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OPEN ACCESS Review

General Anesthesia in Cardiac Surgery: A Narrative Review for Evolving Techniques and Patient-Centered Best Practices

Mohammed Ali Khalifa[1*], Mohammed A. Bahurmuz[2], Fares M.S Muthanna[1]

[1] *Department of Pharmacy, Faculty of Medicine and Health Sciences, University of Science and Technology, Aden, Yemen*
[2] *Department of Basic Sciences, Faculty of Medicine and Health Sciences, University of Science and Technology, Aden, Yemen*

ABSTRACT

This study explores advancements in general anesthesia techniques for cardiac surgery, focusing on their impact on patient safety, surgical outcomes, and alignment with modern patient-centered care. A narrative review synthesizing recent literature and clinical guidelines was conducted, highlighting innovations in anesthetic agents, monitoring technologies, and perioperative strategies.
Methods: Sources included clinical studies, systematic reviews, and expert consensus reports relevant to adult cardiac surgery. The review emphasized induction and maintenance techniques, perioperative concerns, and the effects of anesthesia on patient outcomes, with attention to high-risk groups.
Results: Induction agents such as propofol and etomidate are tailored to cardiovascular status, while maintenance with inhalational agents (isoflurane, sevoflurane) or TIVA demonstrates myocardial protection and reduced complications. Advanced monitoring tools like transesophageal echocardiography and cerebral oximetry enhance hemodynamic management. Perioperative innovations, including multimodal analgesia and fast-track protocols, support enhanced recovery. TIVA reduces postoperative cognitive dysfunction, particularly in elderly patients, and volatile agents provide myocardial protection.
Conclusion: Advancements in anesthetic pharmacology, monitoring, and perioperative strategies improve cardiac surgery outcomes by minimizing complications, optimizing recovery, and enhancing patient safety. Further research is warranted to refine these approaches for broader implementation in diverse patient populations.

Keywords: General Anesthesia, Cardiovascular Surgery, Hemodynamic Stability, Myocardial Protection

**** Corresponding author address:*** *m.khalifa@ust.edu*

INTRODUCTION

Cardiac surgery presents unique challenges requiring sophisticated anesthetic techniques to manage the cardiovascular stresses and hemodynamic fluctuations associated with these procedures (1). The physiologic state induced by general anesthetics typically includes analgesia, amnesia, loss of consciousness, inhibition of sensory and autonomic reflexes, and skeletal muscle relaxation (2). General anesthesia is integral to modern cardiac surgery, providing unconsciousness, muscle relaxation, and hemodynamic stability, all essential for successful surgical outcomes (2). Innovations in anesthetic agents, monitoring techniques, and multimodal anesthetic approaches have significantly advanced perioperative care, improving patient outcomes (3). The increased focus on personalized anesthesia management, including tailored drug selection and hemodynamic monitoring, is key to enhancing recovery and minimizing complications for patients undergoing complex cardiovascular procedures (4).
Recent advances in monitoring techniques, such as the use of transesophageal echocardiography (TEE) and cerebral oximetry, allow for real-time hemodynamic assessment, contributing to improved intraoperative decision-making (5). The absence of advanced technologies in cardiac surgery and anesthesiology presents significant challenges, including reduced procedural precision, increased risk of complications, and prolonged recovery times (5). Surgeons face difficulties in achieving optimal visualization and control during complex procedures, while anesthesiologists struggle to maintain hemodynamic stability without advanced monitoring tools like transesophageal echocardiography (5). These limitations hinder workflow efficiency, elevate stress, and compromise critical decision-making, emphasizing the vital role of modern technologies in ensuring the safety and effectiveness of cardiac surgical care (6). Moreover, total intravenous anesthesia (TIVA) with propofol and opioids is gaining preference due to its lower incidence of postoperative cognitive dysfunction, particularly in elderly patients (6). These advances align with enhanced recovery protocols that aim to shorten intensive care unit (ICU) stays, reduce opioid use, and facilitate early mobilization, leading to better overall recovery and fewer complications (7).
As the landscape of cardiac surgery continues to evolve, a more individualized approach to anesthesia—considering the patient's clinical status, the type of surgery, and available monitoring technologies—is critical to achieving optimal outcomes (8).
This study was aimed at exploring advancements in general anesthesia techniques for cardiac surgery, emphasizing their role in improving patient safety, surgical outcomes, and alignment with modern patient-centered care approaches. And examines the components of general anesthesia in cardiac surgery, highlighting current practices, recent advances, and emerging trends. The focus includes preoperative considerations, such as assessment of comorbidities (e.g., renal and hepatic dysfunction), selection of anesthetic agents, hemodynamic management, advanced monitoring, and postoperative care.

