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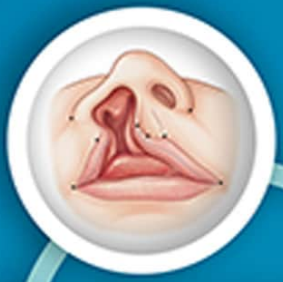

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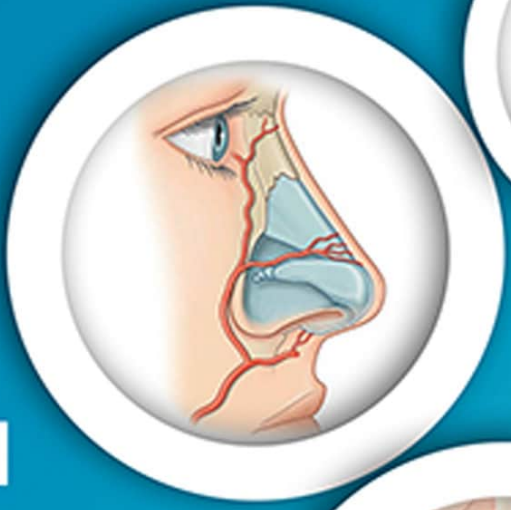

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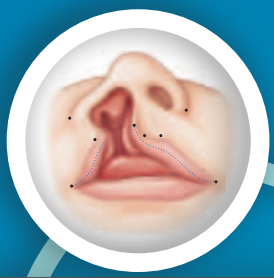

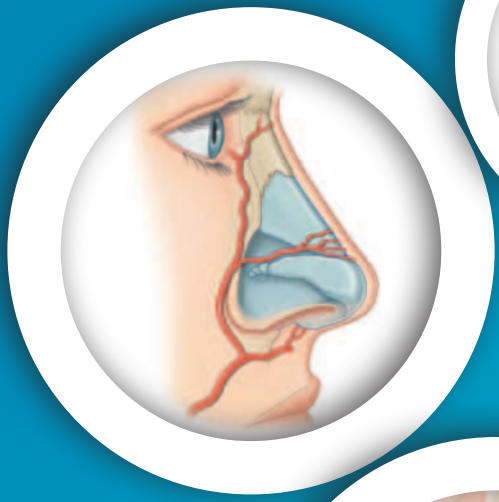

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Philadelphia, PA 19103-2899

REVIEW OF PLASTIC SURGERY, SECOND EDITION ISBN: 978-0-323-77593-9

ISBN: 978-0-323-77593-9

Senior Content Strategist: Belinda Kuhn
Content Development Manager: Meghan Andress
Content Development Specialist: Deborah Poulson
Publishing Services Manager: Shereen Jameel
Project Manager: Nadhiya Sekar
Design Direction: Amy L. Buxton

Printed in the United States of America

Last digit is the print number: 9 8 7 6 5 4 3 2 1

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This book is dedicated to my family, teachers, mentors, and colleagues and to all plastic surgeons—past, present, and future—who carry the legacy of our specialty forward.

PREFACE

When I set out to create *Review of Plastic Surgery*, I had hoped that the book would fulfill a need for students, trainees, and early-career plastic surgeons. Through my own training, I had realized that there was a significant void in exam preparation and plastic surgery review titles. When I approached the wonderful team at Elsevier with my proposal to address this gap, I was optimistic that my review book could help people ease test anxiety, provide a solid foundation in plastic surgery principles, and serve as a guide for future plastic surgeons. I am incredibly humbled and honored to know that the first edition of this book achieved this vision. *Review of Plastic Surgery* has helped thousands of young surgeons worldwide, and I am truly grateful for the incredible opportunity to update this text with a second edition.

Plastic surgery is a vast specialty, encompassing the management of diseases and conditions from head to toe, in both young and old patients. With such a diverse and overarching surgical discipline, it comes as no surprise that our textbooks read like encyclopedias with seemingly limitless pages of detail and descriptions. An entire bookcase can easily be filled with textbook after textbook attempting to cover the topics that we encounter as plastic surgeons. As a student, resident, or young attending, the vastness of plastic surgery can become overwhelming, and it is easy to get lost in the details. One quick look at the six volumes required to cover our specialty in *Plastic Surgery 4th Edition* alone can generate a tremendous amount of heartburn. This is particularly true during examination time, be it the in-service examination for trainees or the written examination for plastic surgery certification.

I vividly remember the anxiety surrounding the exam preparation process and my disbelief at the lack of a "go-to" plastic surgery review book highlighting frequently tested, high-yield facts for the in-service exam and written boards. It seemed that all other specialties had one: a handy companion book with tattered pages of fruitful facts, figures, and illustrations that covered the broad topics and themes of the specialty, perfect for focused studying and examination review. The purpose of this book remains the same—to fill that void and serve as a trustworthy companion to students, residents, and young plastic surgeons alike.

This book is not intended to be a replacement for your favorite plastic surgery textbooks or "encyclopedias," nor is it meant to cover the minutiae of our specialty. Instead, it is intended to provide a foundation of plastic surgery fundamentals and themes to which further details can be added. It is also intended to serve as an added resource for treating the anxiety and heartburn of examination preparation by providing a useful, relevant, and easily accessible collection of high-yield topics and facts covering plastic surgery.

The second edition has been updated and consists of 31 chapters, including a new chapter on Fundamentals of Surgery and Critical Care. Each chapter is conveniently designed to align with the defined topics that are frequently covered in plastic surgery examinations. Within each chapter are numerous pearls of wisdom and abundant facts in bulleted format that cover some of the most frequently tested topics. These pearls are complemented by beautiful figures and illustrations that further drive home important concepts and themes. In addition, each chapter has dedicated exam-style multiple-choice questions written by topic experts from around the world to test your knowledge and enhance your preparation through creation of a practice exam.

It is my sincere hope that you continue to find this book useful and comforting and that it will help to alleviate some of the anxiety associated with rotations, examinations, and review of our awesome specialty. Best of luck!

Donald W. Buck II

FOREWORD

I wrote the following foreword for the first edition. This second edition has been updated, but the concept of the book remains the same, and the fact that it is now appearing in its second edition validates the usefulness of the book. My original foreword below is just as applicable to this second edition:

This book by Donald Buck is unique in several ways. It fills a niche segment of the plastic surgery literature, as it is aimed at residents and fellows training in plastic surgery. However, it is also of use to the full spectrum of those interested in plastic surgery, from medical students to attending physicians. This is not an encyclopedic textbook, nor is it meant to be. It is meant as a review, and that is exactly what it achieves. Each topic is presented in point format, excluding the fluff and including only what has to be known. Condensing information like this requires a lot of skill and knowledge, and Dr. Buck has achieved this with flying colors. The format and layout make it easy to read, yet it is small enough to fit in a backpack or satchel. It is easy to find one's way round this book, and it is ideal for quickly revisiting a topic before rounds or the operating room. It is extremely useful as a review for exams and for testing one's knowledge. This is really the genius of this book. Dr. Buck has invited renowned and recognized experts not specifically to write chapters, as most textbook editors do, but rather to write self-assessment questions that are fashioned as board-type questions. These individuals are not only household names in the specialty but are also obviously experienced in the topic, as well as in educating residents and, more importantly, in examining them. This makes this book unique and incredibly useful.

Dr. Buck is to be congratulated for not only compiling this book but also having the wit to use his experts in an ingenious way. In doing so, he has contributed invaluably to the education of the next generation of plastic surgeons. I think this book will become a standard resource for medical students, residents, and fellows.

Peter C. Neligan

ACKNOWLEDGMENTS

First, I would like to thank the incredible Elsevier team for the opportunity to create this second edition of my book. It is always a pleasure working alongside Belinda Kuhn and Deborah Poulson. Thank you both for your support, encouragement, expertise, and efforts in putting this book together during a global pandemic. I also want to thank all of the past contributors who gave their time and added their expertise to help make *Review of Plastic Surgery* a success—I am truly grateful!

Finally, and most importantly, I would like to thank my beautiful wife, Jennifer, and my children, Benjamin and Brooke, for their love and support. They are my inspiration, and without them none of this would have been possible.

DWB

CONTENTS

1

Anesthesia, Practice Management, Patient Safety, and Coding

Donald W. Buck II, M.D. FACS

GENERAL ANESTHESIA

1. Intravenous agents: primarily used for induction of anesthesia or sedation anesthesia, such as monitored anesthesia care (MAC) sedation
   - Propofol is commonly used because it is short acting, associated with smooth emergence, and reduction of nausea and vomiting. Limitations of propofol include hypotension and pain on injection
   - Ketamine causes a dissociative state and is the only induction agent that increases blood pressure and heart rate
     - Frequently used for conscious sedation in children
     - Intravenous ketamine has more rapid onset, shorter duration of action, and a lower risk of laryngospasm than intramuscular ketamine (Table 1.1)
2. Inhalational agents: often used today for maintenance of anesthesia after intravenous induction
   - Supplemented by intravenous opioids for pain and muscle relaxants or paralytics
   - Most commonly used agents today are isoflurane, sevoflurane, and desflurane (Table 1.2)
3. Neuromuscular blocking agents: useful for muscle paralysis as well as rapid induction
   - Two categories of agents: depolarizing and nondepolarizing
   - Succinylcholine
     - The only depolarizing agent still in use
     - Typically used only for rapid sequence intubation (produces rapid onset and short duration of action)
     - Disadvantages: associated with malignant hyperthermia and hyperkalemia (especially with burns, paralyzed patients, and massive trauma patients)
   - Nondepolarizing agents
     - Most commonly used today
     - Longer duration of action
4. Opioids: used as adjuncts to anesthesia for analgesia
   - Most common agents: fentanyl- and synthetic fentanyl–based agents (e.g., sulfentanil, remifentanil, alfentanil), morphine, hydromorphone, and meperidine
     - Fentanyl, and its synthetic derivatives, is frequently used because it is 100–150 times more potent than morphine and has a rapid onset and short duration of action
   - Disadvantage of opioids: respiratory depression
5. Benzodiazepines: frequently used for anxiolysis before induction, amnesia, as well as in some conscious sedation protocols
   - Common agents include diazepam and midazolam
   - Useful for the treatment of local anesthetic toxicity

LOCAL ANESTHESIA

1. Delivery of anesthetic to local tissues to provide focused anesthesia to the surgical site/field
2. Local anesthetic agents are frequently used with regional blocks, conscious sedation, and deep sedation techniques; may also be used with general anesthesia to provide postoperative anesthesia or assist with hemostasis (e.g., epinephrine effects)
3. Two classes: Ester and amides
   - Ester compounds are more rapidly hydrolyzed by plasma pseudocholinesterases and have shorter durations of action
     - Allergic reactions to local anesthetics are much more common with Ester compounds
   - Amide compounds are degraded by the liver
4. Commonly used local anesthetic agents (Table 1.3)
5. 4% topical cocaine: commonly used earlier for nasal surgery (e.g., rhinoplasty, septoplasty) because of rapid mucosal absorption and subsequent onset of action
   - Maximum dosage: 1.5 mg/kg
   - Infrequently used today because of the potential for coronary vasoconstriction
6. Epinephrine: frequently added to local anesthetics to provide
   - A slight increase in the maximum dosage of anesthetic allowed
   - Local vasoconstriction
     - Reduces the amount of anesthetic required for effect due to reduction in diffusion of the compound
     - Assists with hemostasis
     - For best hemostatic effects, it has been recommended to wait at least 25 minutes from injection prior to incision
   - Epinephrine-containing lidocaine compounds have been safely used in the digits
     - Treatment of ischemia related to epinephrine (e.g., a pale finger) injection includes conservative measures (e.g., elevation; consider warm/cold compresses) and phentolamine injection

TABLE 1.1 Clinical Characteristics of Intravenous Induction Agents

Intravenous Induction Agent	Dose (mg/kg)	Comments	Side Effects	Situations Requiring Caution	Relative Indications
Thiopental	2–5	Inexpensive; slow emergence after high doses	Hypotension	Hypovolemia; compromised cardiac function	Suitable for induction in many patients
Ketamine	1–2	Psychotropic side effects controllable with benzodiazepines; good bronchodilator; potent analgesic at subinduction doses	Hypertension; tachycardia	Coronary disease; severe hypovolemia	Rapid sequence induction of asthmatics, patients in shock (reduced doses)
Propofol	1–2	Burns on injection; good bronchodilator; associated with low incidence of postoperative nausea and vomiting	Hypotension	Coronary artery disease; hypovolemia	Induction of outpatients; induction of asthmatics
Etomidate	0.1–0.3	Cardiovascularly stable; burns on injection; spontaneous movement during induction	Adrenal suppression (with continuous infusion)	Hypovolemia	Induction of patients with cardiac contractile dysfunction; induction of patients in shock (reduced doses)
Midazolam	0.15–0.3	Relatively stable hemodynamics; potent amnesia	Synergistic ventilatory depression with opioids	Hypovolemia	Induction of patients with cardiac contractile dysfunction (usually in combination with opioids)

Reprinted from Townsend CM, Beauchamp RD, Evers BM, et al. *Sabiston Textbook of Surgery.* 19th ed. Philadelphia: Elsevier Saunders; 2012.

TABLE 1.2 Important Characteristics of Inhalational Agents

Anesthetic	Potency	Speed of Induction and Emerging	Suitability for Inhalational Inductions	Sensitization to Catecholamines	Metabolized (%)
Nitrous oxide	Weak	Fast	Insufficient alone	None	Minimal
Diethyl ether	Potent	Very slow	Suitable	None	10
Halothane	Potent	Medium	Suitable	High	20+
Enflurane	Potent	Medium	Not suitable	Medium	<10
Isoflurane	Potent	Medium	Not suitable	Minimal	<2
Sevoflurane	Potent	Rapid	Suitable	Minimal	<5
Desflurane	Potent	Rapid	Not suitable	Minimal	0.02

Reprinted from Townsend CM, Beauchamp RD, Evers BM, et al. *Sabiston Textbook of Surgery.* 19th ed. Philadelphia: Elsevier Saunders; 2012.

TABLE 1.3 Commonly Used Local Anesthetic Agents

Agent	Class	Duration of Action (min)	Recommended Dosage Guidelines (mg/kg)	Maximum Total Damage (mg)
Procaine (Novocain)	Ester	15–60	7	35–600
Chloroprocaine (Novocain)	Ester	15–30	Without epinephrine: 11	800
			With epinephrine: 14	1000
Lidocaine (Xylocaine)	Amide	30–60	Without epinephrine: 4.5	300
		120–360	With epinephrine: 7	
Mepivacaine (Carbocaine)	Amide	45–90	7	400
Bupivacaine (Marcaine)	Amide	120–240	Without epinephrine: 2.5	175
		180–420	With epinephrine: 2.5–4	225–400
Prilocaine (Citanest)	Amide	30–90	8	500–600

Reprinted from Mustoe TA, Buck DW, Lalonde DH. The safe management of anesthesia, sedation, and pain in plastic surgery. *Plast Reconstr Surg.* 2010;126(4):165–176. Adapted from multiple sources.

7. Toxicity: although rare, systemic toxicity can be observed with excess local anesthetic administration
   - Signs of toxicity
     - Headache, tinnitus, perioral and tongue paresthesias (early findings)
     - Restlessness
     - Seizures
     - Respiratory arrest and cardiac collapse (late finding)
   - Treatment
     - Respiratory and circulatory support (e.g., airway control, 100% oxygen administration, intravenous fluids)
     - Benzodiazepines (useful for early neurologic signs)
     - Intravenous lipid administration
   - Intra-arterial injection of bupivacaine can cause irreversible heart block and cardiac collapse
8. Tumescent solution (also known as "wetting solution"): prepared by combining lidocaine and epinephrine to saline to create a dilute solution of local anesthetic that can be safely infiltrated into the soft tissues
   - Allows for much larger dosages of lidocaine use (up to 35 mg/kg)
   - Systemic levels of lidocaine peak at 12–14 hours below the clavicles and 6–12 hours above the clavicles
     - This is important when performing both trunk and head and neck procedures to prevent overlap of peaks and potential for toxicity
9. Topical anesthetics: topical combination anesthetic formulations that are useful in children to provide anesthesia without the trauma of injection
   - Common agents
     - LET (lidocaine, epinephrine, and tetracaine)
     - Eutectic mixture of local anesthetics (EMLA), lidocaine, and prilocaine; small risk of methemoglobinemia because of the prilocaine
     - ELA-Max (liposomal lidocaine): more rapid onset of action
   - Disadvantages: requires prolonged contact with site for anesthetic effect (e.g., 30–60 minutes)
10. Regional nerve block: involves infiltration of local anesthetic in the vicinity of a sensory nerve distant from the surgical site to provide local anesthesia
    - Advantages: avoids tissue distortion from anesthetic infiltration; reduces the amount of anesthetic required for effect
    - Bier block: use of a double tourniquet and intravenous administration of lidocaine to provide upper extremity anesthesia
      - Lidocaine toxicity can occur with a nonfunctioning tourniquet, inappropriate early release of the tourniquet, and a poorly functioning tourniquet (e.g., a tourniquet that is too small or too large for the given extremity)
11. Conscious sedation: a combination of anesthetics and opioids to provide an altered level of consciousness to a relaxed state while maintaining airway protection
    - Titration of medications is tailored to the patient's vital signs and state of alertness
    - Most recommend small, incremental dosing of sedation agents to maintain a stable level of anesthesia and reduce the risk for overmedication and oversedation
    - Advantages: reduced risk of deep venous thrombosis, postoperative nausea and vomiting (PONV), faster recovery, and fewer unplanned admissions
    - Common agents for conscious sedation (Table 1.4)

COMPLICATIONS OF ANESTHESIA

1. Allergy
2. Cardiovascular toxicity
3. PONV
   - Affects approximately one-third of all surgical patients
   - Multifactorial etiology and includes the chemoreceptor trigger zone within the brain stem
     - The chemoreceptor trigger zone has receptors for dopamine, acetylcholine, histamine, and serotonin
   - Risk factors: female sex, nonsmoking status, history of PONV, history of opioid-induced nausea and vomiting, inhalational anesthetics, long operative duration, and young age
   - Treatment is pharmacologic, with a focus on prophylaxis in high-risk patients (Table 1.5)
4. Malignant hyperthermia: life-threatening hypermetabolic event that occurs after exposure to inhalational anesthetics (e.g., halothane, enflurane, isoflurane, sevoflurane) and depolarizing muscle relaxants (e.g., succinylcholine)
   - Autosomal dominant inheritance with variable penetrance
   - Clinical manifestations
     - Fever
     - Tachycardia

TABLE 1.4 Commonly Used Agents for Conscious Sedation

Agent	Class	Common Dosage Guidelines	Side Effects
Midazolam	Benzodiazepine	0.5–1 mg every 5–10 min per patient alertness	Respiratory depression, somnolence, amnesia
Diazepam	Benzodiazepine	10–50 mg preoperatively	Respiratory depression, somnolence
Lorazepam	Benzodiazepine	0.5–2 mg per os 0.25–1 mg intravenously	Respiratory depression, somnolence
Ketamine	Dissociative anesthetic	200–750 mcg/kg bolus, followed by 5- to 20-mcg/kg/min infusion	Hallucinogens, delirium, intracranial hypertension, increased respiratory secretions, cardiac simulation
Clonidine	Alpha-2 agonist	0.1–0.2 mg preoperatively	Hypotension, rebound tachycardia, flushing
Fentanyl	Opioid receptor agonist	25–50 mcg every 5–10 min per patient alertness	Respiratory depression, somnolence, nausea, vomiting
Reversal Agents			
Flumazenil	Benzodiazepine receptor antagonist	0.2-mg incremental doses to maximum of 1 mg	Dizziness, blurred vision, headache, nausea, flushing, injection-site pain, agitation
Naloxone	Opioid antagonist	0.1- to 0.2-mg incremental doses every 2–3 min to desired degree of reversal	Hypotension, hypertension, arrhythmias, dyspnea, pulmonary edema, agitation, flushing, nausea

Reprinted from Mustoe TA, Buck DW, Lalonde DH. The safe management of anesthesia, sedation, and pain in plastic surgery. *Plast Reconstr Surg.* 2010;126(4):165–176. Adapted from multiple sources.

