REVIEW OPEN ACCESS

Perioperative Cardiopulmonary Optimization, Cerebral Oximetry, and Recovery Focused Anesthesia: A Narrative Review

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Modern anesthesia practice extends beyond intraoperative unconsciousness and analgesia. It requires protection of cerebral, cardiovascular, pulmonary, and functional recovery outcomes across the perioperative continuum. Patients undergoing cardiac surgery, laparoscopic abdominal surgery, or surgery after coronavirus disease 2019 (COVID-19) may present with unique physiologic risks that require individualized anesthetic planning. This narrative review discusses perioperative cardiopulmonary optimization, cerebral oximetry, pulmonary function assessment, postoperative nausea and vomiting prevention, opioid-sparing analgesia, and recovery-focused anesthesia strategies. A narrative review was conducted using anesthesia, perioperative medicine, and enhanced recovery literature. Emphasis was placed on clinically relevant evidence applicable to anesthesiologists, perioperative physicians, and surgical teams. Cerebral oximetry using near-infrared spectroscopy may help identify cerebral desaturation during cardiac surgery, although its effect on hard clinical outcomes remains uncertain. Cardiopulmonary reserve, stress-induced blood pressure responses, post-COVID pulmonary dysfunction, and procedure-specific surgical recovery all influence anesthetic risk. Multimodal analgesia, regional anesthesia, nausea prevention, and enhanced recovery pathways are central to improving postoperative outcomes. Perioperative anesthesia should be individualized according to neurologic risk, cardiopulmonary reserve, surgical stress, and expected postoperative recovery needs. Cerebral oximetry, pulmonary assessment, opioid-sparing analgesia, and

enhanced recovery protocols may improve patient-centered care when applied selectively and thoughtfully.

Keywords: Anaesthesia: Perioperative Medicine; Cerebral Oximetry; Near Infrared Spectroscopy; Cardiac Surgery

INTRODUCTION

Anesthesia has evolved from a primarily intraoperative discipline into a perioperative specialty focused on physiologic optimization, organ protection, and recovery. The anesthesiologist is responsible not only for hypnosis, analgesia, and immobility, but also for maintaining cerebral perfusion, cardiovascular stability, oxygen delivery, ventilation, temperature control, and safe emergence from anesthesia.

This broader role is especially important in high-risk populations. Cardiac surgical patients may be vulnerable to cerebral hypoperfusion, embolic injury, postoperative cognitive dysfunction, and prolonged hospitalization [1-2]. Patients with prior COVID-19 may have persistent cardiopulmonary limitations that are not always apparent at rest [3-4]. Patients undergoing laparoscopic abdominal surgery may experience postoperative pain, nausea, and delayed recovery despite minimally invasive technique [5]

A recovery-focused anesthetic plan should therefore combine preoperative risk assessment, intraoperative monitoring, hemodynamic control, lung-protective ventilation, multimodal analgesia, postoperative nausea and vomiting prophylaxis, and early mobilization. This review synthesizes perioperative literature to discuss practical strategies for improving anesthesia-related outcomes.

METHODS

This narrative review was developed using references from anesthesia guidelines, perioperative pain literature, cerebral oximetry reviews, enhanced recovery after surgery literature, and postoperative nausea and vomiting guidance. The review focuses on clinically relevant concepts rather than a formal systematic review methodology. Articles were included if they addressed

cerebral monitoring, cardiac surgery, pulmonary function, post-COVID physiology, hemodynamic response, laparoscopic surgery recovery, multimodal analgesia, or enhanced recovery pathways.

REVIEW

Cerebral Oximetry in Cardiac Anesthesia

Cardiac surgery presents a high-risk environment for neurologic injury. Cerebral oxygen delivery may be affected by cardiopulmonary bypass, nonpulsatile flow, hypotension, anemia, hypoxemia, embolic events, altered carbon dioxide tension, and impaired cerebral autoregulation. Because neurologic complications can increase morbidity, hospital stay, and cost, monitoring strategies that identify cerebral hypoxia have received increasing attention.

Near-infrared spectroscopy is a noninvasive technique used to estimate regional cerebral oxygen saturation. Raza et al reviewed cerebral oximetry in cardiac surgery and emphasized that maintaining cerebral perfusion is clinically important, but also noted that the routine clinical significance of cerebral oximetry remains incompletely established [1]. Other reviews have similarly described near-infrared spectroscopy as a practical bedside trend monitor, while acknowledging that stronger outcome data are needed before universal use can be recommended [2,6-7].