METHOD

This review was conducted by synthesizing recent literature and clinical guidelines on general anesthesia in cardiac surgery. The sources were selected based on relevance to cardiac anesthetic practices, innovations in pharmacology, and monitoring techniques. The narrative synthesis covers major topics such as induction and maintenance of anesthesia, perioperative concerns, anesthetic impact on patient outcomes, and future directions in the field.

Inclusion Criteria:

Clinical studies, systematic reviews, meta-analyses, and original research publications addressing general anesthesia in heart surgery, including developments and breakthroughs in anesthetic procedures, are all included in this study. Included are also expert consensus reports and guidelines on cardiac anesthesia, with a focus on studies involving adult patients having general anesthesia for heart surgery. High-risk groups are given extra consideration, including elderly individuals and those with concomitant conditions like heart or kidney problems.

Exclusion Criteria

The exclusion criteria include case reports, letters to the editor, and non-peer-reviewed articles unless offering significant innovative insights, as well as studies focused solely on non-cardiac surgeries, regional anesthesia, or pediatric and neonatal populations (unless addressing relevant comparisons). Studies on procedures without general anesthesia and those involving outdated anesthetic agents or monitoring technologies no longer in common use were also excluded.

MAIN FINDINGS

Anesthetic Techniques in Cardiac Surgery

1. **Induction of Anesthesia:** The choice of induction agents varies based on the patient's cardiovascular status (9). Propofol is commonly used for its rapid onset, while etomidate is preferred in hemodynamically unstable patients. Ketamine is chosen for those at risk of hypotension (10).
2. **Maintenance of Anesthesia:** Inhalational agents like isoflurane and sevoflurane are widely used for their hemodynamic stability and myocardial protection (11). TIVA with propofol and opioids is preferred for patients with high risks of postoperative complications like nausea or cognitive dysfunction (12).
3. **Neuromuscular Blockade:** Rocuronium and Vecuronium are preferred muscle relaxants, with Sugammadex used for rapid reversal when early extubation is anticipated (13).

Table 1: Comparison Between Modern and Old Techniques in Cardiovascular Anesthesia. Adapted from Cardiac Anesthesia: Principles and Clinical Practice - Edited by David L. Reich and Steven E. Shafer, Chapter Anesthesia for Cardiac Surgery (14)

Aspect	Old Techniques	Modern Techniques
Monitoring	Basic monitoring (e.g., ECG, blood pressure)	Advanced monitoring (e.g., transesophageal echocardiography, continuous cardiac output monitoring)
Drug Options	Limited agents with longer onset and recovery times (e.g., halothane, thiopental)	Newer drugs with rapid onset and recovery, better hemodynamic stability (e.g., propofol, remifentanil)
Airway Management	Conventional intubation methods	Video-assisted intubation and supraglottic airway devices for improved precision
Anesthetic Depth Control	Relying on clinical signs (e.g., heart rate, blood pressure)	Depth monitoring using devices like BIS (Bispectral Index) for better accuracy
Techniques for Cardio-protection	Minimal or no cardioprotective strategies	Strategies like ischemic preconditioning and selective anesthetic cardio-protection
Postoperative Recovery	Prolonged recovery times due to less refined drugs and monitoring	Enhanced recovery protocols with shorter hospital stays and faster rehabilitation
Personalization	One-size-fits-all approach	Tailored anesthesia based on patient-specific needs and conditions
Technology Integration	Minimal technology use	Real-time imaging, robotic assistance, and integrated perioperative care systems