TABLE 1.5 Commonly Used Antiemetic Agents

Drug Class	Common Side Effects
Dopamine Receptor Antagonists (DA-2)	
Phenothiazines	Sedation
Fluphenazine	Dissociation
Chlorpromazine	Extrapyramidal effects
Prochlorperazine	
Butyrophenones	
Droperidol	
Haloperidol	
Substituted benzamide	
Metoclopramide	
Antihistamines (H)	
Diphenhydramine	Sedation
Promethazine	Dry mouth
Anticholinergics	
Scopolamine	Sedation
Atropine	Dry mouth
	Tachycardia
Serotonin Receptor Antagonists	
Ondansetron	Headache
Dolasetron	
Corticosteroids	
Dexamethasone	Glucose intolerance
Methylprednisolone	Altered wound healing
Hydrocortisone	Immunosuppression

Reprinted from Townsend CM, Beauchamp RD, Evers BM, et al. *Sabiston Textbook of Surgery.* 19th ed. Philadelphia: Elsevier Saunders; 2012.

- Arrhythmia
- Acidosis
- Muscle rigidity
- Tachypnea
- Skin flushing
- Hypotension
- Rhabdomyolysis
- Increased end-tidal CO_2

- Characterized by increased end-tidal CO_2, hyperkalemia, hyperphosphatemia, and metabolic acidosis
- Treatment: hyperventilation with 100% oxygen, dantrolene administration, termination of surgery, and supportive care

5. Methemoglobinemia
   - Rare, life-threatening complication associated with topical and local anesthetics (e.g., prilocaine, benzocaine, lidocaine)
   - The anesthetic oxidizes the iron component of hemoglobin such that it cannot bind and transport oxygen
   - Characterized by progressive signs including graying of skin, headache, weakness, cyanosis with brown discoloration of blood, arrhythmias, seizures, and finally anoxic brain injury and death
   - Treatment: administration of 100% oxygen, intravenous methylene blue

PAIN CONTROL

1. Effective postoperative pain control is important for patient comfort, as well as surgical outcome, because untreated pain is associated with prolonged hospital stay, deep venous thrombosis, pulmonary embolus, pneumonia, bowel dysmotility, insomnia, and impaired wound healing
2. Many analgesics today can be administered orally, intravenously, intramuscularly, or locally through indwelling pain "pumps" and patient-controlled systems
3. For severe pain, multimodality and/or multidrug treatment is often necessary
4. Commonly used analgesic agents (see Table 1.6)

ENHANCED RECOVERY AFTER SURGERY

1. Enhanced recovery after surgery (ERAS) protocols are often multimodal, multidisciplinary perioperative care approaches to achieve rapid recover after surgery
2. Many procedure-specific ERAS pathways provide consensus recommendations for postoperative analgesia based on procedural likelihood of producing persistent postoperative pain that is generally considered neuropathic in origin (e.g., mastectomy, thoracotomy, and abdominal procedures)
3. The primary goal of ERAS pain therapy: pain relief which allows early ambulation and movement ("dynamic" pain relief), and reduces opioid use
4. The ideal multimodal dynamic pain relief technique for ERAS protocols typically includes wound infiltration or a peripheral nerve block with a long-acting local anesthetic, such as liposomal bupivacaine, combined with NSAIDs or COX2 inhibitors
5. The addition of pregabalin and gabapentin has also been shown to reduce postoperative narcotic needs

PRACTICE MANAGEMENT

1. Health Insurance Portability and Accountability Act (HIPAA): created to protect patient privacy, covers medical records and photography
   - Patients must be notified of their rights with respect to their personal medical information
     - Right to restrict use/disclosure
     - Right to inspect/copy records
     - Right to amend records
     - Right to audit the disclosure of records
   - Personal medical information must be recorded in a de-identified manner for research purposes. This information includes:
     - Patient name
     - Contact information
       - Address
       - Telephone/fax numbers
       - Email address
     - Identification numbers
       - Social security number
       - Medical record number
       - Insurance numbers
       - Other account numbers
       - Driver's license number
       - Medical device serial numbers
     - Photographs involving the full face or other identifiable body markers (e.g., tattoos)
     - Date of birth
     - Age and sex are not considered identifiers

TABLE 1.6 Commonly Used Analgesics

Agent	Class	Route	Dosage Guidelines	Maximum Daily Dosage	Side Effects/Adverse Reactions
Acetaminophen	NSAID	PO, PR	325–650 mg every 6–8 hr	4000 mg	Hepatic dysfunction in overdose; reduce dose in alcoholics
Ibuprofen	NSAID	PO	200–800 mg	2400 mg	Bleeding, gastrointestinal discomfort, renal failure
Ketorolac	NSAID	IV	30 mg every 8 hr	90 mg	Bleeding, gastrointestinal discomfort, renal failure
Diclofenac	COX-2 inhibitor	PO	75 mg BID	150 mg	Bleeding, gastrointestinal discomfort, renal failure
Celecoxib	COX-2 inhibitor	PO	100–200 mg BID	200–400 mg	Gastrointestinal discomfort, CV risk
Rofecoxib	GABA analog	PO	12.5 mg daily	25 mg	Gastrointestinal discomfort, CV risk
Gabapentin	GABA analog	PO	300–600 mg TID	3600 mg (limit dose in renal failure patients)	Dizziness, somnolence, peripheral edema
Pregabalin	Weak opioid	PO	75–150 mg BID	300–450 mg	Dizziness, somnolence, confusion, dry mouth, blurred vision
Tramadol	Weak opioid	PO, IV, IM	50–100 mg QID		Sedation
Codeine	Weak opioid	PO	15–60 mg every 4 hr	3 mg/kg/day	Sedation
Morphine	Strong opioid	IV	1–2 mg every 2–4 hr		Respiratory depression, nausea, vomiting
Hydromorphone	Strong opioid	PO	2–10 mg every 6 hr		Respiratory depression, constipation, nausea, hypotension
		IV	0.25–1 mg every 2–4 hr		
Acetominophen/ hydrocodone	Mixed	PO	500 mg/5 mg every 4–6 hr	4000 mg acetaminophen	Lightheadedness, dizziness, nausea, vomiting

Reprinted from Mustoe TA, Buck DW, Lalonde DH. The safe management of anesthesia, sedation, and pain in plastic surgery. *Plast Reconstr Surg.* 2010;126(4):165–176. Adapted from multiple sources.
BID, twice daily; *COX-2,* cyclooxygenase-2; *CV,* cardiovascular; *GABA,* gamma-amniobutyric acid; *IM,* intramuscularly; *IV,* intravenously; *NSAID,* nonsteroidal antiinflammatory drug; *PO,* per os (by mouth); *PR,* per rectum; *QID,* four times daily; *TID,* three times daily.

- Medical information cannot be discussed with anyone other than the patient unless prior consent and permission have been obtained from the patient or the patient is a minor (i.e., < 18 years old)

2. Informed consent
   - Elements of discussion and documentation that are required for adequate consent
     - Diagnosis requiring treatment
     - Procedural risks, potential complications, and potential side effects
     - Probability of success based on the patient's medical condition
     - Available alternative methods of treatment
     - Risks associated with noncompliance with postprocedure recommendations and/or restrictions
3. Employment policies/practices
   - It is illegal to discriminate against an applicant, or employee, because of
     - Age
     - Religion
     - Nation of origin
     - Race
     - Sex
     - Child care responsibilities
     - Health-related disabilities
     - Arrest history
   - As such, inquiries into any of the above aspects during the application or interview process are unethical and considered illegal
   - It is legal to ask questions about an applicant's or employee's background or to require a background check
4. Medicare: the federal health insurance program for people aged 65 years or older, younger people with certain disabilities, or people with end-stage renal disease
   - Medicare has four parts, which help to cover specific services:
     i. Medicare Part A: covers services and supplies considered medically necessary to treat a disease. These services include inpatient hospital care, skilled nursing facility care, and hospice environments
     ii. Medicare Part B: covers medically necessary services and preventative care services including physician services, durable medical equipment, and mental health services
     iii. Medicare Part C: also known as Medicare Advantage. Part C allows for a Medicare-eligible individual to select an approved private health insurance plan that covers both Part A and Part B
     iv. Medicare Part D: covers prescription drugs to original Medicare (Part A/B), and can be added to Medicare Advantage plans if prescription drug coverage is not already included
5. Medicaid: a joint federal and state program that provides health coverage to children, pregnant women, parents, seniors, and individuals with disabilities
   a. Medicaid is the single largest source of health coverage in the United States
   b. To participate in Medicaid, federal law requires states to cover certain groups of individuals, including low-income families, qualified pregnant women and children, and individuals receiving supplemental security income
6. American Society of Plastic Surgeons (ASPS) Code of Ethics
   a. Charitable events/donations: Participation in charitable events is permitted under the code of ethics; however, services which imply performance of a procedure for which the patient has not been medically evaluated, or those procedures which require an incision, cannot be donated

PATIENT SAFETY

1. American Society of Anesthesiologists (ASA) classification (Table 1.7)
   - Correlates with overall health of the patient and surgical outcome (i.e., higher ASA is associated with a patient in poorer health and with a greater risk for morbidity and/or mortality from surgery/anesthesia)
2. Deep venous thrombosis
   - Risk factors
     - History of prior venous disease
     - Obesity (body mass index > 30)
     - Immobility
     - Diabetes
     - Smoking
     - History of cancer
     - Increased age
     - Long duration of surgery
     - General anesthesia
     - Abdominoplasty and/or suction-assisted lipectomy
     - Prolonged hospital stay > 4 days
     - Caprini score > 8
   - Prophylaxis
     - Compression stockings
     - Intermittent pneumatic compressive devices
       - Must be placed before induction of anesthesia
     - Preoperative and/or postoperative anticoagulation (e.g., low-molecular-weight heparin, subcutaneous heparin) is generally recommended for high-risk patients
   - Characterized by localized swelling and pain of the affected extremity, exacerbation in the dependent position
     - Often asymptomatic
     - Occasionally present with pulmonary embolus, tachycardia, hypotension, and respiratory distress
   - Diagnosis: high index of suspicion, duplex ultrasound
     - Ventilation-perfusion (V/Q) scan, spiral chest CT for pulmonary embolus
   - Treatment
     - Supportive care (e.g., supplemental oxygen, airway protection)
     - Anticoagulation (e.g., heparin, low-molecular-weight heparin, coumadin, fondaparinux in patients with heparin-induced thrombocytopenia, rivaroxaban)
3. Evidence-based medicine: use of the best available evidence to make informed clinical decisions regarding the care and treatment of patients. The quality of available clinical studies is often rated according to the level of evidence, as described by the ASPS (Table 1.8)
4. Joint Commission Universal Protocol
   a. Established to prevent wrong site, wrong procedure, and wrong person surgery
   b. Requires the following three steps:
      i. The proper preoperative identification of the patient by the three members of the team (surgeon, anesthesiologist, and nurse)
      ii. Preoperative marking of the surgical site
      iii. A final "time out" just prior to the surgery or procedure regardless of where it is performed
5. The American Association for Accreditation of Ambulatory Surgery Facilities (AAAASF) Requirements for certified facilities:
   a. Surgeon must be Board Certified or Board Eligible with a Board recognized by the American Board of Medical Specialties
   b. Patients who undergo general anesthesia need a responsible adult to supervise them for 12–24 hours
   c. Surgeons are required to demonstrate that they hold unrestricted hospital privileges at an acute-care hospital within 30 minutes' driving time of the ambulatory facility
   d. If pediatric patients are cared for, at least one member of the team needs to be certified in Pediatric Advance Life Support (PALS)
   e. Ambulatory care facilities are inspected every 3 years by the AAAASF

TABLE 1.7 American Society of Anesthesiologists (ASA) Classification

ASA I	Normal healthy patient without active disease
ASA II	Patient with mild systemic disease (e.g., hypertension under medical control)
ASA III	Patient with severe systemic disease
ASA IV	Patient with severe systemic disease that is a constant threat to life
ASA V	Patient who is moribund and not expected to survive without surgery
ASA VI	Patient who has been declared brain dead for organ donation

Reprinted from Halperin B. Chapter 8: Patient safety in plastic surgery. In: Neligan PC, ed. *Plastic Surgery*. 3rd ed. China: Elsevier; 2013:124–136.

BILLING AND CODING

1. Billing is performed based on current procedural terminology (CPT) codes used to describe the operation being performed, and/or the evaluation being conducted
   - Evaluation and management (E/M) codes: used to report evaluation and management services that are provided in the office, outpatient facility, ambulatory facility, hospital, and in consultation
     - Level of service is dependent on evaluation of six of seven components (in order of importance): history, examination,

TABLE 1.8 Levels of Evidence

Level of Evidence	Types of Studies	Quality
I	Multicentered or single-centered, randomized controlled trial with adequate power, or systemic review of these studies	Highest
II	Randomized controlled trial without adequate power, prospective cohort of comparative study, or systemic review of these studies	
III	Retrospective cohort or comparative study, case-control study, or systemic review of these studies	
IV	Case series with pre/post-test; or only post-test	
V	Expert opinion developed via consensus process, case report or clinical example	Lowest

medical decision making, counseling, coordination of care, nature of the presenting problem, and time
- Procedural codes: used to report the procedures/operations that were performed
  - Surgical codes include preoperative visits if the decision for surgery was made at a prior visit; local anesthesia; immediate postoperative care; writing orders; evaluation of the patient in the postanesthesia care unit; typical postoperative follow-up care (as defined by the global period)

2. Global period: period following a procedure in which any associated aftercare, including office visits, is considered to be "included" in the CPT code billed
   - The global period varies according to operation and is often based on complexity (e.g., most operations have a global period of 90 days, whereas skin excisions often have a global period of 10 days)
   - An exception to the global period rule is for complications requiring a return to the operating room
3. Many bundled or global CPT codes include most steps or components of an operation or procedure, such that each individual step cannot be coded separately. Common examples relevant to plastic surgery:
   - Excision of lesion codes (both benign and malignant) includes simple closure (single layer); however, intermediate and/or complex closure codes can be listed separately
   - Debridement codes cannot be used with wound closure codes because they are used only for wounds, which are allowed to heal secondarily
     - Debridement codes are reported by the depth of tissue removed and surface area
     - If debridement is performed in the operating room before wound closure, the "surgical preparation of wound bed" codes should be used
   - Free-flap CPT codes include exposure of recipient vessels, microvascular anastomosis and use of the surgical microscope, flap harvest and elevation, and primary closure of the donor site
     - If closure of the donor site requires additional procedures (e.g., split thickness skin graft, adjacent tissue transfer), these procedures can be coded as well
   - Adjacent tissue transfer codes include the excision of a skin lesion, and, thus, the excision cannot be separately coded
   - Nerve decompression codes generally include external neurolysis but do not include internal neurolysis (e.g., carpal tunnel release)
   - Use of the surgical microscope is included in all microsurgery/free-flap codes, except for codes involving nerve repair
   - Capsulotomy is included in the CPT code for stage II prosthetic breast reconstruction procedures in which expanders are being replaced with permanent implants. If a total capsulectomy is performed, it can be coded separately
   - Fat grafting codes include all of the steps from harvest, processing, to injection. The code is used by anatomic area grafted, thus multiple sites of grafting allow for separate coding
   - The breast reconstruction revision code (19380) should be used only in a patient who is undergoing revision of a previously completed reconstruction, and not for routine stage II expander-to-implant exchange procedures
4. Billing for combined reconstructive cosmetic and reconstructive procedures (e.g., abdominoplasty, and umbilical hernia repair)
   - The patient must be billed separately for the cosmetic portion of the operation, including the associated hospital and anesthesia fees
   - This separation is based on time during the operation
     - The surgeon informs the operating room staff when the cosmetic surgery portion is being performed and the time is documented

COMMON CURRENT PROCEDURAL TERMINOLOGY CODE DEFINITIONS

1. Lesion excisions are coded according to the longest diameter of lesion plus the margin
2. Skin closure methods are coded according to the length of the closure
   - If multiple closure procedures are performed on a patient, the closure method is coded according to the sum of the lengths closed using that particular method (e.g., all simple closure lengths are added, intermediate closure lengths are added)
3. Skin closure definitions
   - Simple repair includes all simple one-layered closures
     - Simple repair is included in all excision codes
   - Intermediate repair includes all multilayer closures or single-layer closure of heavily contaminated wounds
   - Complex repair includes wounds requiring more than a one-layered closure (e.g., scar revision, debridement, extensive undermining, stents or retention sutures)
   - Adjacent tissue transfer includes all types of local tissue rearrangement (e.g., local flaps, Z plasty, rotation-advancement flaps, bilobed flaps, rhomboid flaps, Ryan flaps) that are not based on a defined pedicle or axial blood supply
     - Coded according to the area of the defect plus the donor site
     - Coded per defect, not per flap
     - Excision of a lesion is included in all adjacent tissue transfer codes
4. Code modifiers: used to further define or describe the procedure
   - 22 modifier identifies increased complexity or procedural services required for that particular code
   - 52 modifier identifies decreased complexity or procedural services required for that particular code
   - 50 modifier identifies bilateral cases (e.g., breast reduction, brachioplasty)
   - 51 modifier identifies multiple combined procedures performed
   - 59 modifier identifies procedures that were distinct and should be considered independent (e.g., resection of multiple malignant lesions from the same anatomic area)
   - 62 modifier identifies procedure that was performed with a cosurgeon, where each surgeon is performing a separately documented part of the operation