From an anesthesia perspective, cerebral oximetry should be interpreted as an adjunct, not as a stand-alone monitor. A decrease in cerebral oxygen saturation should prompt evaluation of systemic oxygenation, arterial carbon dioxide tension, mean arterial pressure, hemoglobin concentration, cardiac output, pump flow during bypass, head position, venous drainage, and anesthetic depth. The monitor is most useful when its values are linked to a clear intervention algorithm.

Hemodynamic Optimization and Perioperative Risk

Hemodynamic stability is central to safe anesthesia. Induction agents, volatile anesthetics, neuraxial techniques, positive-pressure ventilation, surgical bleeding, and inflammatory responses

can all reduce blood pressure and impair organ perfusion. Mean arterial pressure remains a key clinical target because it approximates perfusion pressure for the brain, kidneys, and other vital organs.

Studies evaluated blood pressure indices, including mean arterial pressure and pulse pressure, after stress induction and six-minute walk testing in healthy adults and post-COVID populations [8-9]. Although these studies were not designed specifically as anesthesia trials, they are relevant to perioperative medicine because they highlight the importance of cardiovascular reserve rather than resting vital signs alone.

In clinical anesthesia, an apparently normal preoperative blood pressure does not guarantee adequate reserve under anesthetic stress. Patients with abnormal exertional symptoms, poor functional capacity, post-COVID dyspnea, autonomic instability, or cardiovascular disease may require more careful monitoring, invasive arterial blood pressure measurement, vasopressor readiness, and individualized hemodynamic targets.

Pulmonary Function, Post-COVID Physiology, and Anesthetic Planning

Pulmonary function has direct implications for anesthesia safety. General anesthesia can reduce functional residual capacity, promote atelectasis, impair hypoxic pulmonary vasoconstriction, and increase the risk of postoperative pulmonary complications. Opioids, residual neuromuscular blockade, abdominal insufflation, and postoperative immobility can further compromise ventilation.

Raza et al compared pulmonary functions after stress induction between post-COVID and healthy adults, showing the clinical relevance of pulmonary assessment after COVID-19 infection [3]. Additional work by the same research group evaluated sex-linked differences in pulmonary function after stress testing [4]. These studies support a practical perioperative point: patients with prior COVID-19 should be assessed according to current symptoms and functional status, not merely by the time elapsed since infection.

For anesthesia planning, post-COVID patients with persistent dyspnea, reduced exercise tolerance, abnormal oxygen saturation, chronic cough, chest pain, or fatigue may require additional evaluation. Depending on the procedure and severity of symptoms, this may include pulmonary function testing, electrocardiography, echocardiography, chest imaging, or specialist consultation. Intraoperatively, lung-protective ventilation, careful recruitment, avoidance of excessive fluids, full reversal of neuromuscular blockade, and early mobilization may reduce postoperative pulmonary risk.

Laparoscopic Surgery and Recovery-Focused Anesthesia

Laparoscopic surgery is associated with smaller incisions, reduced tissue trauma, and faster recovery in many procedures. However, it also creates anesthetic challenges. Pneumoperitoneum can increase intra-abdominal pressure, reduce lung compliance, increase airway pressures, affect venous return, and increase carbon dioxide absorption. Patient positioning may further affect ventilation and hemodynamics.

A study comparing 3-port and 4-port laparoscopic cholecystectomy, with outcomes related to postoperative pain, nausea, satisfaction, hospital stay, and complications [5]. These outcomes are directly relevant to anesthesia because postoperative pain and nausea are influenced by intraoperative analgesic choices, opioid exposure, antiemetic prophylaxis, local anesthetic use, hydration strategy, and anesthetic technique.

Recovery focused anesthesia for laparoscopic surgery should include multimodal analgesia, opioid minimization, prevention of postoperative nausea and vomiting, careful ventilation during pneumoperitoneum, temperature control, and discharge readiness assessment.

Multimodal Analgesia and Opioid-Sparing Anesthesia

Postoperative pain remains a major determinant of recovery. Poorly controlled pain can impair breathing, delay ambulation, worsen sleep, increase sympathetic activation, and reduce patient satisfaction. At the same time, excessive opioid use can cause sedation, respiratory depression, nausea, vomiting, constipation, ileus, urinary retention, delirium, and prolonged recovery.

