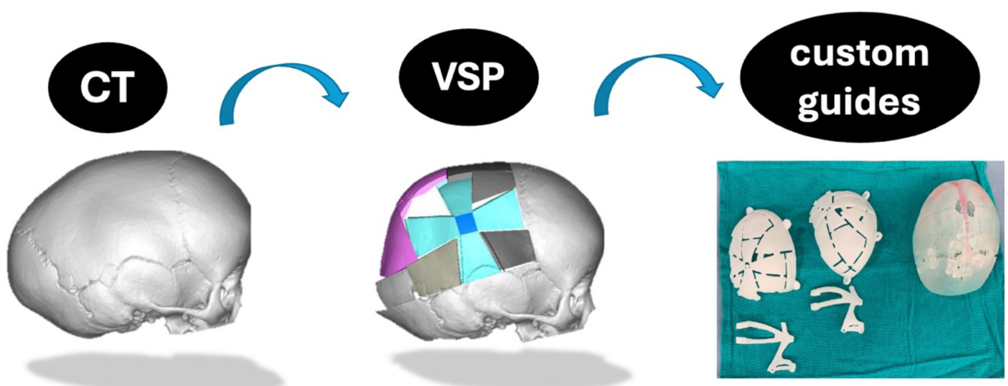

Figure 2. Example of virtual surgical planning for a patient with sagittal craniosynostosis and subsequent output of custom guides for surgery. *From Sawh-Martinez, 2025.*

B. Patient consultation: Patients can visualize potential aesthetic outcomes (e.g., rhinoplasty, breast augmentation) in a highly realistic and interactive manner, improving communication and managing expectations. This fosters shared decision-making and enhances patient satisfaction.

C. Perforator mapping: AR can assist in identifying and mapping perforator vessels for complex flap reconstructions (e.g., DIEP flaps). By projecting pre-operative CT angiography data onto the patient's skin, surgeons can accurately locate and track these vital vessels, improving surgical efficiency and reducing complications.

II. Intraoperative guidance

A. "X-Ray vision": AR headsets (e.g., Microsoft HoloLens) can project internal anatomical structures (bones, nerves, vessels) onto the skin surface during surgery, aiding in precise dissections and avoiding critical structures. This is particularly useful in craniofacial surgery, tumor resections, or deep dissections where vital structures are not immediately visible.

B. Real-time data display: Display of vital signs, imaging data, and pre-planned surgical trajectories within the surgeon's field of view eliminates the need to constantly look away from the surgical field, improving focus and efficiency.

III. Surgical education and training

A. Immersive simulations: AR provides realistic, interactive environments to practice complex procedures without risk to patients. This allows for repetitive practice of delicate maneuvers, anatomical dissections, and emergency scenarios, accelerating skill acquisition.

B. Remote mentoring: Expert surgeons can virtually "join" an operating room via AR streaming to provide real-time guidance and feedback to trainees in remote locations. This democratizes access to specialized expertise and facilitates collaborative learning.

ARTIFICIAL INTELLIGENCE (AI) IN PLASTIC SURGERY

I. Image analysis and diagnosis

A. Skin cancer detection: AI algorithms, particularly deep learning models, can analyze dermatoscopic images with high accuracy to identify suspicious lesions (melanoma, basal cell carcinoma, squamous cell carcinoma), assisting in early diagnosis and referral.

B. Facial analysis and symmetry: AI can objectively analyze facial aesthetics, identify subtle asymmetries, and assist in planning corrective procedures for both aesthetic and reconstructive purposes. This can lead to more consistent and predictable outcomes.

C. Wound healing prediction: Predictive analytics powered by AI can assess various wound characteristics (e.g., size, depth, presence of infection, patient comorbidities) and predict healing trajectories, guiding personalized treatment strategies and identifying patients at risk for delayed healing.

II. Predictive analytics and risk assessment

A. Outcome prediction: AI can analyze vast datasets of patient characteristics, surgical techniques, and postoperative outcomes to predict individualized results and potential complications for specific procedures. This aids in patient counseling and informed consent.