SUGGESTED READINGS

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2

Principles of Surgery, Trauma, Transplantation, and Critical Care

Donald W. Buck II, M.D. FACS

HEMATOLOGY

1. Coagulation cascade: initial response to vascular injury is vasoconstriction, platelet adhesion, and thrombin generation (from the intrinsic or extrinsic pathway) which will convert fibrinogen to fibrin
   - Intrinsic pathway: activated by exposed collagen and clotting factor XII
   - Extrinsic pathway: activated by tissue factor from injured cells and clotting factor VII
   - Factor X is the convergence point for both paths
     - Factor X, factor V, calcium, platelet factor 3, and prothrombin form on platelets and together catalyze the formation of thrombin from prothrombin
   - Fibrin links platelets together to form a platelet plug and create hemostasis
   - Thrombin is the key to coagulation: it converts fibrinogen to fibrin, and also activates factors V, VII, and platelets
   - Thromboxane: from platelets; increases platelet aggregation and promotes vasoconstriction; triggers calcium release from platelets
   - Factors II, VII, IX, and X are vitamin K dependent
2. Anticoagulation (Fig. 2.1)
   - Antithrombin III: key to anticoagulation as it binds and inhibits thrombin, inhibits factors IX, X, and XI
   - Protein C: vitamin K-dependent protein that degrades factors V and VIII, and degrades fibrinogen
   - Protein S: vitamin K-dependent protein that is a cofactor for protein C
   - Tissue plasminogen activator (tPA): released from endothelium and converts plasminogen to plasmin
   - Plasmin: degrades factors V and VIII, fibrinogen, and fibrin resulting in loss of platelet plug
   - Prostacyclin: from endothelium, decreases platelet aggregation and promotes vasodilation
3. Coagulation measurements
   - Prothrombin time (PT): good marker of liver function by measuring factors II, V, VII, X, and fibrinogen
   - Partial thromboplastin time (PTT): measures all factors except VII and XIII. Range for routine anticoagulation is 60–90 seconds
   - International normalized ratio (INR): measures a ratio of patient PT compared with a control PT in an effort to remove laboratory variability in testing. INR $>$ 1.5 considered anticoagulated and relative contraindication to surgical procedures
4. Coagulant products
   - Cryoprecipitate: contains the highest concentration of von Willebrand factor (vWF) and factor VIII; also contains fibrinogen
   - Fresh frozen plasma (FFP): includes all clotting factors, protein C, protein S, and antithrombin III
     - Effect in reversing anticoagulation is almost immediate
   - Desmopressin (DDAVP): causes release of factor VIII and vWF from endothelium
   - Vitamin K: provides support for vitamin-K dependent factor synthesis and activity
     - Effect in reversing anticoagulation is up to 12 hours
   - Tranexamic acid: synthetic lysine which inhibits conversion of plasminogen to plasmin; has been shown to reduce intraoperative and postoperative blood loss if administered at the time of cranial reconstruction in infants
5. Bleeding disorders
   - von Willebrand's disease
     - Most common congenital bleeding disorder
     - Characterized by frequent nose bleeds
     - Can have normal PT, but abnormal PTT, with long bleeding time
     - Treatment: cryoprecipitate, DDAVP
       - Preoperative DDAVP dosage is determined by preoperative measurement of activity levels of vWF:ristocetin cofactor (vWF:RCoF), and coagulation factor VIII
   - Hemophilia
     - Hemophilia B: factor IX deficiency; prolonged PTT; treatment: recombinant factor IX or FFP
     - Hemophilia A: factor VIII deficiency; characterized by bleeding into joints; prolonged PTT; treatment: recombinant factor VIII or cryoprecipitate
   - Platelet disorders
     - Glanzmann's thrombocytopenia: GpIIb/IIIa receptor deficiency on platelets; treatment: platelet transfusion
     - Bernard-Soulier syndrome: GpIb receptor deficiency (cannot bind collagen); treatment: platelet transfusion
     - Heparin-induced thrombocytopenia (HIT): caused by antiheparin antibodies which can result in platelet destruction and platelet aggregation/thrombosis
       - Characterized by: platelets $<$ 100, $>$ 50% drop in platelets after heparin administration, or thrombosis while on heparin

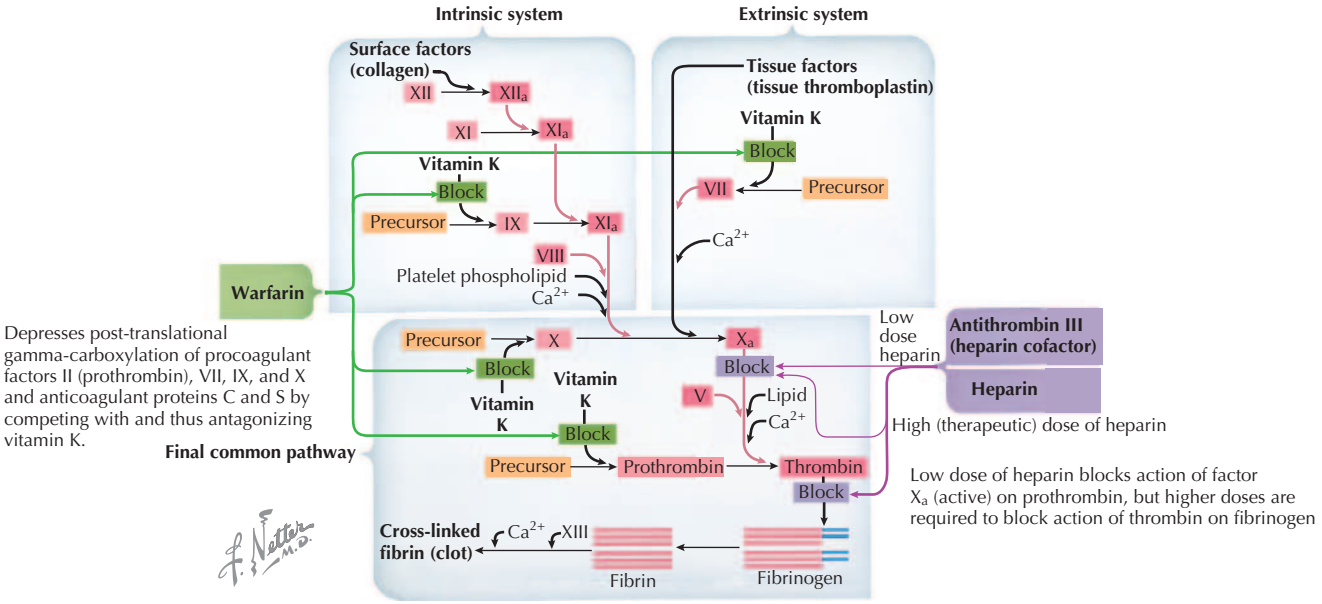


Fig. 2.1 The cascade of clotting factors and sites of action of warfarin and heparin. (Reprinted with permission from Teplick A. Disorders of Thrombosis and Hemostasis. Netter illustration used with permission of Elsevier Inc. All rights reserved. www.netterimages.com)

- Treatment: stop heparin, start argatroban which is a direct thrombin inhibitor

6. Hypercoagulable disorders
   - Factor V Leiden: most common congenital hypercoagulability disorder
     - Caused by mutation resulting in resistance to activated protein C
     - Treatment: heparin, warfarin
   - Protein C or S deficiency: treatment by heparin or warfarin
   - Antiphosopholipid antibody syndrome
     - Characterized by history of thrombosis, miscarriages; often associated with lupus
     - Have a prolonged PTT but are hypercoagulable; PTT not corrected with FFP
     - Antibodies include anticardiolipin and lupus anticoagulant
     - Treatment: heparin or warfarin
7. Anticoagulation drugs
   - Heparin
     - Unfractionated heparin: activates antithrombin III; also neutralizes prothrombin and factor Xa; reversed with protamine
     - Low-molecular-weight heparin has lower risk of HIT; activates antithrombin III and neutralizes factor Xa; not reversible with protamine
     - Recommended to stop 12–24 hours before surgery
   - Warfarin
     - Inhibits vitamin-K dependent factor activity; must follow INR levels
     - Reversed with vitamin K and FFP
     - Recommended to stop 7 days before surgery; can bridge to surgery with heparin where necessary
   - Rivaroxaban
     - Direct thrombin inhibitor; not reversible
   - Argatroban
     - Direct thrombin inhibitor; often used in patients with HIT
   - Aspirin
     - Inhibits cyclooxygenase in platelets which decreased thromboxane
     - Many recommend that full-strength aspirin (325 mg) be stopped 7 days before major surgery
     - Recent research supports continuation of aspirin therapy in all minor cutaneous surgeries, as patients on aspirin are at no greater risk of bleeding complications than those not taking aspirin
     - If aspirin is being taken for prophylaxis following coronary stent placement, it should be continued for at least 6 months and does not need to be stopped unless the surgical procedure carries a high risk of bleeding (e.g., intracranial or spinal surgery)
   - Clopidogrel
     - Adenosine diphosphate (ADP) receptor antagonist; often used following coronary stent insertion
     - Recommended that clopidogrel be stopped 7 days before surgery
     - Reversal: platelets
     - If clopidogrel is being taken for prophylaxis following coronary stent placement, it should be continued for at least 6 months and does not need to be stopped unless the surgical procedure carries a high risk of bleeding (e.g., intracranial or spinal surgery)
   - Thrombolytics
     - Activate plasminogen; often used for thrombosis and given with heparin; in microsurgery, delivered locally to avoid systemic complications
     - Includes tPA, streptokinase, and urokinase
     - Must follow fibrinogen levels; can treat overdose with aminocaproic acid
     - Absolute contraindications: active internal bleeding, recent stroke, recent neurosurgical procedure, intracranial mass, recent gastrointestinal (GI) bleeding

Each risk factor = 1 point

- Age 40–59 years
- Minor surgery planned
- BMI ≥ 30kg/m^2
- History of prior major surgery (<1 month)
- Swollen legs (current)
- Varicose veins
- Sepsis (<1 month)
- Abnormal pulmonary function (COPD)
- Acute myocardial infarction (<1 month)
- Congestive heart failure (<1 month)
- History of IBD
- Medical patient currently at bed rest

For women only (1 point each)

- Pregnant of post-partum
- History of unexplained or recurrent spontaneous abortion
- Oral contraceptives or hormone replacement therapy

Each risk factor = 2 points

- Age 60–74 years
- Arthroscopic surgery
- Major open surgery (> 45 minutes)
- Laparoscopic surgery (> 45 minutes)
- Prior cancer (except non-melanoma skin cancer)
- Present cancer (except breast and thyroid)
- Confined to bed (>72 hours)
- Immobilizing plaster cast
- Central venous access

Caprini risk category based on total risk score

Total score	Category
0 – 4	Low
5 – 8	Moderate
≥ 9	High

Each risk factor = 3 points

- Age ≥ 75 years
- History of VTE
- Family history of VTE
- Present chemotherapy
- Positive Factor V Leiden
- Positive Prothrombin 20210A
- Positive Lupus anticoagulant
- Elevated anticardiolipin antibodies
- Elevated serum homocysteine
- Heparin-induced thrombocytopenia (HIT)
- Other congenital or acquired thrombophilias

Each risk factor = 5 points

- Major surgery lasting > 6 hours
- Stroke (<1 month)
- Elective major lower extremity arthroplasty
- Hip, pelvis, leg fracture (< 1 month)
- Acute spinal cord fracture or paralysis (< 1 month)
- Multiple traumas (< 1 month)

Fig. 2.2 Caprini risk factors and score risk category association. *BMI*, body mass index; *COPD*, chronic obstructive pulmonary disease; *IBD*, inflammatory bowel disease; *VTE*, venous thromboembolism. (Reprinted with permission from Sterbling HM, Rosen AK, Hachey KJ, et al. Caprini risk model decreases venous thromboembolism rates in thoracic surgery cancer patients. *Ann Thorac Surg.* 2018;105:879–885.)

8. Deep venous thrombosis (DVT) and pulmonary embolism (PE)
   - DVT: Virchow's triad: stasis, venous injury, and hypercoagulability (e.g., hypercoagulable disorders above, cancer)
     - Most common location: deep veins of the lower extremity
       - Characterized by asymmetric swelling, discomfort of affected extremity, positive Homan's sign (pain in calf during dorsiflexion of the foot with knee extended)
       - Diagnosis: ultrasound
       - Treatment: heparin bridge to therapeutic warfarin (6 months for first occurrence, 1 year for second occurrence, and lifetime for third occurrence of significant PE history)
       - In patients who develop a PE despite anticoagulation or cannot receive anticoagulation, and inferior vena cava (IVC) filter is appropriate
     - Risk assessment for postoperative DVT and prophylaxis recommendations
       - Caprini risk score (Fig. 2.2)
       - Evidence-based recommendations for DVT prevention (Fig. 2.3)
   - Pulmonary embolus
     - Suspected in patients with known/unknown DVT who develop acute dyspnea, tachycardia, and hypoxia postoperatively
     - Caused by propagation of DVT (most commonly from iliofemoral DVTs) proximally to the pulmonary veins resulting in obstruction, and can progress to respiratory failure and death
     - Diagnosis: computed tomography (CT) angiography
     - Treatment: anticoagulation (e.g., heparin, warfarin), thrombectomy considered in severe cases or those with hemodynamic collapse
       - If clinical suspicion is high, do not wait for CT scan results and bolus with heparin unless there is a contraindication

INFECTION AND SEPSIS

1. Postoperative fever: most common causes are wind, water, and wound
   - Atelectasis (wind): most common source of infection within 48 hours postoperatively; treatment: incentive spirometry
   - Urinary tract infection (water): most common source of infection between days 2–5; treatment: antibiotics, remove/exchange urinary catheter
   - Wound infection (wound): most common source of fever after 5 days postoperatively; treatment: antibiotics, drain abscess
2. Sepsis: life-threatening organ dysfunction caused by a dysregulated host response to infection
   - Characterized by fever, leukocytosis, elevated lactate levels, tachycardia, hypotension, and end-organ dysfunction
   - Septic shock identified by presence of two criteria: vasopressor requirement to maintain mean arterial pressure > 65 mmHg and serum lactate level > 2 mmol/L in the absence of hypovolemia
   - Treatment: end-organ support, administration of intravenous antibiotics within 1 hour of diagnosis, fluid resuscitation
   - Gram-negative sepsis:
     - Most common cause: *Escherichia coli*; related to endotoxin resulting in release of tumor necrosis factor α
   - Pseudomonal sepsis: benefit from double coverage with empiric antibiotics. Tigecycline is contraindicated

Evidence-based recipe for VTE prevention

Ingredients
One patient
One surgeon
A concern for patient safety
A few extra minutes in clinic

Step 1
Full history and physical including completion of a 2005 Caprini score or similar risk assessment model

Step 2
Consider hematology referral if individualized risk stratification does not fully reflect surgeon's perceived VTE risk

Step 3
Pre-operative risk modification in elective procedures (address obesity, chemo-port, oral contraceptives, recent operative procedure, etc)

Step 4
Intra-operative risk modification and risk reduction
a. Plan to limit operative time and concurrent procedures
b. Non-general anesthesia if possible and appropriate
c. Sequential compression devices if calf muscle pump is compromised
d. Procedure-specific concerns (such as plication, compression garments)

Step 5
Post-operative inpatient chemoprophylaxis for Caprini 7–8 or >8

Step 6
Consider post-discharge prophylaxis for Caprini 7–8 or >8 in outpatient or inpatient surgery

Fig. 2.3 Evidence-based recipe for venous thromboembolism prevention in plastic surgery patients. (Reprinted with permission from Pannucci CJ. Evidence-based recipes for venous thromboembolism prophylaxis: a practical safety guide. *Plast Reconstr Surg.* 2017;139(2):520e–532e.)

3. Pseudomembranous colitis
   - Caused by *Clostridium difficile*
   - Characterized by foul-smelling diarrhea; often occurring after administration of antibiotics
   - Treatment: metronidazole (Flagyl); oral vancomycin
4. Abscess
   - Most abscesses have a combination of aerobic and anaerobic bacteria
   - Typically occur 7–10 days postoperatively
   - Treatment: drainage, antibiotics
5. Surgical site infection (SSI)
   - Risk of SSI is directly dependent upon degree of presumed bacterial contamination at the time of surgery (clean case = lowest risk; contaminated case = highest risk)
     - Other risk factors: long operative time, hematoma/seroma, age, chronic disease, malnutrition, immunosuppressive drugs
   - Prophylactic antibiotics are administered before skin incision to prevent SSIs
     - Must be given within 1 hour of incision for best effectiveness
     - Generally stopped after 24 hours, except in cardiac procedures or procedures with known contamination
     - ASPS guidelines for antibiotic prophylaxis in plastic surgery:
       - Antibiotic prophylaxis generally limited to a single preoperative dose
       - Antibiotics recommended for clean-contaminated, contaminated, or dirty cases
       - Antibiotic prophylaxis not recommended in clean surgical cases, except clean cosmetic breast surgery
       - Most common antibiotic: cefazolin; clindamycin in penicillin allergy
   - Most common organism in SSI: *Staphylococcus aureus* (coagulase-positive organism)
   - Treatment: antibiotics to offending organism; potential drainage/reoperation if abscess present
   - CDC classifies a superficial incisional SSI as one that occurs within 30 days of a procedure (or within 1 year if a prosthetic implant is placed), involves only skin and subcutaneous tissue, and involves at least one of the following: purulent drainage, positive cultures, required surgical opening, and/or diagnosed by the attending surgeon
6. Necrotizing soft-tissue infection
   - Most often occurs in patients who are immunocompromised, have diabetes, or poor perfusion
   - Characterized by: pain out of proportion to skin findings, mental status changes, severe leukocytosis, fevers, skin changes (e.g., blistering/necrosis, induration/edema, crepitus/soft-tissue gas on x-ray); can progress to sepsis
   - Necrotizing fasciitis: usually caused by group A beta-hemolytic Streptococcus or methicillin-resistant *S. aureus* (MRSA)
     - Infection spreads along fascial planes
     - Overlying skin can progress from normal (early stage) to violaceous, blistered, or bullae development
     - Characteristic finding: dishwater drainage, crepitus
     - Treatment: early debridement, high-dose penicillin; may require serial debridement prior to consideration of reconstruction

