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Anesthesia: Principles, Clinical Practice, and Recent Advances

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ABSTRACT

Anesthesia is a fundamental component of modern surgical and interventional care, enabling procedures to be performed safely and humanely through the achievement of analgesia, hypnosis, amnesia, and appropriate muscle relaxation, while maintaining physiological homeostasis. Contemporary anesthetic practice extends beyond drug administration to encompass comprehensive perioperative management, including pre-anesthetic risk assessment, intraoperative monitoring, airway management, and postoperative recovery care. Advances in anesthetic pharmacology, monitoring technologies, and equipment design have substantially improved patient safety and expanded the scope of anesthesia across diverse clinical settings, including ambulatory surgery, non-operating room anesthesia, and critical care. The selection of anesthetic techniques, ranging from general, neuraxial, and regional anesthesia to monitored anesthesia care, is increasingly individualized and guided by surgical requirements, patient comorbidities, functional status, and patient preferences. Innovations such as ultrasound-guided regional anesthesia, multimodal analgesia, processed electroencephalographic monitoring, and enhanced recovery pathways have further optimized perioperative outcomes while reducing complications and resource utilization costs. In parallel, the implementation of standardized safety protocols, improved communication strategies, and system-based approaches have contributed to a marked decline in anesthesia-related morbidity and mortality. This review provides an integrated overview of the core principles of anesthesia, current clinical practices, and recent advances that continue to shape the evolution of anesthesiology toward a safer, more precise, and patient-centered perioperative care.

Keywords

Anesthesia, General Anesthesia, Neuraxial Anesthesia, Regional Anesthesia, Monitored Anesthesia Car.

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INTRODUCTION

Anesthesia provides the foundational principles that enable surgical and interventional procedures to be performed safely and without pain through the rapid induction of analgesia, attenuation of anxiety or loss of consciousness during general anesthesia, and achievement of adequate muscle relaxation [1,2]. In contemporary clinical practice, perioperative anesthetic management extends beyond drug administration to encompass the continuous maintenance of physiological homeostasis, including hemodynamic stability, effective oxygenation and ventilation, and preservation of normothermia [3]. This integrated approach requires the coordinated use of fluid and blood product therapy, vasoactive pharmacological agents, ventilatory strategies, correction of metabolic disturbances, optimal patient positioning, and structured crisis management to ensure patient safety and favorable outcomes [4]. This review provides a comprehensive overview of the available anesthetic modalities and the scope of anesthesia services. Preoperative assessment and postoperative management, which are essential components of perioperative anesthetic care, are discussed in the relevant

sections. In-depth descriptions of individual anesthetic techniques and their clinical applications are addressed in specialized resources, as referenced in the corresponding sections.

Scope of Anesthetic Care

Personnel and Modalities

Anesthetic care is delivered by a multidisciplinary team that includes anesthesiologists, Certified Registered Nurse Anesthetists (CRNAs), and Anesthesiologist Assistants (AAs), who provide perioperative management for patients undergoing surgical and other interventional procedures. Depending on patient factors, procedural requirements, and clinical context, a range of techniques may be employed, including general anesthesia, neuraxial anesthesia (spinal or epidural), regional anesthesia using peripheral nerve blocks, and monitored anesthesia care (MAC).

Settings for Anesthetic Care

Anesthetic care is delivered across diverse in-hospital environments beyond the operating room, including labor and delivery units, diagnostic imaging suites (magnetic resonance imaging and computed tomography), interventional radiology and cardiology facilities, electrophysiology laboratories, and gastrointestinal endoscopy units. Each setting presents unique procedural, physiological, and logistical challenges that require tailored anesthetic planning, appropriate monitoring strategies, and close interdisciplinary coordination [4].

Most surgical and interventional procedures in the United States are now performed on an outpatient basis in hospital outpatient departments or freestanding ambulatory surgery centers [5,6]. To support patient safety in these environments, clinical guidelines emphasize appropriate patient and procedure selection, including the assessment of comorbidities, anticipated postoperative resource needs, and the feasibility of managing the deterioration of preexisting medical conditions without inpatient capabilities.

Safety of Anesthetic Care

Anesthesiology has played a central role in global patient safety initiatives through continuous advancements in anesthetic equipment, physiologic monitoring technologies, safer anesthetic agents, and standardized safety practices, including structured handoffs, medication safety systems, and cognitive aids. [7]. Collectively, these efforts have contributed to a substantial reduction in anesthesia-related morbidity and mortality over the past few decades [3–7].