Modern guidelines support multimodal analgesia, which combines medications and techniques that act through different pain pathways [10-11]. Common components include acetaminophen, nonsteroidal anti-inflammatory drugs when appropriate, local anesthetic infiltration, regional anesthesia, neuraxial techniques, ketamine, dexmedetomidine, and limited rescue opioids. The goal is not always complete opioid elimination. A more practical goal is opioid-sparing analgesia, where opioids are used selectively and at the lowest effective dose.

Regional anesthesia is especially important because it can provide targeted analgesia while reducing systemic opioid exposure. The 2026 American Society of Anesthesiologists guideline on perioperative pain management emphasizes local and regional techniques for selected cardiothoracic, mastectomy, and abdominal procedures.¹² When used appropriately, regional anesthesia may improve pain control, reduce opioid requirements, and support early rehabilitation.

Postoperative Nausea and Vomiting Prevention

Postoperative nausea and vomiting is one of the most common and distressing anesthesia-related complications. It can delay oral intake, prolong post-anesthesia care unit stay, reduce patient satisfaction, and increase the risk of dehydration or wound stress. Risk factors include female sex, nonsmoking status, history of postoperative nausea and vomiting or motion sickness, volatile anesthetic use, nitrous oxide exposure, and perioperative opioid use.

Consensus guidelines recommend risk assessment and multimodal prophylaxis for patients at increased risk [13]. Practical strategies include reducing perioperative opioids, using total intravenous anesthesia in selected patients, avoiding nitrous oxide when appropriate, providing adequate hydration, and combining antiemetics from different drug classes. For laparoscopic surgery, where nausea is common, prophylaxis should be planned before emergence rather than treated only after symptoms develop.

Enhanced Recovery After Surgery

Enhanced recovery after surgery pathways are multimodal perioperative care programs designed to reduce surgical stress and accelerate recovery. ERAS principles include patient education, preoperative optimization, standardized anesthetic and analgesic plans, avoidance of prolonged fasting, normothermia, nausea prevention, opioid-sparing analgesia, early feeding, and early mobilization [14-15].

Anesthesia is central to ERAS success. The anesthesiologist contributes through risk stratification, regional anesthesia, fluid management, antiemetic prophylaxis, lung-protective ventilation, glucose control when appropriate, temperature management, and postoperative pain planning. The best ERAS pathways are procedure-specific rather than generic.

Practical Perioperative Framework

A clinically useful anesthesia framework should begin before surgery. The preoperative assessment should identify cardiac disease, pulmonary disease, post-COVID symptoms, obstructive sleep apnea, chronic opioid use, renal dysfunction, liver disease, frailty, anemia, and poor functional capacity. For cardiac surgery or other high-risk procedures, cerebral monitoring may be considered when neurologic risk is high.

Intraoperatively, the anesthetic plan should focus on oxygen delivery, hemodynamic stability, ventilation, normothermia, analgesia, and prevention of complications. Cerebral oximetry, arterial pressure monitoring, advanced hemodynamic monitoring, or regional anesthesia should be selected according to patient and procedure risk rather than used routinely in every case.

Postoperatively, recovery should be assessed by more than pain scores alone. Important outcomes include alertness, respiratory safety, nausea control, mobility, oral intake, bowel recovery, urinary function, and readiness for discharge. This broader view aligns anesthesia care with patient-centered recovery.

Future Directions

Future research should clarify which patients benefit most from cerebral oximetry, whether cerebral desaturation correction improves neurologic outcomes, and how post-COVID cardiopulmonary findings predict perioperative complications. Additional studies are needed to connect stress-test physiology with intraoperative hemodynamic instability and postoperative recovery outcomes.

There is also a need for procedure-specific anesthesia protocols that combine cerebral monitoring, pulmonary protection, multimodal analgesia, nausea prevention, and enhanced recovery principles. Personalized perioperative medicine will likely depend on better risk prediction, clearer monitoring thresholds, and stronger links between intraoperative interventions and patient-centered outcomes.

CONCLUSION

Perioperative anesthesia requires integrated protection of neurologic, cardiovascular, pulmonary, and recovery outcomes. Cerebral oximetry may provide useful information during selected high-risk cardiac procedures, but it should be applied as part of a broader physiologic strategy. Cardiopulmonary reserve, post-COVID symptoms, hemodynamic response, surgical approach, pain control, and nausea prevention all influence recovery. A patient-specific anesthetic plan that combines careful monitoring, opioid-sparing analgesia, regional techniques, pulmonary optimization, and enhanced recovery principles can improve the quality and safety of perioperative care.

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