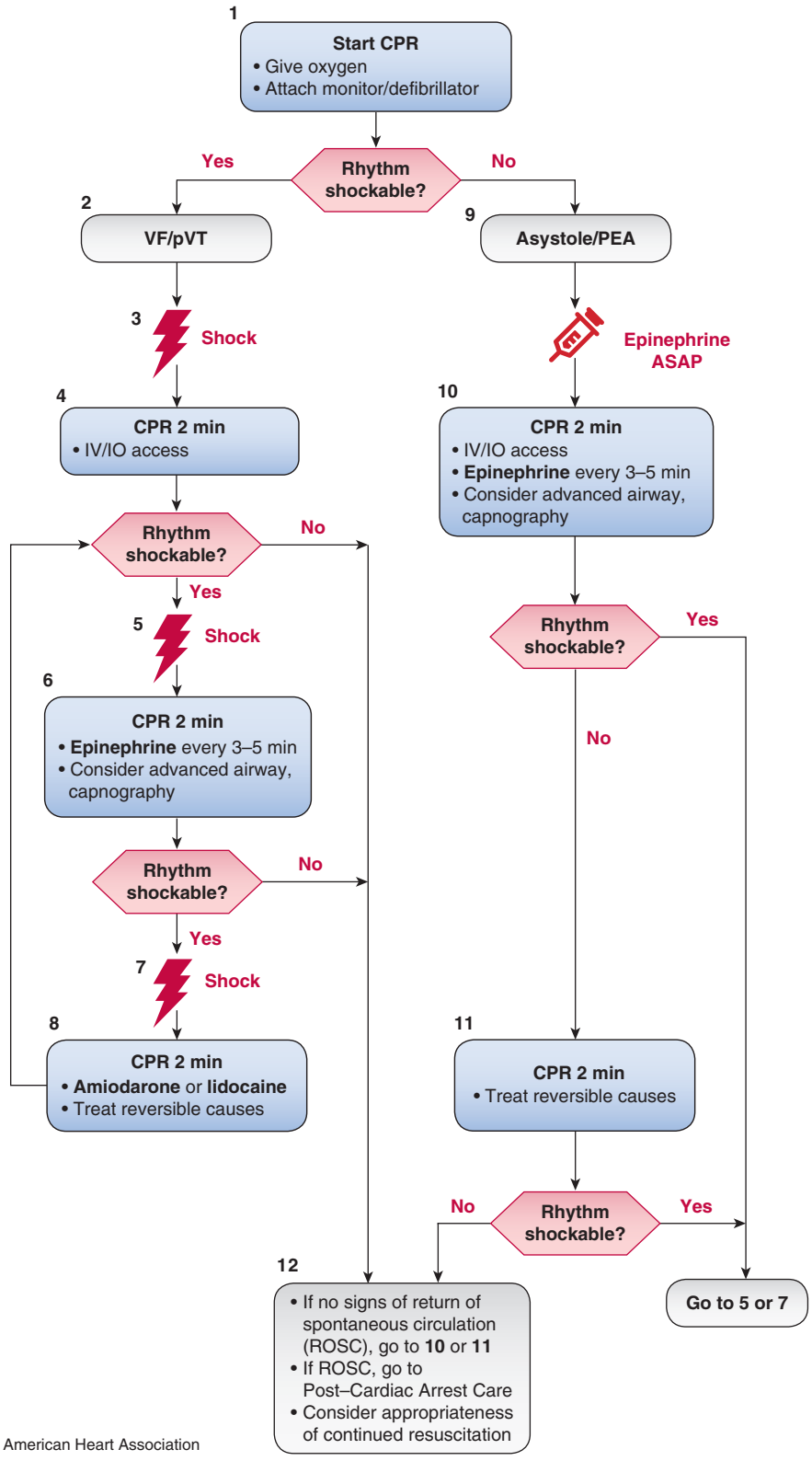
- *Clostridium perfringens* infection
  - Characterized by: pain out of proportion, myonecrosis, gas gangrene
  - Commonly occur with farming injuries (contaminated wounds)
  - Treatment: early debridement and high-dose penicillin
- Fournier's gangrene
  - Severe infection in the perineal and scrotal region
  - Risk factors: diabetes and immunocompromised patients
  - Caused by mixed organisms
  - Treatment: early debridement, broad-spectrum antibiotics (must cover gram-positive, gram-negative, and anaerobes)

7. Commonly tested infectious diseases
   - Hepatitis C
     - Chronic viral infection that primarily affects the liver and is spread through contact with contaminated blood (e.g., needles sticks, blood products)
     - Symptoms related to degree of hepatic dysfunction (e.g., fatigue, nausea, jaundice, cirrhosis)
     - Most common cause of hepatocellular carcinoma
     - Diagnosis: immediate testing for anti-HCV antibodies and immunoassays for HCV-RNA, with repeat testing at 6 weeks, 3 months, and 6 months
     - Treatment: new antiviral medications; supportive therapy
   - Human immunodeficiency virus (HIV)
     - A viral infection that attacks immune cells leading to increased risk for secondary infections and is spread through contact with infected blood or body fluids (e.g., needle sticks, sexual contact)
     - Often asymptomatic early in disease until it progresses to acquired immune deficiency syndrome (AIDS) which is associated with weight loss, fever, night sweats, fatigue, and recurrent infections
       - AIDS diagnosed with an absolute CD4 count $<$ 200 cells/mm3
     - Treatment: antiretroviral therapy
     - Risk factors for complications in patients with HIV: higher ASA class, viral load $>$ 10,000 copies/mL, absolute CD4 count $<$ 200 cells/mm3
   - Tuberculosis
     - Caused by *Mycobacterium tuberculosis*
     - An acid-fast bacillus, with caseating granulomas on histologic examination, and presence of rice bodies (pathognomonic for tuberculosis)
     - Should be considered in infections in all immunocompromised patients
     - Diagnosis: purified protein derivative (PPD) test

CRITICAL CARE

1. Advanced cardiac life support (ACLS)
   - Cardiopulmonary resuscitation (CPR) should begin immediately and continued for 2 minutes, followed by rhythm/pulse check
     - Appropriate CPR: 5 cm sternal depression, at a rate of 100–120 compressions/minute at a ratio of 30:2 (compression:ventilation)
   - Following rhythm/pulse check and appropriate management (see below), CPR should be resumed immediately and continued for another 2-minute cycle and rhythm check
   - Rhythm check and appropriate response
     - Pulseless electrical activity: epinephrine administration
     - Asystole: epinephrine administration
     - Ventricular fibrillation: defibrillator shock (Fig. 2.4)
2. Ventilation
   - Minute ventilation = respiratory rate $\times$ tidal volume
     - Has an inverse relationship with plasma carbon dioxide levels (e.g., increased minute ventilation associated with decreased carbon dioxide levels, such as hyperventilation)
   - Tidal volume = volume of air/gas displaced during a normal breath without extra inspiratory effort
   - Inspiratory capacity = volume of air that enters lungs during the most forcible inspiration possible
   - Residual volume = volume of air remaining in the lungs after most forcible expiration possible
   - Inspiratory reserve volume = inspiratory capacity – tidal volume
   - Vital capacity = total amount of air that can be forcefully expired from the lungs after reaching inspiratory capacity (Fig. 2.5)
   - Pulse oximetry measurements most commonly change with changes in hemoglobin oxygen saturation but can also change with peripheral vasoconstriction from hypothermia, hypotension, and/or vasopressor use, interference from motion, and highly calloused skin, or nail polish
3. Circulation
   - Common circulatory definitions
     - Cardiac output = stroke volume $\times$ heart rate
     - Blood pressure is dependent upon cardiac output and peripheral vascular resistance
     - Central venous pressure (CVP): a measurement of right atrial pressure, and corollary for preload/blood volume; normally 2–6 mmHg. Low CVP = hypovolemia, high CVP = fluid overload
   - Common cardiac dysrhythmias
     - Atrioventricular (AV) block: conduction delay through the AV node and bundle of His
       - First degree: prolonged PR interval
       - Second degree: intermittent failure of conduction to the ventricles from progressive prolongation of the PR interval until a QRS complex is dropped
       - Third degree: complete heart block
     - Atrial fibrillation (AFib): irregularly irregular heart beat
       - One of the most common dysrhythmias encountered in the ICU
       - Associated with left atrial dilation from fluid shifts of structural heart disease
       - Characterized on electrocardiogram (EKG) with irregular rate, and absence of P-waves
       - AFib with rapid ventricular response, or symptomatic AFib (e.g., angina, hypotension) requires immediate cardioversion (e.g., external electrical cardioversion)
       - In the absence of hemodynamic instability, medical management with rate control is appropriate (e.g., beta blockers, diltiazem, amiodarone), and antiocoagulation is often recommended in AFib cases $>$ 48 hours in duration
     - Atrial flutter
       - Associated with atrial enlargement from a reentrant circuit
       - Characterized by atrial rates of 250–350 beats/minute; but not all beats pass to the ventricle
       - EKG has a classic "sawtooth" flutter wave
     - Asymptomatic nonsustained ventricular tachycardia
       - Common occurrence, along with asymptomatic ventricular premature beats, following myocardial infarction (MI)
       - Caused by intermittent electrical activity or triggered by ischemic cardiac region

Adult Cardiac Arrest Algorithm



CPR Quality

- Push hard (at least 2 inches [5 cm]) and fast (100–120/min) and allow complete chest recoil.
- Minimize interruptions in compressions.
- Avoid excessive ventilation.
- Change compressor every 2 minutes, or sooner if fatigued.
- If no advanced airway, 30:2 compression-ventilation ratio.
- Quantitative waveform capnography
  - If $PETCO_2$ is low or decreasing, reassess CPR quality.

Shock Energy for Defibrillation

- **Biphasic:** Manufacturer recommendation (eg, initial dose of 120–200 J); if unknown, use maximum available. Second and subsequent doses should be equivalent, and higher doses may be considered.
- **Monophasic:** 360 J

Drug Therapy

- **Epinephrine IV/IO dose:**
  - 1 mg every 3–5 minutes
- **Amiodarone IV/IO dose:**
  - First dose: 300 mg bolus.
  - Second dose: 150 mg.

  or

  Lidocaine IV/IO dose:
  - First dose: 1–1.5 mg/kg.
  - Second dose: 0.5–0.75 mg/kg.

Advanced Airway

- Endotracheal intubation or supraglottic advanced airway
- Waveform capnography or capnometry to confirm and monitor ET tube placement
- Once advanced airway in place, give 1 breath every 6 seconds (10 breaths/min) with continuous chest compressions

Return of Spontaneous Circulation (ROSC)

- Pulse and blood pressure
- Abrupt sustained increase in $PETCO_2$ (typically ≥40 mm Hg)
- Spontaneous arterial pressure waves with intra-arterial monitoring

Reversible Causes

- **H**ypovolemia
- **H**ypoxia
- **H**ydrogen ion (acidosis)
- **H**ypo-/hyperkalemia
- **H**ypothermia
- **T**ension pneumothorax
- **T**amponade, cardiac
- **T**oxins
- **T**hrombosis, pulmonary
- **T**hrombosis, coronary

Fig. 2.4 Adult Cardiac Arrest Algorithm—2015 Update. (Reprinted with permission from Link MS, Berkow LC, Kudenchuk PJ, et al. *Circulation.* Vol. 132, No. 18_suppl_2 Part 7: Adult Advanced Cardiovascular Life Support.)

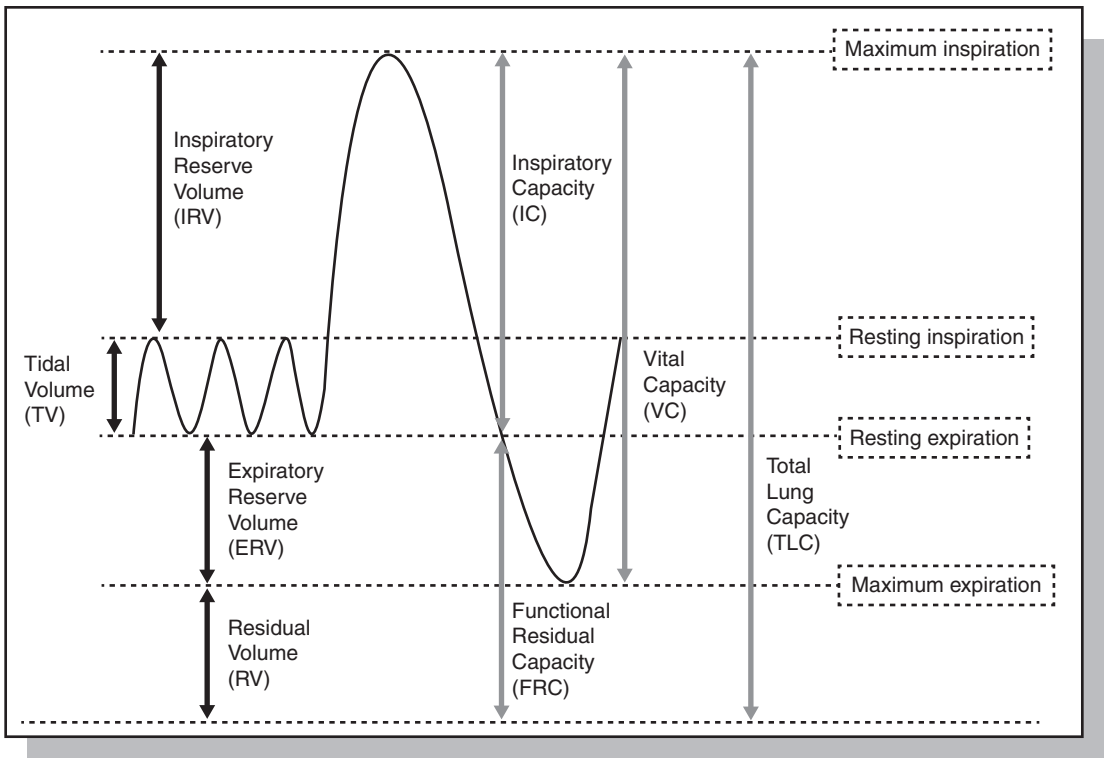


Fig. 2.5 Standard lung volumes and capacities from a spirometer trace. The solid black and gray arrows indicate lung volumes and capacities, respectively. (Reprinted with permission from Lutfi MF. The physiological basis and clinical significance of lung volume measurements. *Multidiscip Respir Med* 2017;12(3):1–2.)

- Treatment: avoid antiarrhythmic medications, maintain potassium > 4.0 mEq/L, magnesium > 2mg/dL, and supportive care
- Symptomatic sustained ventricular tachycardia
  - An indicator of ongoing ischemia and sudden cardiac death following MI
  - Group includes ventricular fibrillation
  - Treatment: rapid identification, defibrillation, with or without antiarrhythmic medications (e.g., amiodarone) according to ACLS protocols

- Guidelines on perioperative cardiovascular evaluation for noncardiac surgery (NCS)
  - Is there a need for emergency NCS? If yes, proceed
  - Are there active cardiac conditions (e.g., angina, heart failure, arrhythmias, severe valve disease)? If yes, evaluate and treat before considering NCS
  - Is the NCS considered low risk (e.g., superficial and/or ophthalmologic procedure)? If yes, proceed
  - Does the patient have good functional capacity without symptoms (e.g., able to climb stairs without shortness of breath)? If yes, proceed with NCS
  - Note: No additional cardiac work up is necessary for an elective, greater-than-low-risk procedure, without any evidence of active cardiac conditions or clinical risk factors, and with moderate functional capacity
- Cardiac tamponade
  - Potential complication following cardiac surgery, including sternal reconstruction
  - Characterized by Beck's triad: hypotension, venous distention, diminished heart sounds
  - Diagnosed: auscultation (muffled heart sound with pericardial friction rub), followed by ultrasound (pericardial effusion)
  - Treatment: decompression

4. Nutrition
   - Indirect calorimetry
     - Used to help calculate resting energy expenditure (REE) and respiratory quotient (RQ) to determine caloric needs of a patient; measures the amount of oxygen consumed (VO_2) and the amount of carbon dioxide produced (VCO_2)
     - $REE = (3.94 \times VO_2) + (1.1 \times VCO_2)$
     - $RQ = VCO_2/VO_2$
       - Optimal values 0.8–0.9
       - RQ < 0.8 suggests underfeeding
       - RQ > 1.0 suggests overfeeding
       - RQ > 1.3 suggests significant overfeeding and lipogenesis
5. Acute kidney injury (AKI)
   - Characterized by an abrupt decrease in kidney function signaled by significant postoperative increase in creatinine
   - Can be classified into three types: most common causes are prerenal and intrinsic renal
     - Prerenal disease: associated with decreased kidney perfusion (e.g., hypovolemia, heart failure, sepsis)
       - Normal urinalysis
       - Blood urea nitrogen (BUN):serum creatinine < 20:1
       - Urinary sodium < 20 mEq/L
       - Fractional excretion of sodium (FENa) < 1%
     - Intrinsic renal disease: associated with organ dysfunction (e.g., acute tubular necrosis)
       - BUN: serum creatinine normal (> 20:1)
       - Urinary sodium > 40 mEq/L

- Abnormal urinalysis
- FENa > 1%–2%
- Can differentiate from prerenal disease by: normovolemia (e.g., normal CVP), and calculation of FENa which measures the percentage of filtered sodium
  - FENa = [(UNa × PCr)/(PNa × UCr)] × 100% (PCr, plasma creatinine; PNa, plasma sodium; UCr, urinary creatinine; UNa, urinary sodium)
  - FENa < 1% suggests prerenal disease, whereas FENa > 2% suggests inappropriate sodium wasting and intrinsic renal disease
- Postrenal cause: associated with obstruction of urinary flow, or renal vein occlusion

- Recommendations for prevention and treatment of AKI
  - Administer insulin therapy to maintain plasma glucose between 110 and 149 mg/dL
  - Avoid colloids
  - Avoid protein intake restriction
  - Provide enteral nutrition where possible
  - Avoid diuretics, except in the setting of volume overload
  - Avoid dopamine