Preanesthetic Evaluation

Risk Assessment

Risk stratification is a core element of the preanesthetic evaluation. The American Society of Anesthesiologists (ASA) Physical Status Classification System is widely used to communicate baseline health status and estimate perioperative risk and is best interpreted in conjunction with patient- and procedure-specific risk factors [8]. Increasing ASA physical status has consistently been associated with higher rates of perioperative complications, unanticipated hospital admissions, intensive care unit utilization, prolonged length of hospital stay, and mortality [9].

Table 1. Common Perioperative Risk Assessment Instruments

Instrument	Primary Purpose	Key Variables	Clinical Application
ASA Physical Status Classification	Global perioperative risk stratification	Severity of systemic disease	Communication of baseline risk, outcome prediction
Revised Cardiac Risk Index (RCRI)	Cardiac risk estimation	Ischemic heart disease, CHF, creatinine, surgery type	Noncardiac surgery planning
METs Functional Capacity	Functional assessment	Exercise tolerance	Decision-making for further cardiac testing
Surgical Apgar Score	Intraoperative risk assessment	Blood loss, MAP, heart rate	Prediction of postoperative complications

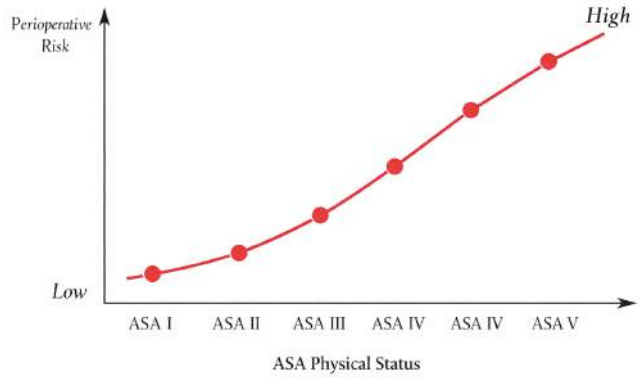

Figure 1. Relationship between ASA Physical Status and perioperative risk.

Airway complications

Anticipation of airway-related complications is a fundamental component of the preanesthetic evaluation. The assessment aims to identify predictors of difficult facemask ventilation, difficult supraglottic airway ventilation, and difficult endotracheal intubation, and to define an airway strategy with appropriate backup plans and equipment [10]. Sedation or induction of anesthesia may precipitate upper airway obstruction and apnea; therefore, preparation for rescue oxygenation and ventilation is essential in these patients.

Table 2. Airway Assessment, Devices, and Complications

Category	Key Items	Clinical Implication
Difficult Facemask Ventilation	Obesity, limited mandibular protrusion, beard, OSA, age >55 years	Increased risk of inadequate ventilation
Difficult Tracheal Intubation	Mallampati III–IV, short thyromental distance, limited neck extension, restricted mouth opening, prior difficult airway	Higher likelihood of intubation failure
Airway Devices	Facemask, supraglottic airway, endotracheal tube, video laryngoscope	Stepwise escalation of airway control
Airway-Related Complications	Sore throat, hoarseness, laryngospasm, aspiration	Mostly self-limited but clinically relevant

Pulmonary complications

Evaluation of pulmonary risk is essential because postoperative pulmonary complications are a major source of perioperative morbidity. A structured assessment of patient- and procedure-related respiratory risk factors supports individualized anesthetic planning and the implementation of preventive strategies throughout the perioperative period.

Cardiovascular complications

Cardiovascular risk assessment is central to the preanesthetic evaluation, given the substantial impact of cardiac complications on perioperative morbidity and mortality.

Table 3. Perioperative Cardiovascular Risk Factors and Risk-Reduction Strategies

Category	Key Elements	Clinical Implication
Cardiovascular Risk Factors	Ischemic heart disease, heart failure, valvular disease, arrhythmias, poor functional capacity	Increased risk of perioperative cardiac events
Risk-Reduction Strategies	Optimization of heart failure, continuation of beta-blockers, targeted hemodynamic monitoring, avoidance of tachycardia, postoperative surveillance	Reduction of myocardial stress and early complication detection

A structured evaluation of the underlying cardiovascular disease, functional capacity, and surgical stress informs risk stratification and perioperative optimization strategies [9].

Adverse outcomes associated with anemia and neurocognitive vulnerability

Preoperative anemia is increasingly recognized as an independent risk factor for adverse perioperative outcomes, including increased morbidity, transfusion requirements and prolonged recovery. Early identification and treatment are key components of patient blood management strategies [10]. Baseline neurocognitive assessment is also important because pre-existing impairment increases the vulnerability to perioperative neurocognitive disorders.