B. Patient selection: Identifying patients who are most likely to benefit from specific procedures or who are at higher risk for adverse events, allowing for more tailored patient selection and pre-optimization strategies.

III. Personalized medicine and treatment planning

A. Tailored approaches: AI can help customize treatment plans based on a patient's unique anatomy (derived from imaging), genetics, and desired outcomes, moving beyond a "one-size-fits-all" approach.

B. Surgical simulation: AI-powered simulations allow surgeons to virtually perform procedures multiple times, optimizing their approach, anticipating challenges, and minimizing errors before touching the patient.

IV. Ethical considerations and limitations

A. Data privacy: Ensuring the security and privacy of sensitive patient data used by AI algorithms is paramount, requiring robust anonymization and secure data handling protocols.

B. Algorithmic bias: Addressing potential biases in AI algorithms that could arise from non-representative training data. If AI models are trained predominantly on data from certain demographics, they may perform suboptimally or even inequitably for other groups.

C. Human oversight: Emphasizing that AI is a tool to augment, not replace, human surgical expertise and judgment. The surgeon remains ultimately responsible for patient care, and AI should serve as a powerful assistant.

NEXT-GENERATION MRI IN PLASTIC SURGERY

I. Enhanced imaging for soft tissue and vascular structures

A. Improved resolution: Next-gen MRI offers significantly higher spatial and contrast resolution, providing unprecedented detail of soft tissues, nerves, and small vessels crucial for plastic and reconstructive surgery. This is invaluable for delineating tumor margins, assessing nerve integrity, and planning intricate microvascular reconstructions.

B. Dynamic imaging (4D Flow MRI): Capturing blood flow in real-time, 4D flow MRI aids in the precise planning of microvascular anastomoses and the detailed assessment of flap perfusion. This can help identify dominant perforators and assess flap viability non-invasively, reducing the need for exploratory surgery.

II. Pre-operative planning and reconstruction

A. Detailed anatomy: Precise visualization of complex anatomical regions (e.g., head and neck, breast, perineum) for accurate tumor resection and comprehensive reconstructive planning. MRI can differentiate various tissue types (muscle, fat, scar tissue, glandular tissue) with superior clarity compared to other modalities.

B. Nerve mapping: High-resolution MRI sequences can aid in mapping peripheral nerves (e.g., brachial plexus, facial nerve branches) for targeted nerve transfers and reconstructions in cases of paralysis or nerve injury, improving functional outcomes.

C. Black bone MRI: Novel capture protocols allow for bony capture with MRI. This technique uses gradient echo sequences with short echo times and optimized contrast settings to enhance the signal from cortical bone, which traditionally appears dark on standard MRI. Black Bone MRI provides high-resolution 3D images of craniofacial skeletal anatomy without radiation exposure, making it particularly valuable in pediatric patients. It is increasingly being explored for applications in surgical planning, craniosynostosis assessment, and even virtual surgical modeling.

III. Monitoring and assessment

A. Flap viability: Non-invasive monitoring of reconstructive flaps for perfusion and early detection of complications like arterial thrombosis or venous congestion, allowing for timely intervention and salvage.

B. Quantitative analysis: Providing objective measurements of tissue volume changes, fluid accumulation, and inflammation, which can be critical for assessing postoperative swelling, hematoma formation, or response to therapy.

IV. Future potential

A. Faster scan times: Innovations aimed at reducing scan times through advanced sequences and AI-powered reconstruction, improving patient comfort and increasing throughput.

B. Integration with AI: AI algorithms can be applied to MRI data for automated image analysis, segmentation (e.g., identifying specific muscle groups or fat compartments), and advanced diagnostics, streamlining workflow and improving diagnostic accuracy.

CONCLUSION

The landscape of plastic surgery is rapidly evolving, driven by these technological advancements. As future leaders in this field, it is imperative to not only understand these innovations but also actively engage with them. Embrace lifelong learning, critical thinking, and ethical considerations as you navigate this exciting era of transformative medical technology. Your ability to integrate these tools thoughtfully and skillfully will define the future of patient care in plastic surgery.

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