6. Contrast-induced nephropathy
   - Occurs in patients undergoing procedures that require administration of contrast (e.g., angiogram, imaging with contrast)
   - Caused by ischemic injury to the renal medulla
   - Third most common cause of hospital-acquired renal failure
   - Risk factor: preexisting renal dysfunction (e.g., patients with diabetes, or elevated creatinine clearance)
   - Prevention: risk stratification, intravenous hydration with normal saline (#1), withhold nephrotoxic medications
7. Postoperative delirium
   - Acute brain dysfunction characterized by changes in consciousness, inattention, and disorganized thinking
   - Two types: hyperactive (agitation, restlessness), or hypoactive (lethargy, inattentiveness)
   - Very common in ventilated patients
   - Risks: avoid benzodiazepines and antihistamines (e.g., diphenhydramine) in patients at risk for delirium (e.g., elderly)
8. Allergic reactions
   - Anaphylaxis: most severe acute life-threatening allergic reaction
     - Characterized by acute onset of allergic symptoms, anxiety, diffuse skin erythema, perioral swelling, and shortness of breath that can progress to stridor and failure. Diagnosed when two or more of the following are observed minutes to hours after exposure:
       - Skin–mucosal tissue reactions (e.g., generalized hives, perioral swelling, pruritus, flushing)
       - Respiratory compromise (e.g., dyspnea, wheeze, spasm, stridor, hypoxia)
       - Hypotension or associated findings (e.g., syncope, confusion, collapse, incontinence)
       - Persistent GI reactions (e.g., abdominal pain, vomiting)
   - Treatment: epinephrine is the first line of treatment; administered intramuscularly as soon as anaphylaxis is suspected. Following epinephrine, ACLS protocols should be followed and support provided where needed
   - Red man syndrome
     - Commonly caused by rapid vancomycin administration
     - Characterized by acute onset of diffuse erythematous skin rash over the trunk, neck, and face, with generalized pruritus and headache
     - Treatment: discontinuation of antibiotic and antihistamine administration
9. Hypernatremia
   - Elevated sodium concentration that can have neurologic sequelae
   - Commonly occurs after closed injuries (e.g., diabetes insipidus)
     - Diabetes insipidus: typically results from damage to the hypothalamus and/or pituitary resulting in reduced vasopressive (antidiuretic hormone [ADH]) release
     - ADH is responsible for water retention in the kidneys
   - Free water deficit (FWD): amount of free water required to bring the sodium concentration to normal (135–145); FWD = 0 when serum sodium is normal
     - FWD = normal body water × (1 – [serum Na/140])
10. Acute hyperkalemia
    - Can be caused by: supratherapeutic potassium replacement, rhabdomyolysis, hemolysis, tumor lysis syndrome, severe sepsis, acute renal failure, and Addison disease
      - Also can be caused by succinylcholine administration in patients with paraplegia, severe burns, crush injury (commonly tested scenario)
    - Characterized by elevated serum potassium levels (> 5 mEq/L), and in severe cases, progressive neuromuscular paralysis and cardiac conduction changes (e.g., EKG changes can progress from peaked T-waves, decreased P-wave amplitude, prolonged QRS complex to ventricular fibrillation to asystole)
    - Treatment: rapid reduction in serum potassium including insulin with glucose administration (rapidly sequesters potassium), calcium, beta-2 adrenergic agonists (e.g., albuterol, sodium bicarbonate), potassium wasting diuretics (e.g., furosemide/Lasix), cation-exchange resin (e.g., kayexalate), and dialysis
11. Code team
    - Goal of intervening in the setting of acute respiratory or circulatory failure
    - Typically called for cardiac arrest, respiratory arrest, and airway obstruction
12. Rapid response team (RRT)
    - Goal of intervening in the care of patients at an earlier stage of deterioration to prevent catastrophic adverse events
    - Typically called for hypotension, rapid heart rate, respiratory distress, and altered mental status; also can assess and manage sepsis, pulmonary edema, arrhythmia, and respiratory failure
13. Surgical fires
    - Rare, with an estimated incidence of 600 cases/year
    - Risk factors: open oxygen sources that allow for trapping or pooling of oxygen (e.g., masks or nasal cannula), incision above the xiphoid, an available ignition source (see below)
      - Closed-system oxygen sources (e.g., endotracheal tubes, cuffed tracheostomy tubes, laryngeal masks) reduce the risk of surgical fires
    - Fire requires fuel, an oxidizer, and an ignition source. In the operating room, these include:
      - Fuel: alcohol-containing prep solutions, drapes and bandages, gowns and PPE, petroleum jelly
      - Oxidizer: open oxygen source that traps or pools oxygen with or without nitrous oxide
      - Ignition source: electrocautery, lasers, fiberoptic light sources, defibrillators
    - Common signs of a potential surgical fire: unexpected flash, flame, smoke or heat, unusual sounds (e.g., pop, snap), odors, unexpected movement of drapes, discoloration of drapes or breathing circuit, unexpected patient movement

- Management:
  - Immediately halt the procedure and evaluate
  - In a confirmed airway fire: remove the tracheal tube, interrupted flow of airway gases, remove all sponges or other materials away from airway, pour saline into the airway, reestablish ventilation once fire is extinguished

TRAUMA

1. Primary survey
   - ABCDE (Airway, Breathing, Circulation, Disability, Environment/Exposure)
   - Cervical spine injury should be assumed in all trauma patients and should be managed as such (with stabilization) until it can be definitively excluded
2. Secondary survey
   - Individual system evaluation, begin only after primary survey is completed
3. Commonly tested trauma scenarios
   - Grossly dirty wound
     - Administration of tetanus toxoid is appropriate
   - Cerebral edema
     - Can occur after closed head injury
     - Characterized by: signs of progressive intracranial pressure
     - Treatment: hypertonic (3%) saline, hyperventilation, mannitol, diuretics, and surgical decompression where necessary
   - Trauma in the pregnant patient
     - Most commonly presents as blunt trauma to the abdomen (e.g., motor vehicle collision)
     - Following primary and secondary survey (including ultrasound of the abdomen in all pregnant patients; and CT scan where indicated), determination of Rh status is mandatory, and all Rh-negative patients should be given anti-D immunoglobulin to protect against Rh-sensitization from traumatic placental injury
     - In the setting of normal ABCs per ATLS protocol, and decrease in blood pressure, most appropriate next step is to log-roll a pregnant patient onto her left side to relieve potential compression of the IVC from the growing uterus
   - Tension pneumothorax
     - Caused by injury to the lung with air leakage into the pleural space that cannot escape; each breath increases the volume of air in the pleural space resulting in increased intrapleural pressure
       - As pressure increases, chest structures can be compressed, impairing ventilation and decreasing venous return
     - Characterized by tachypnea, hypotension, and hypoxia despite supplemental oxygen administration; on exam, there can be jugular venous distention, hyperresonance on the affected side, and tracheal deviation toward the contralateral side
     - Commonly occurs following blunt trauma to the chest, penetrating trauma to the chest, and occasionally following rib harvest
     - Treatment: emergent needle decompression at the second intercostal space; after stabilized, a definitive chest tube can be placed
   - Lower extremity open fracture
     - See chapter on lower extremity reconstruction for detailed description in management
     - Infection prevention: early administration of antibiotics (< 3 hours) has the greatest impact on infection reduction in trauma patients with lower extremity open fractures
   - Rhabdomyolysis
     - Commonly occurs in the setting of patient being "found down" for hours on affected part resulting in a crush injury to the underlying muscle
     - Characterized by edema, shock, hyperkalemia, hypocalcemia, metabolic acidosis, compartment syndrome, and acute renal failure (secondary to hypovolemia, renal vasoconstriction, and nephrotoxicity from myoglobin, urate, and phosphate)
   - Penetrating neck trauma
     - Location can assist with assessing potential injuries
     - Anatomy of the neck
       - Triangles: based on sternocleidomastoid muscle (SCM)
         - Anterior triangle
           - Borders: midline (anterior), SCM (posterior), mandibular border (superior)
           - Contains most vital structures
         - Posterior triangle
           - Borders: SCM (anterior), anterior border of trapezius (posterior), and clavicle (inferior)
           - Much lower likelihood of significant injury unless spine involved
       - Zones
         - Zone 1: inferior neck; from sternal notch and clavicles to cricoid cartilage
           - Contains the thoracic outlet vasculature, vertebral and proximal carotid arteries, lung apices, trachea, esophagus, spinal cord, and thoracic duct
         - Zone 2: mid neck; from cricoid cartilage to the angle of the mandible
           - Contains the jugular veins, vertebral and common carotid arteries, internal/external branches of the carotid arteries, trachea, esophagus, larynx, and spinal cord
         - Zone 3: upper neck; from above the angle of mandible to base of the skull
           - Contains the pharynx, jugular veins, vertebral arteries, and distal internal carotid arteries
   - Massive transfusion protocol
     - Begin universal blood product infusion rather than crystalloid or colloid
     - Transfuse universal packed red blood cells and FFP in a ratio between 1:1 and 2:1
     - Transfuse one platelet pack for each 6 units of packed red blood cells

TRANSPLANTATION

1. Brain death: permanent and irreversible state indicating no return of cerebral or cortical function
   - A required criteria for nonliving organ donation
   - Brain death examination initiated after cause of brain death established, anoxic injury observed for at least 24 hours, neuromuscular blockade reversed, and hypothermia reversed for at least 4 hours
   - Requires absence of all brain stem reflexes (e.g., absence of corneal reflexes, absence of pupillary reflexes, absence of cough/gag during tracheal manipulation)
2. Organ donation
   - Minors require parental/guardian consent to receive or donate an organ

- Metastatic cancer is a contraindication to organ donation
- HIV status is no longer a contraindication to donate or receive an organ, so long as both the donor and recipient are HIV-positive

3. Rejection
   - Hyperacute: antibody response present in the host at the time of transplantation; begins in the operating room resulting in complement activation and diffuse thrombosis of the graft typically within the first few minutes/hours of reperfusion
     - Typically associated with ABO or antibody incompatibility
   - Accelerated: cellular and humoral response occurring between postoperative days 2 and 5; considered a variant of hyperacute rejection
   - Acute: activated T-cell response that occurs any time after the 5th postoperative day, but typically occurs within the first 4–6 months of transplantation
     - Characterized by short-term organ dysfunction or graft cutaneous/mucosal manifestations
     - Diagnosed by biopsy
       - Skin is the most reactive component of vascularized tissue allograft because it contains antigen-presenting cells; thus in skin biopsy is the preferred site for acute rejection monitoring
     - Treatment: increase in immunosuppressive medications, and steroid administration
   - Chronic: antibody and T-cell–mediated immune response that causes a chronic, progressive arterial sclerosis and fibrosis of the organ
     - Characterized by organ dysfunction or changes occurring months to years after transplant
     - Type IV hypersensitivity reaction (delayed type)
     - Generally progressive and irreversible
     - Immunosuppression medications required to delay and/or try to avoid this type of rejection
   - Graft-versus-host disease: cellular response caused by activation of immune cells within the graft by the recipient's tissues; commonly occurs several months after transplant (especially with bone marrow or stem cell transplants)
4. Immunosuppressant medications (Table 2.1)
   - Calcineurin nephrotoxicity
     - Well-known complication of tacrolimus/calcineurin inhibitor usage
     - Requires close monitoring of kidney function, and regular measurement of tacrolimus trough levels
     - Characterized by increase in creatinine and reduction in glomerular filtration rate
     - Treatment: reduction in trough levels

TABLE 2.1 Immunosuppressive Drugs

Agent	Mechanism	Action	Side Effects
Calcineurin Inhibitors			
Cyclosporine	Binds to cyclophilin, blocks the NF-AT transcription factor, inhibits production of IL-2, and promotes production of TGF-β	Prevents cytokine transcription and arrests T-cell activation	Nephrotoxicity, hypertension, neurotoxicity
Tacrolimus (FK506)	Binds to FK-binding protein, blocks the NF-AT transcription factor, inhibits production of IL-2, and promotes production of TGF-β	Prevents cytokine transcription and arrests T-cell activation	Nephrotoxicity, hypertension, diabetogenicity
Antiproliferative Agents			
Azathioprine (Imarun)	Inhibits DNA synthesis, interferes with DNA repair mechanisms, and inhibits conversion of IMP to AMP and GMP	Blocks the proliferative response (T and B cells)	Bone marrow suppression, hepatotoxicity
Mycophenolate mofetil	Noncompetitive, reversible inhibitor of IMP dehydrogenase; interrupts production of GTP and dGTP, prevents critical step in RNA and DNA synthesis	Blocks the proliferative response (T and B cells), inhibits antibody formation, and prevents clonal expansion of cytotoxic T cells	Gastrointestinal toxicity, bone marrow suppression
Corticosteroids			
Corticosteroids	Binds to intracellular receptor, increases transcription of gene for IκBα, and prevents the transcription of NF-κB (a key activator of pro-inflammatory cytokines)	Blocks IL-1 and TNF-α production by antigen-presenting cells, blocks upregulation of the MHC, inhibits production of interferon-γ by T cells and lysosomal enzymes and migration by polymorphonuclear cells	Osteonecrosis, osteoporosis, growth suppression, glucose intolerance, hypertension, central nervous system effects
Macrolide Inhibitors			
Sirolimus (rapamycin)	Binds to FK-binding protein, impairs signal transduction by the IL-2 receptor, and arrests the cell cycle of lymphocytes	Interrupts T-cell activation pathway	Hypertriglyceridemia, bone marrow suppression

AMP, adenosine monophosphate; *GMP*, guanosine monophosphate; *IL*, interleukin; *IMP*, inosine 5′-monophosphate; *MHC*, major histocompatibility complex; *NF-κB*, nuclear factor kappa B; *TGF-β*, tumor growth factor β; *TNF-α*, tumor necrosis factor α.

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OTHER TOPICS

1. Sutures
   - Chromic gut: absorbable natural monofilament suture; loses 50% of strength in 14 days, near 100% loss by 3 weeks
   - Polyglactin (Vicryl): absorbable synthetic polyfilament/braided suture; loses 50% strength at 2–3 weeks, near 100% loss by 4 weeks
   - Poliglecaprone (Monocryl): absorbable synthetic monofilament suture; loses 50% strength at 7–10 days, near 100% loss at 3 weeks
   - Polydioxanone (PDS): absorbable synthetic monofilament suture; loses 50% strength at 4 weeks, near 100% loss at 6 weeks
   - Polypropylene/nylon: nonabsorbable synthetic monofilament suture; permanent
2. Temporal strength of incisions: scar will have its full strength (~80% of unscarred strength) at 12 weeks after repair

Post-Closure Time (Weeks)	Ultimate Strength (%)
After 1 week	5
After 2 weeks	10
After 3 weeks	20
After 4 weeks	40
After 6 weeks	80

3. Preoperative MRSA decolonization
   - Nasal mupirocin ointment × 5 days
   - Chlorhexidine body wash × 5 days
4. Body dysmorphic disorder
   - An obsessive-compulsive related disorder
   - Criteria: preoccupation with perceived appearance flaws, or asymmetry, for at least 1 hour/day, repetitive behaviors related to the preoccupation, clinically significant distress as a result of the preoccupation, and exclusion of an eating disorder

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3

Head and Neck Anatomy and Facial Palsy

Donald W. Buck II, M.D. FACS

FACIAL NERVE (CRANIAL NERVE [CN] VII)

1. Facial nerve anatomy
   - Course
     - Brain stem → pontomedullary junction → traverses internal auditory meatus → geniculate ganglion → stylomastoid foramen → parotid → muscles of facial expression
   - Intratemporal branches
     - Chorda tympani: parasympathetic, taste to anterior two-thirds of the tongue
     - Stapedius nerve: motor to stapedius muscle
     - Greater petrosal nerve: parasympathetic
   - Stylomastoid foramen branches
     - Posterior auricular nerve
     - Posterior belly of digastric nerve
     - Stylohyoid nerve
   - Parotid branches
     - Temporal/frontal branch: found within the superficial temporal or temporoparietal fascia
     - Zygomatic branch: overlap with buccal branch; near parotid duct, superficial to masseter muscle
     - Buccal branch: overlap with zygomatic branch; near parotid duct, superficial to masseter muscle
     - Marginal mandibular nerve: motor to lower lip depressors and mentalis muscles, located up to 1 cm below mandibular border, crosses facial vessels
     - Cervical nerve: lowest division, motor to platysma (Fig. 3.1)
2. Temporal anatomy
   - Layers from superficial to deep in this region include (1) skin, (2) subcutaneous tissue, (3) superficial temporal fascia, also known as the temporoparietal fascia, (4) superficial layer of the deep temporal fascia, (5) superficial temporal fat pad, (6) deep layer of the deep temporal fascia, and (7) temporalis muscle
     - When the coronal flap is raised, as soon as the yellow superficial temporal fat pad is seen beneath the superficial layer of the deep temporal fascia, the superficial layer of the deep temporal fascia must be incised and included with the coronal flap to protect the frontal branch, which is in the superficial temporal fascia (temporoparietal fascia), one layer superficial to this (Fig. 3.2)

FACIAL PALSY

1. Etiology
   - Most common cause in children is idiopathic (Bell's palsy), followed by infectious (and traumatic, neoplastic, and congenital) etiologies. Most likely cause of unilateral facial nerve paralysis in a newborn with a normal physical examination is a temporal bone abnormality.
   - Bell's palsy: most common, suddenly acquired, unilateral facial palsy
     - Associated with diabetes mellitus (DM), pregnancy, upper respiratory infections; must exclude stroke, tumor
     - Other symptoms include pain, epiphora, oral incompetence, hyperacusis, and taste impairment
     - Treatment: observation; 85% will show improvement in neurologic function within 3 weeks
     - No evidence for facial nerve decompression
   - Pontine lesions (tumor, motor neuron disease, Moebius syndrome, infarction)
     - Millard-Gubler and Raymond-Foville syndromes: pontine stroke
       - Facial and abducens palsy, contralateral hemiplegia
     - Moebius syndrome: most common, bilateral, congenital facial palsy
       - Often associated with abducens palsy as well
   - Infranuclear lesions (Guillain-Barré, Bell's), muscle diseases (myasthenia gravis, myotonic dystrophy, facioscapulohumeral dystrophy)
     - Ramsay Hunt syndrome: herpes zoster virus involvement of facial nerve leading to extreme ear pain, with shingles/vesicles along the facial nerve course, accompanying facial palsy
   - Lyme disease
     - Most common tick-borne illness in the United States
     - Caused by the bacteria *Borrelia burgdorferi*
     - Symptoms: fever, headache, fatigue, and a target-shaped rash (erythema migrans). Neurological manifestations, including facial paralysis, can develop within a few days to a few weeks after the initial tick bite
     - Treatment: antibiotics, most commonly doxycycline
   - Trauma
     - Location is important

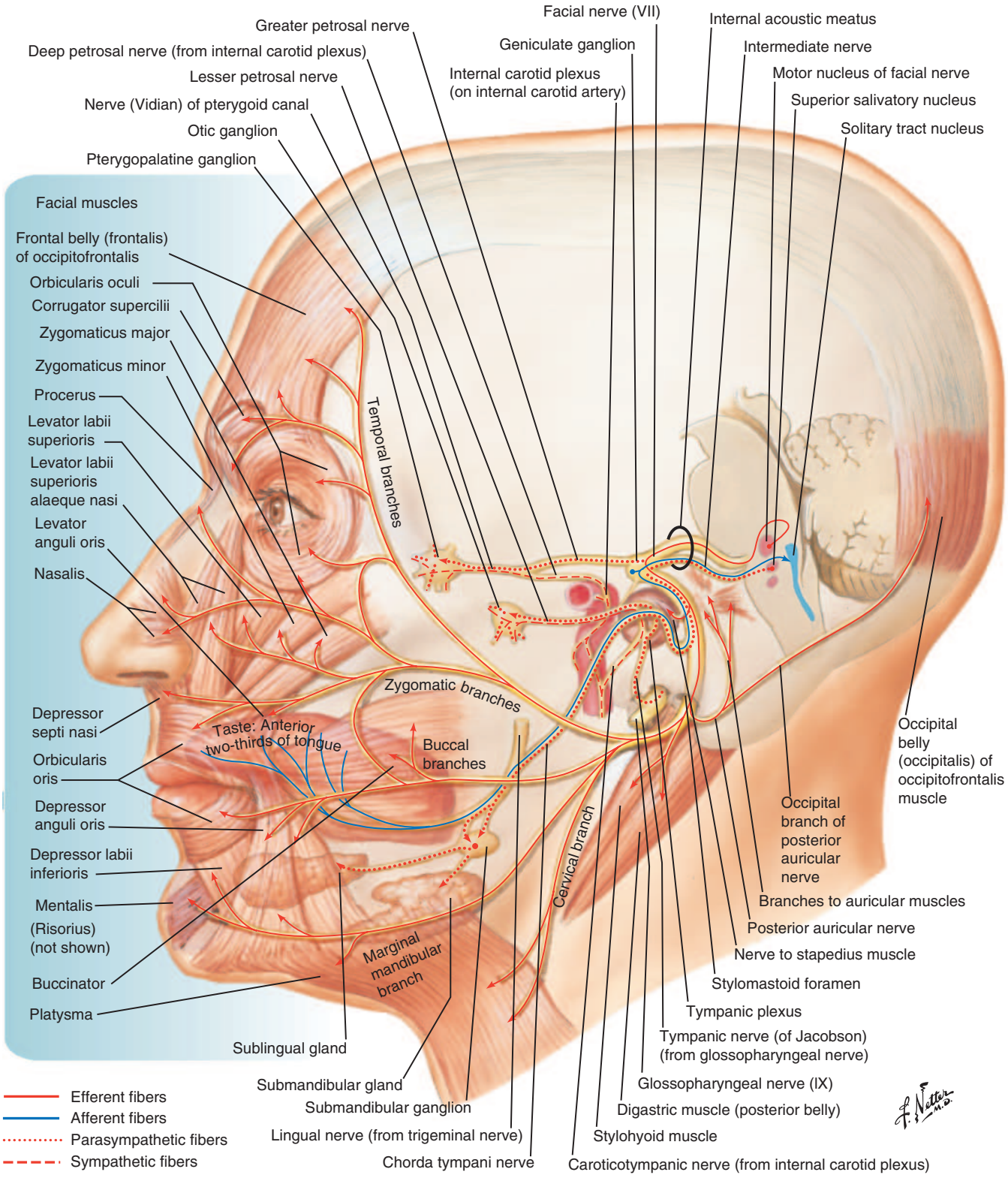


Fig. 3.1 Typical pattern of facial nerve branching. The main branch is divided into two components, each of which then branches in a random manner to all parts of the face. Extensive distal arborization and interconnections are apparent. (Reprinted with permission from www.netterimages.com ©Elsevier Inc. All rights reserved.)