Table 4. Patient-Related Factors Associated with Adverse Perioperative Outcomes

Category	Key Factors	Clinical Impact
Physiologic Vulnerability	Preoperative anemia, malnutrition	Increased transfusion requirement and impaired recovery
Neurofunctional Risk	Cognitive impairment, frailty	Delirium and postoperative functional decline
Demographic Risk	Advanced age	Reduced physiologic reserve and multisystem vulnerability

Postoperative functional decline and frailty

Frailty evaluation has become an essential component of preoperative assessment in older adults because it is strongly associated with postoperative complications, delayed functional recovery, and loss of independence. The identification of frailty allows for targeted perioperative strategies, including prehabilitation programs aimed at improving physiological reserve.

Communication, reassurance, and informed consent

Effective perioperative communication supports shared decision-making, patient understanding, and informed consent processes. A clear explanation of anesthetic options, risks, and expectations enhances patient satisfaction and promotes ethical, patient-centered care [11].

Fasting guidelines

Preanesthetic fasting reduces the risk of pulmonary aspiration and is applied across anesthetic modalities, including general anesthesia, neuraxial or regional techniques, and monitored anesthesia care (MAC). The current ASA Anesthesiologists practice guidelines provide updated recommendations for fasting and pharmacological strategies to mitigate the risk of aspiration in elective procedures.

Types of Anesthesia

Selection of anesthetic technique

The selection of an anesthetic technique requires balancing the potential benefits and risks while considering procedural requirements, duration, comorbidities, postoperative analgesia goals, and patient preference. When multiple techniques are appropriate, no single modality is universally superior, and combined approaches are often used.

General anesthesia

General anesthesia is a reversible pharmacological state characterized by loss of consciousness, amnesia, effective analgesia, and appropriate immobility or muscle relaxation with suppression of undesirable autonomic responses to surgical stimuli [1,2]. It is conventionally described in three phases: induction, maintenance, and emergence phase.

Induction and induction agents

Induction can be achieved using intravenous, inhalational, or a combination of these techniques. Common intravenous agents include propofol, etomidate, and ketamine, which are often administered with opioids and adjunctive agents. Neuromuscular-blocking drugs are frequently used to facilitate airway instrumentation.

Airway management

Airway management ensures effective oxygenation, ventilation, and the delivery of inhaled anesthetics. These techniques include face mask ventilation, supraglottic airway devices, and endotracheal intubation. Supraglottic airway (SGA) devices are positioned above the glottis and may be used for spontaneous or controlled ventilation; however, they do not provide complete protection against aspiration. Postoperative pharyngolaryngeal discomfort is common, with randomized trials demonstrating reduced symptoms when cuff pressure is appropriately monitored [12,13].

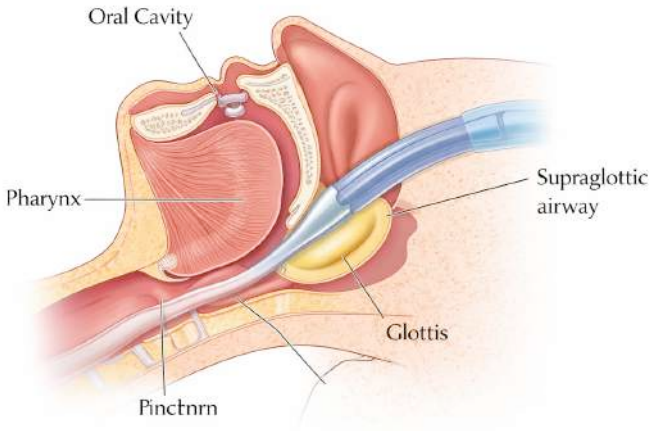

Figure 2. Supraglottic airway device position:

Endotracheal tubes (ETTs) provide cuffed seals that facilitate positive-pressure ventilation and aspiration protection. Postoperative sore throat is common, with reported incidences ranging from approximately 21% to 72%, and evidence demonstrates an association between larger ETT size and an increased risk of postoperative pharyngolaryngeal symptoms [13–16].