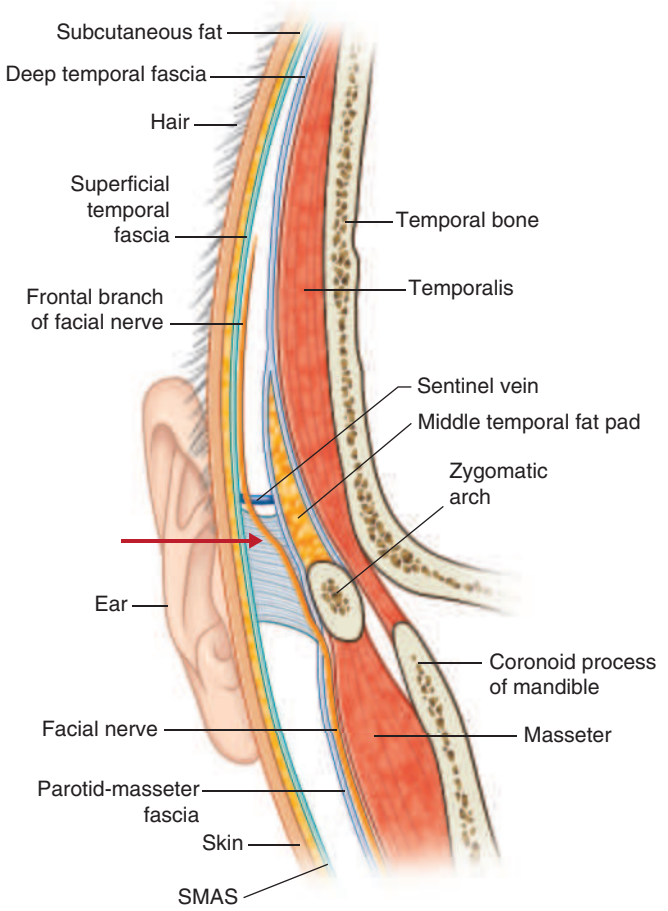


Fig. 3.2 Facial layers of the temporal region. The fat/fascia in the subaponeurotic plane *(red arrow;* between the temporal fascia and deep temporal fascia) is intimately related to the facial nerve. Some investigators believe that there is a separate fascial layer in this space, referred to as the parotidomasseteric fascia. (Reprinted from Neligan PC. *Plastic Surgery.* 3rd ed. St. Louis: Elsevier; 2013; pp. 3–22.)

  - Penetrating injury anterior to a vertical line drawn down from the lateral canthus often not explored (ends too difficult to find due to small diameter); in addition, with buccal branch injury, extensive overlap may allow reinnervation
    - Some would argue that even these anterior injuries should be explored operatively, even if repair is unlikely.
- Major buccal branch of facial nerve travels with the parotid duct; suspect injuries to duct for any lacerations that violate a line from tragus to upper lip or when upper lip dysfunction is noted.
  - For parotid duct injuries: cannulate Stensen duct intraorally, inject saline or methylene blue to diagnose duct injury, and repair over stent or feeding tube if disrupted
- Distal nerve end can be stimulated up to 72 hours after injury, after which time it undergoes Wallerian degeneration (important implications for direct repair).
- Tumors

FACIAL NERVE REPAIR/RECONSTRUCTION

1. Primary direct repair
   - Gives best results when end-to-end coaptation can be performed without significant tension (otherwise, nerve graft is advised)
   - Performed in a clean wound, ideally within 72 hours of injury because during this time, the distal nerve end can still be stimulated to ensure proper target identification
2. Nerve grafting
   - Success depends on relative number of axons, potential for regeneration through the graft, and status of facial muscles (motor end plate loss occurs from 12 to 24 months post injury).
   - Common donor nerves for facial palsy include great auricular, branches of cervical plexus, and sural
3. Nerve transfer
   - Useful when distal stumps are present and facial musculature motor end plates are still intact
   - CN donors include trigeminal and hypoglossal
   - Ipsilateral motor nerve to masseter also now used
   - Donor nerve axon density will have the greatest influence on the outcome of nerve transfer and nerve grafting
   - Cross-face nerve grafting is the most favorable option in terms of restoring spontaneous facial movement.
     - Note that the temporal and marginal mandibular branches have less overlap with other branches in terms of function, so degree of donor morbidity may be higher for cross-face nerve grafting.
     - Often better to graft from larger branch over to the affected side and leave smaller branch behind on the normal side, such that the function is slightly weakened on the normal side; will give better symmetry
     - Cross-face nerve grafts are passed through the upper buccal sulcus region to the opposite side and coapted to the distal stumps on the affected side
4. Free neurotized muscle transfer (e.g., for reanimation)
   - More likely to get spontaneous smile development than that with regional muscle transfer (e.g., temporalis transfer, where biting motion must initiate the smile); regional muscles also have suboptimal vector of pull.
   - Use of the gracilis muscle popularized by Zuker and Manktelow
     - Can be harvested in segmental fashion (½ to ⅓ of muscle) to reduce bulk in the face; harvested with obturator nerve
   - Inset to deep temporal fascia and oral commissure (modiolus) with appropriate tensioning; vector parallels the course of zygomaticus major muscle (Table 3.1)
   - Cross-face nerve grafting can be used to innervate versus ipsilateral motor nerve to masseter
     - Cross-face nerve graft is not as powerful but allows total spontaneity of smile.
       - Must wait for Tinel's sign with cross-face nerve graft (or nerve biopsy) to establish that axons have reached the distal end before free muscle transfer
     - Cross-face nerve graft with free gracilis is a two-stage procedure, whereas coaptation to ipsilateral masseteric nerve is done in one stage.
5. Brow asymmetry
   - For recent occurrence of facial paralysis in which the extent of recovery is unclear, asymmetry can be addressed with

TABLE 3.1 Dimensions of the Levators of the Upper Lip

Muscle	Length (mm)	Width (mm)	Thickness (mm)
Zygomaticus major	70	8	2
Levator labii superioris	34	25	1.8
Levator anguli oris	38	14	1.7

(Reprinted from Freilinger G, Gruber H, Happak W, et al. Surgical anatomy of the mimic muscle system and the facial nerve: Importance for reconstructive and aesthetic surgery. *Plast Reconstr Surg.* 1987;80:686.)

BOX 3.1 Most Common Surgical Options for Each Region of the Face

BROW (BROW PTOSIS)
- Direct brow lift (direct excision)
- Coronal brow lift with static suspension
- Endoscopic brow lift

UPPER EYELID (LAGOPHTHALMOS)
- Gold weight
- Temporalis transfer
- Spring
- Tarsorrhaphy

LOWER EYELID (ECTROPION)
- Tendon sling
- Lateral canthoplasty
- Horizontal lid shortening
- Temporalis transfer
- Cartilage graft

NASAL AIRWAY
- Static sling
- Alar base elevation
- Septoplasty

COMMISSURE AND UPPER LIP
- Nerve transfer either directly or via nerve graft to reinnervate recently paralyzed muscles
- Microneurovascular muscle transplantation with the use of ipsilateral seventh nerve, cross-facial nerve graft, or other cranial nerve for motor innervation
- Temporalis transposition with or without masseter transposition
- Static slings
- Soft-tissue balancing procedures (rhytidectomy, mucosal excision, or advancement)

LOWER LIP
- Depressor labii inferioris resection (on normal side)
- Muscle transfer (digastric, platysma)
- Wedge excision

(Reprinted from Zuker RM, Gur E, Hussain G, et al. In: Neligan PC (ed). *Plastic Surgery*. 3rd ed. China: Elsevier; 2013.)

botulinum toxin injection into the unaffected side to weaken it.
- Once it is clear that recovery is unlikely and denervation probable, static procedures to correct asymmetry (e.g., forehead lift, brow lift, blepharoplasty, canthoplasty) can be considered.

6. Facial dyskinesis
   - Hyperkinesis after facial reanimation surgery can be addressed with injection of botulinum toxin into facial muscles that are most hyperkinetic.
   - Synkinesis may also be addressed with injection of botulinum toxin (e.g., eyelid closure with chewing in a patient who has recovered from Bell's palsy) (Box 3.1).

TRIGEMINAL NERVE (CN V)

1. Trigeminal nerve anatomy
   - The ophthalmic division of the trigeminal nerve (V1)
     - Sensation to the forehead and anterior scalp
     - Exits the skull through the supraorbital foramen
     - Three sensory branches: lacrimal, frontal, and nasociliary nerves
     - Nasociliary nerve courses above the optic nerve and below the superior rectus muscle
       - First branch is the posterior ethmoidal nerve, which provides sensation to the posterior ethmoid sinuses.
       - The terminal branches are the anterior ethmoidal nerve and the infratrochlear nerves, which supply the septum and lateral walls.
       - The dorsal nasal nerve, which supplies innervation to the tip
   - The maxillary division of the trigeminal nerve (V2)
     - Sensation to the cheek and upper lip and to the upper teeth via the superior alveolar nerve
     - Transmitted through the infraorbital foramen
   - Mandibular division (V3): inferior alveolar, buccal, mandibular nerves
     - Inferior alveolar nerve
       - Enters the mandible on the medial side of the ramus approximately 10 mm below the sigmoid notch
       - Courses through the canal closest to the buccal cortical plate in the region of the ramus, angle, and down to the third molar with an average distance of 1.8 ± 1 mm
       - The nerve then swerves away at a position of 4.1 ± 1 mm from the buccal cortex as it passes the region of the first and second molars
       - As it traverses the mandibular body, it is lowest and closest to the inferior cortex (7.5 ± 1.5 mm) near its exit site at the level of the first molar and second premolar via the mental foramen on the anterior surface of the mandible
       - The mental nerve supplies the skin of the lower lip and chin, right up to the midline

ESSENTIAL SENSORY INNERVATION OF HEAD AND NECK STRUCTURES (FIGS. 3.3 AND 3.4)

1. Sensory innervation of the ear
   - Great auricular nerve: sensory to earlobe and lower half of ear
   - Auricular branch of the vagus nerve (Arnold's nerve): concha
   - Auriculotemporal nerve: anterior and superior helix/external auditory canal
   - Lesser occipital nerve: posterior superior ear
2. Sensory innervation of the nose
   - See above
3. Sensory innervation of the lips
   - Infraorbital nerve
     - The maxillary canine may be used as a landmark for needle insertion toward the infraorbital foramen during infiltration of the infraorbital nerve.
     - Bilateral blockade of the infraorbital nerve in the midline provides complete anesthesia to all central components of the upper lip, including the vermillion, Cupid's bow, and philtrum.
   - Mental nerve
     - Bilateral mental nerve blocks effectively anesthetize the central section of the lower lip.
   - Buccal nerve: branch of cranial nerve (CN) V3; supplies sensory to the commissure
     - For lacerations near the commissure, you must inject anesthetic locally.
4. Sensory innervation of the cheek
   - Buccal nerve: central cheek

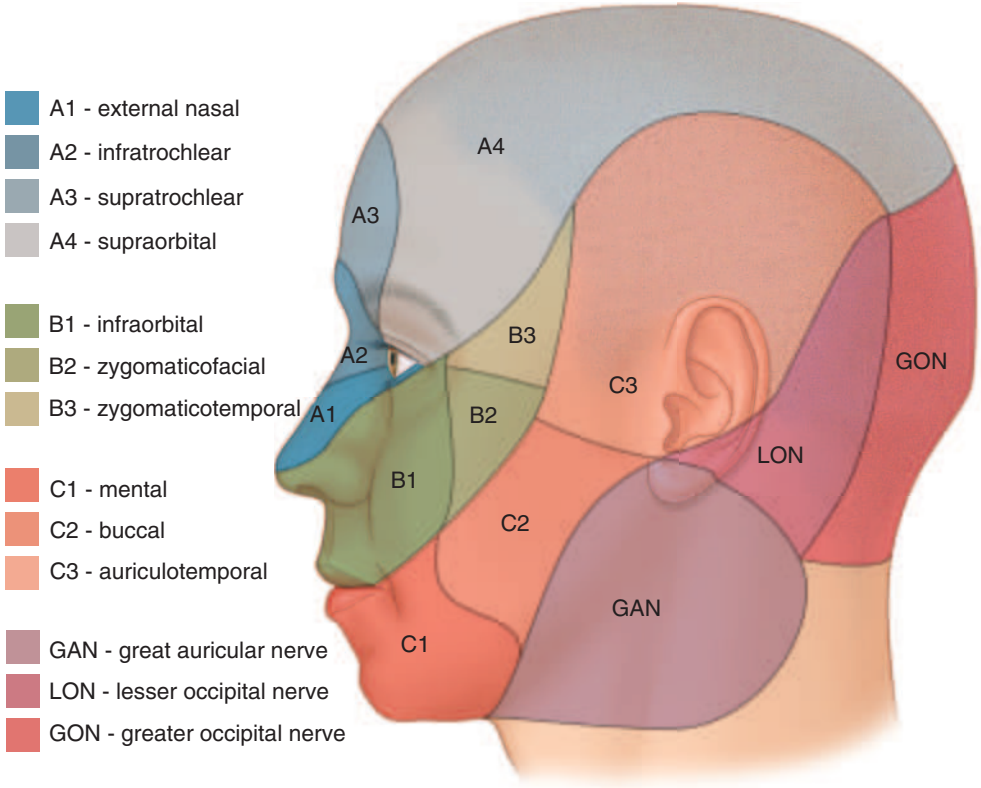


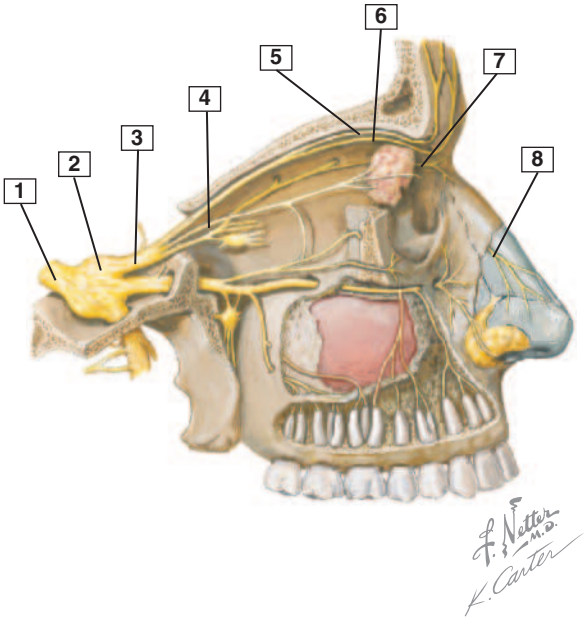
Fig. 3.3 Sensory supply of the face. (Reprinted from Neligan PC. *Plastic Surgery*. 3rd ed. St. Louis: Elsevier; 2013. pp. 3–22.)

- Landmark: retromolar fossa, posterior to the mandibular third molar

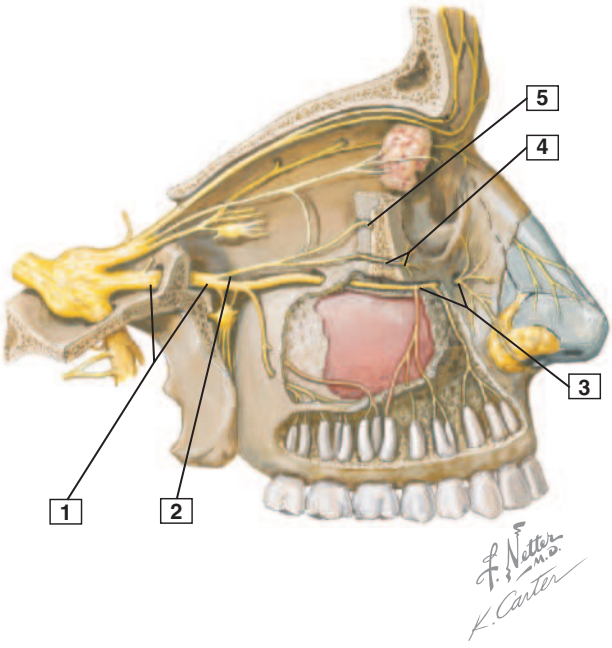
5. Sensory innervation of the forehead
   - Supraorbital nerve (SON): superficial division—paramedian forehead and anterior scalp; deep division—frontoparietal scalp
     - The deep division travels initially along the temporal periosteum and then more cephalad pierces the deep galea plane and enters the galea fat pad. This information is key to avoiding injury when performing a forehead lift.
     - Superficial branch travels superficial to the frontalis muscle.
   - Supratrochlear nerve: medial skin of the forehead. The supratrochlear nerve also runs superficial to the frontalis muscle.
6. Innervation to tongue
   - Sensory
     - Anterior two-thirds: lingual nerve (branch of CN V3)
     - Posterior third: glossopharyngeal (CN IX)
   - Motor
     - Hypoglossa nerve: if injured, results in ipsilateral tongue paralysis
   - Sense of taste
     - Anterior two-thirds: chorda tympani from CN VII (join lingual nerve)
     - CN V (lingual): sensations of salt, bitter, sweet, and sour
       - A 7%–9% decrease in taste of these sensations after septoplasty/rhinoplasty
     - Posterior third: glossopharyngeal (CN IX)

ESSENTIAL ANATOMICAL FORAMEN/STRUCTURES

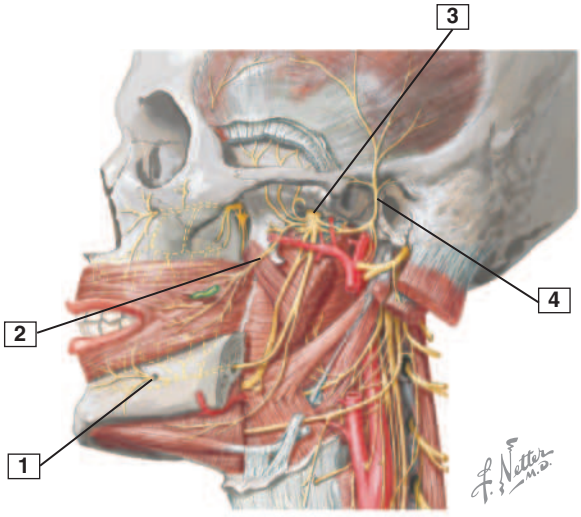
1. Foramen
   - Foramen lacerum: internal carotid artery
   - Foramen ovale: mandibular division trigeminal nerve (V3)
   - Foramen rotundum: maxillary division trigeminal nerve (V2)
   - Stylomastoid foramen: facial nerve
   - Jugular foramen: glossopharyngeal nerve (CN IX), vagus (CN X), spinal accessory (CN XI) (Figs. 3.5 and 3.6)
2. Stensen duct
   - The maxillary second molar is a landmark typically used to locate the opening of the Stensen duct.
   - The parotid (Stensen) duct opens into the mouth at the level of the upper second molar. It is approximately 4–7 cm long, extends from the anterior border of the superficial lobe of the parotid gland, and is frequently accompanied by accessory parotid tissue. The duct runs anteriorly over the masseter muscle about halfway between the zygomatic arch and the angle of the mouth. It turns medially beyond the anterior border of the masseter muscle, pierces the buccinator muscle, and opens into the mouth through the parotid papilla at about the level of the upper second molar.
     - Zygomatic and buccal branches of the facial (VII) nerve may cross superficially over the parotid duct.
   - Location of the parotid duct has implications for placement of surgical incisions
     - Vertical incisions at the anterior border of the parotid gland may cause injury to the parotid duct or to branches of the facial (VII) nerve. Horizontal incisions are less likely to damage these structures.
       - Because of the parotid septae, parotid abscesses tend to be compartmentalized and may not be fluctant
       - Pitting edema over the parotid gland usually indicates an abscess



A
1. Trigeminal n.
2. Trigeminal ganglion
3. Ophthalmic division
4. Lacrimal n.
5. Supraorbital n.
6. Supratrochlear n.
7. Infratrochlear n.
8. External nasal n.



B
1. Maxillary division of the trigeminal n.
2. Zygomatic n.
3. Infraorbital n.
4. Zygomaticofacial n.
5. Zygomaticotemporal n.



C
1. Mental n.
2. Buccal n.
3. Mandibular division of the trigeminal n.
4. Auriculotemporal n.

Fig. 3.4 (A–C) Sensory nerves of the face. *n,* nerve. (Reprinted with permission from www.netterimages.com ©Elsevier Inc. All rights reserved.)

- Abscesses may need to be drained via multiple horizontal incisions

3. The buccinator muscle is the only muscle of facial expression that compresses the cheeks, an essential function for playing air-based instruments such as the trumpet
   - It ordinarily contributes to the function of forming a food bolus during mastication
   - Both the buccinator and the orbicularis oris compress the lips, also necessary for playing the trumpet
4. The levator labii superioris, risorius, and zygomaticus major muscles all have a function that contributes to separating the lips, which releases pressure from inside the mouth
   - These muscles arise from the bone and fascia and attach to the lips
5. Only two muscles would be in the area of a high bifurcation of the carotid that may need to be cut for better exposure during microsurgical cases: Posterior belly of the digastric and the stylohyoid, which span across the skull base to the hyoid

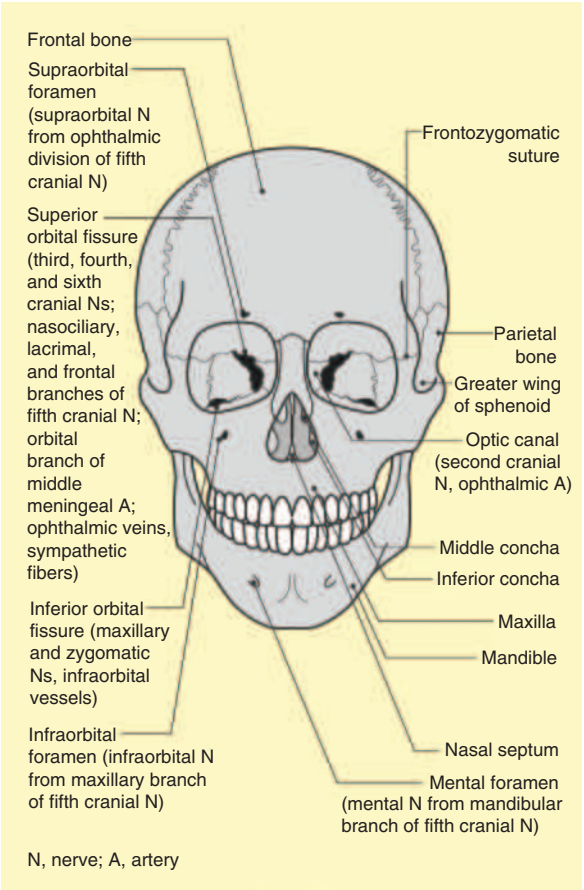


Fig. 3.5 Anterior aspects of the skull showing foramina and their contents. (Reprinted from Craven J. Anatomy of the skull learning objectives. *Anaesth Intensive Care Med*. 2014;15(4):146–148.)

6. The supraorbital and supratrochlear arteries are branches of the internal carotid artery via the ophthalmic artery, and, therefore, receive their blood supply from the internal carotid
7. The branches of the external carotid artery, from proximal to distal, are as follows:
   - Superior thyroid
   - Ascending pharyngeal
   - Lingual, occipital, facial
   - Posterior auricular
   - Maxillary arteries
8. The arteries of the scalp travel through the subcutaneous fat from the periphery toward the vertex, then anastomose in the midline with branches of the ophthalmic artery. They are branches of the external carotid directly (occipital, posterior auricular) or from the superficial temporal.

LAYERS OF THE FACE: THE SKIN, SUBCUTANEOUS TISSUE, SUPERFICIAL MUSCULAR APONEUROTIC SYSTEM (SMAS), FASCIA, AND FACIAL (VII) NERVE

1. Dissection within the subcutaneous plane is safe because this plane does not contain the facial (VII) nerve
2. The SMAS is a heterogenous structure consisting of facial muscles and fibrous and adipose tissue
   - Cephalad: the SMAS continues as the temporoparietal fascia
   - Dissection superficial to the SMAS layer is safe because the muscles of facial animation are innervated from below, except for the buccinator, mentalis, and levator anguli oris muscles, which are innervated via their superficial surfaces
     - The depressor anguli oris, orbicularis oculi, orbicularis oris, and zygomaticus major are all innervated from their deep surfaces

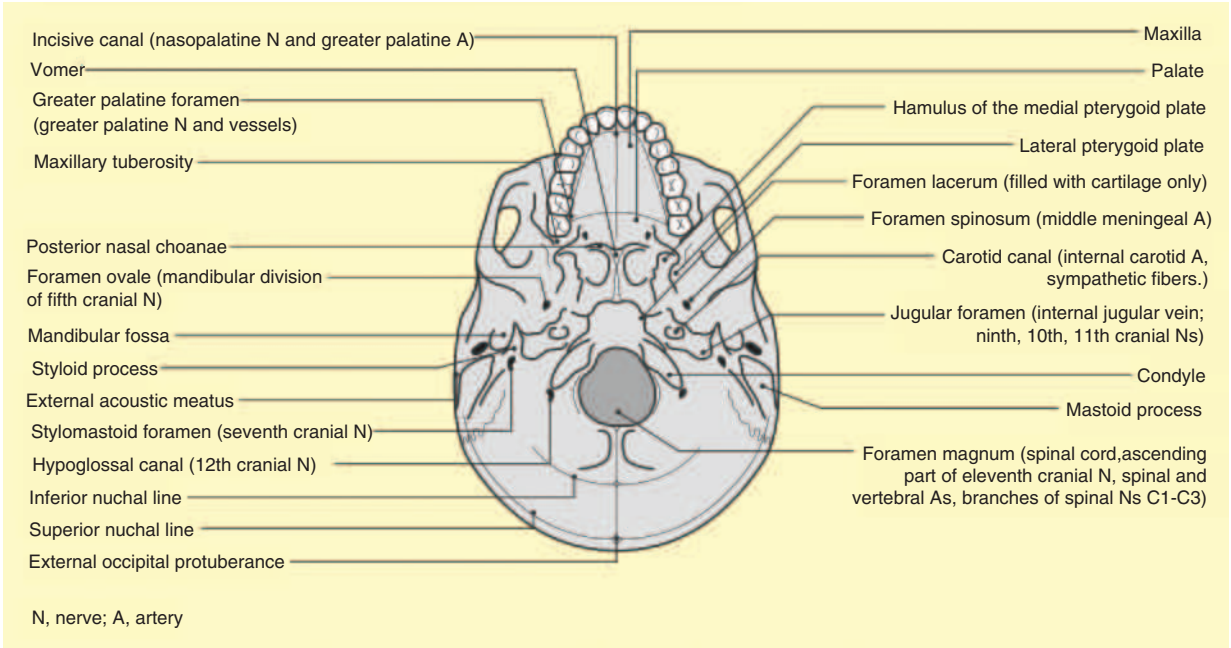


Fig. 3.6 Inferior aspect of the skull showing foramina and their contents. (Reprinted from Craven J. Anatomy of the skull learning objectives. *Anaesth Intensive Care Med*. 2014;15(4):146–148.)

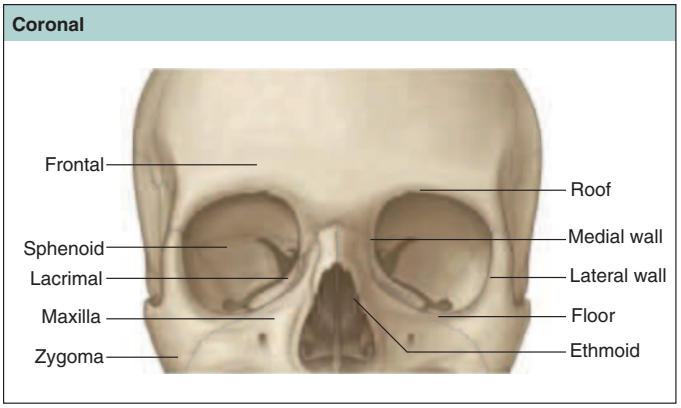


Fig. 3.7 Surgical anatomy of the orbits. (Reprinted from Guyuron B, Eriksson E, Persing JA, et al. *Plastic Surgery: Indications and Practice.* Elsevier; 2009. pp. 619–644.)

- When dissecting below the SMAS plane, the zygomaticus major muscle serves as an important landmark. In this plane, dissection should proceed more superficially to preserve innervation of the zygomaticus major muscle

ORBITAL ANATOMY

1. Seven bones make up the orbit: frontal bone, maxilla, zygoma, ethmoid, lacrimal, greater and lesser wings of the sphenoid, and palatine.
   - The frontal, maxilla, zygoma, and ethmoid bones constitute the strong outer rim of the orbit and protect the more delicate bones in the interior orbit
   - The lesser wing of the sphenoid forms the posterior aspect of the roof of the orbit and transmits the optic nerve and ophthalmic artery through the optic canal
   - The greater wing of the sphenoid contains the superior orbital fissure, which transmits the lacrimal nerve, frontal nerve, trochlear nerve, superior and inferior branches of the oculomotor nerve, the nasociliary nerve, and the abducens nerve (Fig. 3.7)

EMBRYOLOGY

1. Branchial arches are embryologic structures that develop into specific anatomic structures of the lower face, neck, and upper thorax in the adult human. Failure of the branchial arches to correctly develop result in anatomical and developmental defects (Table 3.2)

TOOTH ERUPTION

1. First molar is the first permanent tooth to erupt, typically occurring between ages 6 and 7 years
   - Age of mixed dentition, in which both deciduous (primary) and permanent (secondary) teeth erupt in the oral cavity simultaneously, begins with eruption of the first molars
2. Central incisors erupt between ages 6 and 8 years, lateral incisors between ages 7 and 9, canine teeth between ages 9 and 12, and first premolars between ages 10 and 12
3. With the exception of the third molars, the maxillary canines are typically the last teeth to erupt and occur around 11 to 12 years of age

COMMONLY TESTED CONGENITAL DISORDERS

1. Choanal atresia
   - Cyanosis that is relieved by crying (paradoxical cyanosis): classic symptoms
     - Inability to pass catheter through the nose to nasopharynx. Computed tomography (CT) scan shows narrow posterior nasal cavity secondary to medial displacement of lateral nasal wall and pterygoid plates.
2. Thyroglossal duct cyst
   - May form anywhere along the thyroglossal duct, which extends from the foramen cecum of the tongue to the final position of the thyroid gland in the neck, below the laryngeal cartilage
   - Normally, the thyroglossal duct atrophies and disappears
     - However, a remnant of it may persist and form a cyst in the tongue or anterior midline of the neck, most commonly inferior to the hyoid bone
   - Often asymptomatic unless it becomes infected
3. Reactive lymph nodes
   - Most common neck mass in children
   - Usually found laterally in the submandibular and jugulodigastric areas
4. Branchial cleft remnants (sinuses and cysts)
   - Arise from a remnant cleft between the second and third branchial arches. They are located laterally, along the anterior border of the sternocleidomastoid muscle (SCM), usually just inferior to the angle of the mandible

TABLE 3.2 Derivatives of the Pharyngeal Arches

Arch	Skeletal Element	Musculature	Nerve	Artery
1st (mandibular and maxillary)	Incus, malleus, zygomatic, squamous. Part of the temporal, mandible, and maxilla	Muscles of mastication	Trigeminal	Maxillary artery
2nd (hyoid)	Stapes, styloid process of temporal bone, stylohyoid ligament. Lesser horn and body of hyoid bone	Muscles of facial expression	Facial	Stapedial artery
3rd	Greater horns and lower body of hyoid	Muscles of the stylopharyngeus (throat)	Glossopharyngeal	Common carotid/internal carotid
4th and 6th	Cartilages of the larynx	Muscles of pharynx constriction, muscles of phonation, palatoglossus (tongue), muscles of upper esophagus	Vagus	Arch of aorta, right subclavian artery, original sprouts of pulmonary artery, ductus arteriosus, roots of pulmonary arteries

(Modified from Moody SA (ed). *Principles of Developmental Genetics.* Burlington, MA: Academic Press; 2007, Ch. 30, Table 1.)

- Can be bilateral in 30% of cases
- Histology: lined with squamous epithelium, contains keratin, hair follicles, sweat glands, and sebaceous glands
- Must be completely excised to prevent recurrence

5. Lingual thyroid glands
   - A type of ectopic thyroid located within the tongue, along the course of the thyroglossal duct, resulting from failure of thyroid to descend
   - Unlike thyroglossal duct cysts, they represent the only thyroid tissue present in the patient
6. Mucocele
   - A common benign, cystic lesion of the oral cavity that commonly develops as a result of retention or extravasation of mucus material from the minor salivary glands
   - Most frequently located on the lower lip mucosa, away from the midline, but can be found anywhere in the oral mucosa
   - Characterized by: single, soft, painless, smooth, round, translucent, and fluctuant nodule
   - Many require excisional biopsy for removal. Other treatments including laser ablation and intralesional steroid injection have been described
7. Ranula
   - A mucocele or mucous extravasation phenomenon in the floor of the mouth, arising from the ducts of the sublingual or submandibular glands, often as a sequela of obstruction of the sublingual gland
   - Usually presents as a unilateral swelling of the floor of the mouth that is fluctuant and tinted blue or glossy white
   - Treatment includes marsupialization or surgical excision including the sublingual gland
   - The ranula may herniate through the muscles of the floor of the mouth and present as a cervical mass
8. Failed closure of the fonticulus frontalis, an embryonic fontanel between the inferior frontal bone and nasal bone, may result in three main types of midline anterior anomalies: nasal dermal sinus, anterior cephalocele, and nasal glioma
   - Although closure may be affected by various factors such as gender and race, the anterior fontanel closes by 24 months of age in 96% of children
   - Nasal gliomas: thought to originate as encephaloceles but fail to maintain their intracranial connections
     - May be external, internal, or a combination of both
     - External gliomas typically appear at or just lateral to the nasal root
       - They are reddish, firm, noncompressible, lobular lesions that exhibit telangiectasias of the overlying skin but do not transilluminate or pulsate
       - Bony defects, intracranial connections, and cerebrospinal fluid leakage occur only rarely
       - Histologic evaluation shows astrocytic neuroglial cells and fibrous and vascular connective tissue that is covered with skin or nasal mucosa
   - Nasal dermoid cyst arises from a dermoid sinus, the cutaneous inward passage lined with stratified squamous epithelium
     - May also be external or internal
     - External nasal dermoid: firm, noncompressible, nonpulsatile lesion that does not transilluminate and may be lobulated
     - Although bony defects are infrequent, cerebrospinal fluid leakage and meningitis may occur
     - Derived from ectoderm and mesoderm and thus contains adnexal structures including hair follicles, pilosebaceous glands, and smooth muscles
   - Encephaloceles involve herniation of the cranial tissue through a skull defect
     - Classified as meningoceles (containing meninges only), meningoencephaloceles (containing meninges and brain), or meningoencephalocystoceles (containing meninges, brain, and part of the ventricular system)
     - External, or sincipital, encephaloceles are soft, bluish, compressible, pulsatile masses located at the nasal root and transilluminate
     - They typically enlarge with crying and Valsalva maneuver
9. Torticollis
   - Congenital neck deformity resulting from shortening of the SCM
   - Symptoms: head tilt, limited range of motion, and often a firm mass in the body of the SCM
   - Physical exam: flexion of the head and neck toward the ipsilateral shoulder, rotation of the head and neck to the contralateral shoulder, and lack of lateral flexion toward the contralateral shoulder
   - Treatment: most often resolves in the first year of life. If large portions of SCM become fibrotic, it will need to be surgically released