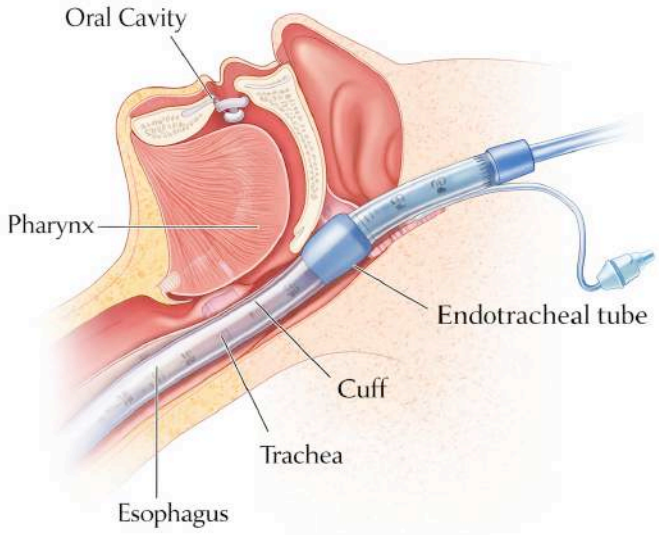

Figure 3. Endotracheal tube positioning.

Special situations

In patients at high risk of aspiration, rapid sequence induction and intubation are commonly employed to minimize the duration of unprotected airways, requiring strict adherence to established procedural principles [14]. The management of a potentially difficult airway emphasizes preparation, decision-making algorithms, and, in selected cases, awake airway techniques, as recommended by the ASA guidelines [10].

Maintenance

Maintenance of general anesthesia is typically achieved using balanced techniques that combine inhalational and intravenous agents. Total intravenous anesthesia is an alternative approach. Inadequate anesthetic depth may increase the risk of intraoperative awareness, particularly in high-risk environments.

Emergence

Emergence involves the restoration of consciousness and protective airway reflexes following the cessation of anesthetic agents and reversal of neuromuscular blockade. Safe transfer from the operating room requires stable hemodynamics, adequate ventilation, and oxygenation.

Neuraxial anesthesia

Neuraxial anesthesia includes spinal, epidural, and combined spinal–epidural techniques. Adjunctive sedative or analgesic medications may be administered, and neuraxial techniques may be combined with general anesthesia when clinically indicated.

Peripheral nerve blocks

Peripheral nerve blocks, commonly performed under ultrasound guidance, are frequently used for extremity surgery and may involve a single injection or continuous catheter technique to enhance postoperative analgesia. Intravenous regional anesthesia (Bier block) remains an option for short-duration distal upper-extremity procedures.

Monitored anesthesia care (MAC) and conscious sedation

MAC involves continuous monitoring by an anesthesia professional, with readiness to convert to general anesthesia if required. In the United States, MAC accounts for a substantial proportion of ambulatory anesthetic services, representing approximately one-third of the cases [17]. Practice guidelines distinguish MAC from moderate or deep sedation administered by non-anesthesiologists, who have different monitoring and safety requirements [18].

MONITORING DURING ANESTHESIA

Standard monitoring during anesthesia follows the ASA Standards for Basic Anesthetic Monitoring and includes continuous evaluation of oxygenation, ventilation, circulation, and temperature [3]. During general anesthesia, monitoring is expanded to include continuous end-tidal carbon dioxide, inspired oxygen, and end-tidal anesthetic concentrations. In selected patients, invasive cardiovascular monitoring may be employed to guide the perioperative management.

Postoperative Anesthetic Care

Disposition

Most patients recover in the post-anesthesia care unit under anesthesia oversight, whereas critically ill patients or those requiring ongoing ventilatory support are transferred directly to the intensive care unit. Postanesthetic recovery and discharge criteria are guided by established practice guidelines emphasizing physiological stability, airway protection, and readiness for a safe transition of care [19].

Common PACU problems

Common postoperative issues include pain, postoperative nausea and vomiting, respiratory and cardiovascular instability, temperature disturbances, urinary retention, delayed emergence, delirium, and rare neurological complications, all of which require prompt recognition and management.

CONCLUSION

Anesthesia is a fundamental component of modern medical practice that combines scientific principles, clinical expertise, and technological advances to ensure safe and effective, perioperative care. Ongoing developments in anesthetic drugs, monitoring systems, and individualized patient management continue to improve outcomes, safety, and overall quality of surgical care.

DECLARATIONS

None

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The authors declare no conflicts of interest in this case report.

AUTHORS' CONTRIBUTIONS

The author conceived and designed this study. He was responsible for the data acquisition, analysis, and interpretation. SG also drafted the manuscript, critically revised it for important intellectual content, and approved the final version for publication. The author takes full responsibility for the integrity and accuracy of this work.

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