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4

Head and Neck Cancer, Odontogenic Tumors, and Vascular Anomalies

Donald W. Buck II, M.D. FACS

SALIVARY GLAND TUMORS

1. Salivary glands include the parotid, submandibular, and sublingual glands
2. The majority (80%) of salivary gland tumors occur in the parotid gland and are benign pleomorphic adenomas (80%). Tumors that arise in the submandibular and/or sublingual glands are more likely to be malignant (Table 4.1)
3. Diagnosis of neck masses often includes fine-needle aspiration and imaging (ultrasound, computed tomography [CT], and/or magnetic resonance imaging [MRI])
4. Benign salivary gland tumors
   - Pleomorphic adenoma ("benign mixed tumor")
     - Most common tumor of the salivary glands (parotid)
     - Characterized by a painless, firm mass that does not cause facial nerve dysfunction
     - Treatment: superficial parotidectomy with protection of the facial nerve
   - Papillary cystadenoma lymphomatosum ("Warthin's tumor")
     - Second most common tumor of the parotid gland
     - Male predilection, between 50 and 60 years old
     - Characterized by a smooth, painless mass that can be bilateral in approximately 10% of patients
     - Treatment: surgical excision with narrow margins
   - Hemangioma
     - Most common parotid mass in children
     - Characterized by typical growth pattern of hemangiomas: rapid growth after birth, followed by involution
     - Treatment: oral prednisone for enlarging lesions
       - If lesion regresses with prednisone, treatment continues
       - If lesion continues to grow despite treatment, surgical excision may be indicated
5. Malignant salivary gland tumors
   - Mucoepidermoid carcinoma
     - Most common malignant salivary gland tumor
     - Characterized by slow-growing, firm mass that can cause facial nerve dysfunction
     - Treatment is based on tumor grade (low vs. high)
       - Low-grade tumors can be treated with superficial parotidectomy with or without radiation therapy, depending on surgical margins
       - High-grade tumors are more aggressive and have a higher rate of lymph node and facial nerve involvement. These tumors require total parotidectomy, resection of involved nerve branches, neck dissection, and adjuvant radiation therapy
   - Adenoid cystic carcinoma
     - Second most common malignant tumor of the parotid gland; most common malignancy of the submandibular and sublingual glands
     - Characterized by a painful, firm, fixed lesion with an affinity for nerve invasion resulting in facial nerve and/or trigeminal nerve dysfunction
     - Treatment: total parotidectomy and resection of all involved nerves in the path of the tumor
   - Acinic cell carcinoma
     - Characterized by solid or cystic multifocal masses in the parotid gland
     - Can be bilateral in approximately 3% of patients
     - Treatment: total parotidectomy, resection of the facial nerve, and repair with nerve grafts, neck dissection
   - Adenocarcinoma
     - Characterized by slow-growing, firm, fixed masses
     - Often involves the facial nerve, with metastases to cervical nodes or systemically
     - Treatment: total parotidectomy, resection of the facial nerve, cervical node dissection, and adjuvant radiation
6. Frey's syndrome
   - Gustatory sweating that can occur after parotidectomy, secondary to interconnection of the parasympathetic nerve fibers from the parotid gland and the sympathetic nerve fibers of the sweat glands in the overlying skin
   - Diagnosis: clinical history, starch-iodine test
   - Treatment options
     - Reelevation of the cheek flap with insertion of fascia or acellular dermal matrix to separate the nerve endings
     - Botox chemodenervation

ORAL CAVITY AND PHARYNGEAL CANCER

1. Cancer of the oral cavity and pharynx is commonly caused by chronic substance abuse, including tobacco and alcohol in the United States and tobacco and betel nut use in South Asia. In addition, these cancers are secondary to viral infections (e.g., Epstein-Barr virus, human papilloma virus)

- There is also an association with some occupational exposure, including nickel and radium

2. Most cancers of the oral cavity and pharynx present as squamous cell carcinoma (SCC), with advanced disease, including nodal metastases (Fig. 4.1)
3. Staging of lip, oral cavity, and pharyngeal cancer follows the tumor/node/metastasis (TNM) classification (Table 4.2)

TABLE 4.1 Tumors of the Salivary Glands

	Benign (%)	Malignant (%)
Parotid	80	20
Submaxillary	60	40
Sublingual	40	60
Minor salivary glands	20	80

(Reprinted from Neligan, P.C., Rodriguez, E.D. (Eds.), 2013. Plastic Surgery, vol. 3, 3rd ed. Elsevier, St. Louis, 360–379.)

4. Treatment often depends on stage. In general:
   - For stage I or II disease (no nodal metastases), complete surgical resection with or without neck dissection versus radiation therapy to the primary site
     - Radiation therapy is frequently used for stage I or II lesions of the larynx, hypopharynx, and nasopharynx
     - Surgery is frequently recommended for lesions of the oropharynx, oral cavity, and paranasal sinuses (e.g., maxillary sinus)
   - For stage III or IV disease, complete surgical resection, neck dissection, adjuvant radiation therapy
   - For early-stage oral cancers, elective neck dissection has been associated with increased overall survival and decreased nodal recurrence, despite an increased risk of postoperative complications
5. Complications of head and neck cancer resection and reconstruction
   - Recurrence
   - Wound infection
     - Treated with antibiotics, debridement of nonviable tissue, and local wound care

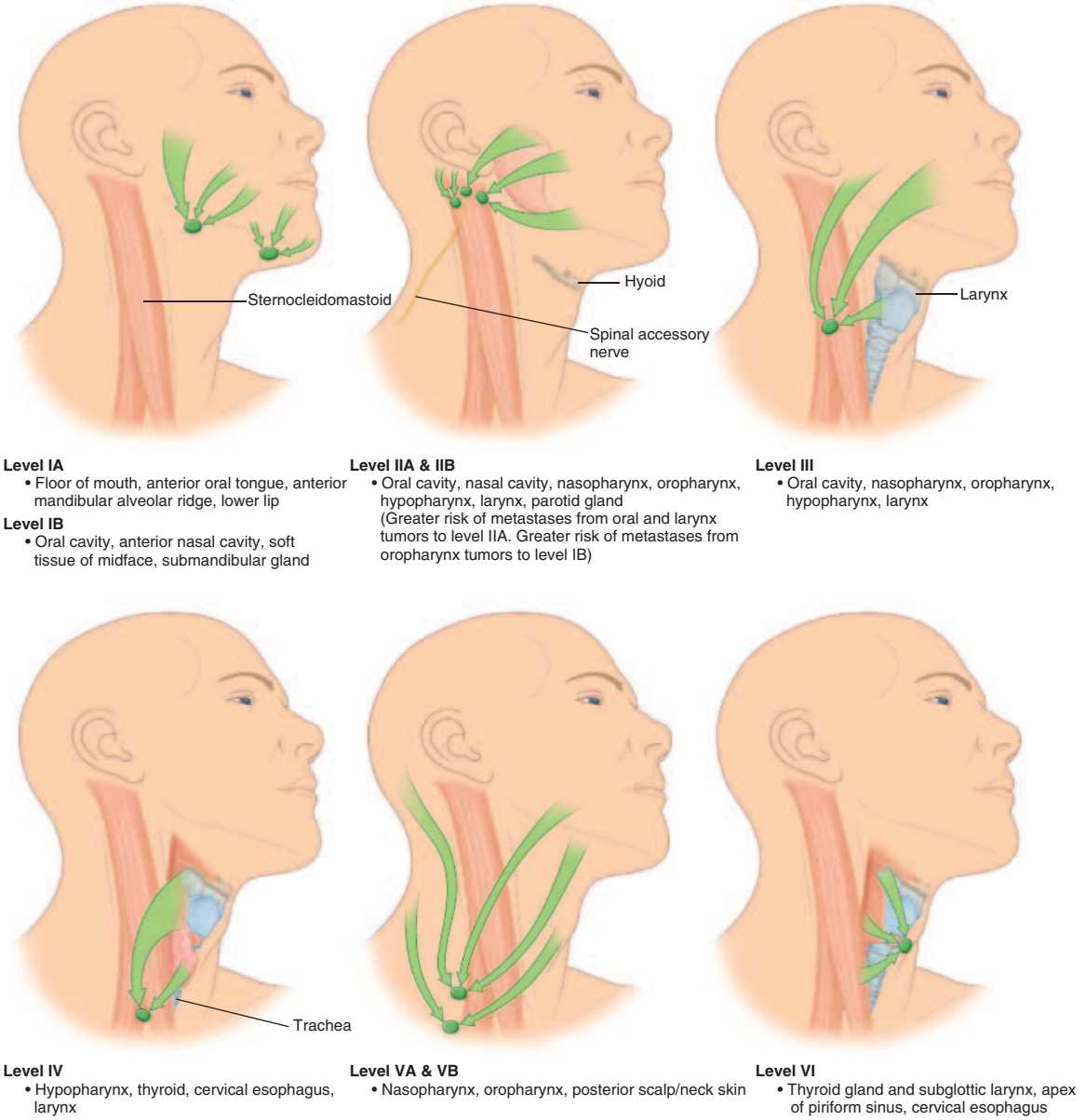

Fig. 4.1 Drainage pattern of head and neck lymph nodes. (Reprinted from Neligan PC, Rodrigueze ED (Eds.) 2013. Plastic Surgery, vol. 3, 3rd ed. Elsevier, China, 420–439).

TABLE 4.2 TNM Clinical Staging System for Lip and Oral Cavity

Tx	Primary Tumor Cannot Be Assessed	Nx	Nodes cannot Be Assessed
T0	No evidence of primary tumor	N0	No evidence of nodal metastasis
Tis	Carcinoma in situ		
T1	≤2 cm in greatest dimension	N1	Single ipsilateral node <3 cm
T2	2–4 cm	N2a	Single ipsilateral node 3–6 cm
		N2b	Multiple ipsilateral nodes 3–6 cm
		N2c	Bilateral or contralateral nodes <6 cm
		N3	Any lymph node >6 cm
T3	>4 cm		
T4a	Lip: invasion of mandible, skin, floor of mouth, nerve		
	OC: invasion of mandible, extrinsic tongue, maxilla, skin		
T4b	Invasion of masticator space, skull base, or carotid sheath		

Stage		
0	TisN0M0	IVA T4aN012M0
I	T1N0M0	T123N2M0
II	T2N0M0	IVB T4B any NM0
III	T3N0M0	T1-4A N3
	T123N1M0	IVC any T any NM1

OC, occult; *TNM,* tumor, node, metastasis.
(Modified from Patel SG, Shah JP. TNM staging of cancers of the head and neck: Striving for uniformity among diversity. *CA Cancer J Clin.* 2005;55:242–258.)

- Stable bony hardware may be left in place and mobile hardware must be removed.
- Suture dehiscence and salivary fistula
- Osteoradionecrosis
  - Devitalization and necrosis of bone secondary to radiation therapy
  - Mandible is most commonly affected
  - Risk factors: infection, higher levels of radiation, trauma, dental caries
  - Treatment: hyperbaric oxygen and limited sequestrectomy may be an option for early-stage disease, with radical debridement and free vascularized bone graft (e.g., free fibula flap) for advanced disease

6. Lip cancer
   - Greater than 90% of cases are SCC
   - Most common site of head and neck cancer, excluding skin malignancies
   - Characterized by an ulcerated or exophytic lesion (especially of the lower lip)
   - Lesions > 2 cm should have a CT scan to evaluate for cervical nodal metastases
     - Commonly metastasize to level I nodes (submandibular or submental area)
   - Treatment: surgical excision is the primary management. Radiation therapy is limited to patients who cannot tolerate surgery
   - Reconstructive options depend on defect location and size. The primary goal is oral competence. Layered closure of the defect, including the orbicularis oris, is critical (Figs. 4.2 and 4.3)
     - In general, primary closure can be performed for lesions smaller than one-third of the lower lip and one-fourth of the upper lip
     - Lesions involving commissure typically require an Estlander flap
     - Large central lesions can be reconstructed with Karapandzic, Gillies, or Webster-Bernard flaps
     - Central upper lip defects can often be reconstructed with an Abbe or lip switch flap
     - Total lower lip reconstruction can be performed with a free radial forearm flap, commonly using the palmaris tendon as a fascial sling for oral competence
7. Floor of mouth (FOM) cancer
   - Difficult to evaluate because of proximity to mandible and dentition
   - Approximately 30% will present with nodal metastasis
   - Treatment: surgical excision plus adjuvant radiation therapy in patients with more than one positive lymph node, extranodal invasion, perineural invasion, and close margins
     - May require a mandibulotomy for exposure
     - A marginal mandibular resection is required for tumors that abut the lingual mandibular cortex. Involves surgical excision of the alveolus only
     - A segmental mandibular resection is required for tumors that invade the mandible
   - Reconstructive options depend on defect size
     - For large FOM resections without segmental mandibular resection, a free radial forearm flap is an excellent option
     - For large composite defects, including bone, a vascularized osteocutaneous flap may be necessary (e.g., fibula flap, scapular flap)
8. Tongue cancer
   - Most commonly, SCC that arises from areas of preexisting leukoplakia or erythroplasia
   - Tongue cancer has the highest rate of regional metastases of all oral cavity cancers
   - Base of tongue tumors are often more infiltrative and have a higher incidence of nodal metastases, including the possibility of bilateral nodal metastases
   - Treatment: most recommend surgical excision with wide margins, neck dissection, and adjuvant radiation therapy
   - Reconstructive options depend on defect size
     - Lesions < 4 cm of the anterior and middle one-third of the tongue can often be closed primarily

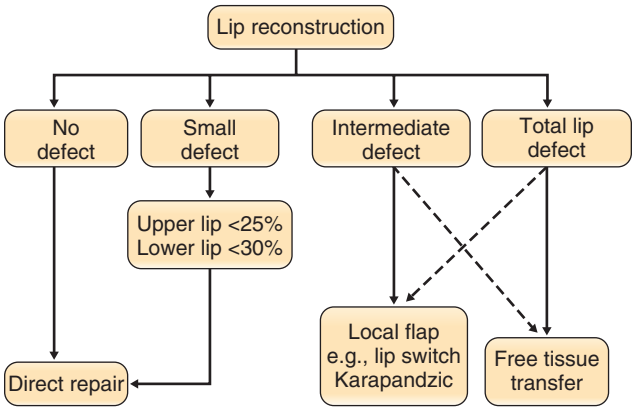

Fig. 4.2 Algorithmic approach to lip reconstruction. (Reprinted from Neligan, P.C., Rodrigueze, E.D. [Eds.], 2013. Plastic Surgery, vol. 3, 3rd ed. Elsevier, China, 254–277.)

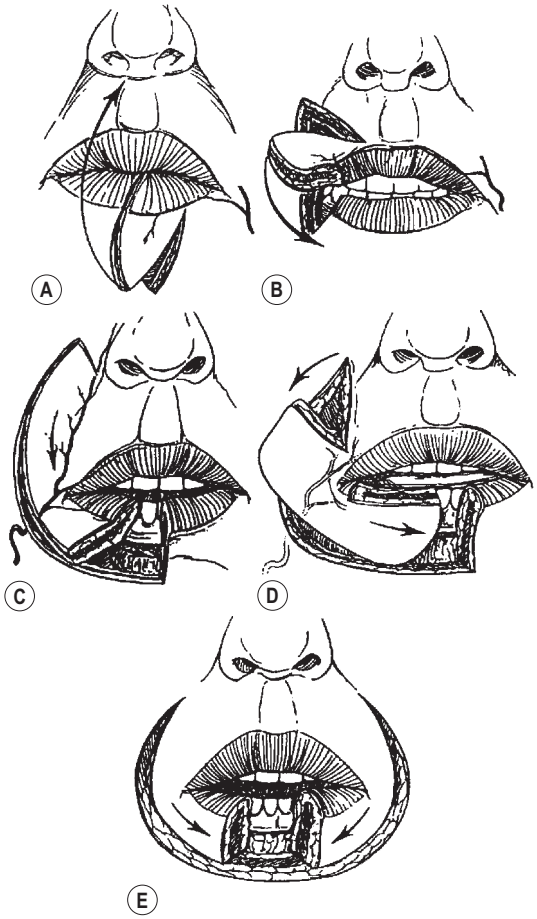

Fig. 4.3 Full-thickness musculocutaneous flaps for lip reconstruction. These flaps can be based on the right or left superior or inferior labial arteries and are useful for lip and oral sphincter reconstruction. (A) Abbe flap arc to central upper lip. (B) Estlander flap arc to oral commissure and lower lip. (C) Gillies fan flap to central upper lip. (D) McGregor flap arc to central lower lip. (E) Karapandzic flap arc to central lower lip. (Reprinted from Weinzweig, J. [Ed.], 2010. Plastic Surgery Secrets Plus, 2nd ed. Mosby, Philadelphia, 401–408.)

- Larger, more posterior lesions can be reconstructed with a skin graft or fasciocutaneous free flaps (e.g., radial forearm free flap, anterolateral thigh [ALT] free flap, sural artery perforator flap)
- Subtotal tongue reconstruction is often performed with a free ALT flap

9. Hypopharyngeal and laryngeal cancer
   - The hypopharynx is the area inferior to the oropharynx and base of tongue, behind the larynx, and superior to the cervical esophagus
     - Most patients with cancer of the hypopharynx present with dysphagia, whereas most patients with laryngeal cancer present with hoarseness
     - Majority develop in the piriform sinus and invade surrounding structures (e.g., larynx, thyroid, thyroid cartilage, esophagus)
     - Treatment often requires total laryngopharyngectomy with adjuvant radiation therapy in advanced disease. Small, localized lesions can be treated with radiation therapy alone or partial laryngopharyngectomy
   - Larynx consists of the epiglottis, glottis (vocal cords), and subglottis (1 cm below the vocal cords to the inferior edge of the cricoid cartilage)
     - Most patients with laryngeal cancer present with hoarseness
     - Treatment
       - Small supraglottic cancers are often treated with radiation therapy, whereas other small lesions can be removed via transoral laser resection or partial laryngectomy
       - Advanced disease and/or larger lesions often require total laryngectomy with or without adjuvant radiation
   - Reconstructive options often depend on defect size and typically rely on free flap reconstruction including jejunum flaps, tubed ALT flaps, or tubed radial forearm flaps (Table 4.3)

MANDIBULAR TUMORS

1. Odontogenic keratocyst (OKC)
   - Recently renamed keratocystic odontogenic tumor (KCOT) by the World Health Organization

TABLE 4.3 Advantages and Disadvantages of Commonly Used Flaps for Pharyngoesophageal Reconstruction

	ALT	Jejunum	Radial Forearm	Pectoralis
Flap elevation	Moderately difficult	Moderately difficult	Easy	Easy
Flap reliability	Good	Good	Good	Variable
Flap thickness	Can be too thick	Good	Good	Too thick
Primary healing	Good	Best	Good	Can be poor
Donor site morbidity rates	Low	High	Moderate	Moderate
Recovery time	Quick	Can be slow	Quick	Quick
Fistula rates	Low	Low	Moderate	High
Stricture rates	Low	High	Moderate	Moderate
TEP voice	Good	Poor	Good	Unknown
Swallowing	Good	Good	Good	Fair
Use for circumferential defects	Yes	Yes	Second choice	No
Use for partial defects	Yes	No	Yes	Yes
Contraindications	Obesity, with a very thick thigh	High-risk disease, severe COPD, prior abdominal surgery	Thin patient with a small arm, radial dominance	Female gender, obesity, smoking, circumferential defects

ALT, anterolateral thigh (flap); *COPD,* chronic obstructive pulmonary disease; *TEP,* tracheoesophageal puncture.
(Reprinted from Yu P. Intraoral, pharynx, and esophagus. In: Butler CE [Ed.]. *Head and Neck Reconstruction*, St. Louis: Elsevier; 2009:167–196.)