Table 2: Summary of Anesthetic Techniques in Cardiac Surgery
Adapted from (Cardiac Anesthesia: Principles and Clinical Practice - Edited by David L. Reich and Steven E. Shafer, Chapter Anesthesia for Cardiac Surgery) (14).

Aspect	Types of Techniques	Clinical Implications
Induction of Anesthesia	- Propofol: Rapid onset, commonly used. - Etomidate: Preferred for hemodynamic instability. - Ketamine: Suitable for hypotension-prone patients.	Ensures stable induction tailored to cardiovascular status.
Maintenance of Anesthesia	- Inhalational Agents: Isoflurane and Sevoflurane for hemodynamic stability and myocardial protection. - TIVA: Propofol and opioids for reduced complications.	Minimizes postoperative nausea and cognitive dysfunction.
Neuromuscular Blockade	- Rocuronium and Vecuronium as preferred agents. - Sugammadex for rapid reversal when early extubation is needed.	Enables effective muscle relaxation and supports fast-track recovery protocols.

Hemodynamic Management and Monitoring

Advanced monitoring, including pulmonary artery catheters and TEE are crucial in managing hemodynamic fluctuations (15). Emerging technologies like cerebral oximetry and non-invasive cardiac output devices are gaining popularity for their accuracy and real-time data (16,17).

Table 3: Hemodynamic Management and Monitoring Advances. Adapted from (Clinical Anesthesia (8th Edition) - By Paul G. Barash, Bruce F. Cullen, Robert K. Stoelting) (18).

Monitoring Tool	Application	Advantages
Pulmonary Artery Catheters	Assesses pulmonary pressures and cardiac output.	Facilitates precise hemodynamic control.
Transesophageal Echocardiography	Provides real-time imaging for cardiac function and volume status.	Enhances intraoperative decision-making.
Cerebral Oximetry	Monitors brain oxygenation during surgery.	Reduces the risk of neurological complications.
Non-Invasive Cardiac Output Monitoring	Tracks cardiac function without invasive procedures.	Safer and suitable for more patients.

Perioperative Concerns

Myocardial protection, anticoagulation management, and postoperative pain control are key challenges (19). Multimodal analgesia, regional anesthesia techniques, and fast-track protocols for early extubation are increasingly utilized to enhance recovery (20). Enhanced recovery protocols and non-opioid analgesic strategies are reducing opioid use and promoting faster patient mobilization (21).

Impact of Anesthetic Choice on Outcomes

TIVA appears to reduce postoperative cognitive dysfunction, particularly in elderly patients, while volatile anesthetics offer myocardial protection

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during surgery (23). Innovations in monitoring and drug selection are associated with improved cardiac and renal outcomes (24,25).

Table 4: Perioperative Strategies and Outcomes. Adapted from (Miller's Anesthesia (9th Edition) - Edited by Michael A. Gropper) (22).

Aspect	Description	Outcomes
Myocardial Protection	Optimized with anesthetic agents like volatile anesthetics and meticulous management of ischemia-reperfusion injury.	Reduced intraoperative myocardial damage and improved long-term cardiac function.
Anticoagulation Management	Careful titration of anticoagulants and reversal agents to balance bleeding risk and thromboembolism prevention.	Decreased incidence of perioperative bleeding and thrombotic events.
Multimodal Analgesia	Use of non-opioid analgesics, regional techniques, and adjuncts like Dexmedetomidine.	Enhanced pain control, reduced opioid dependence, and faster recovery.
Early Extubation Protocols	Fast-track anesthesia techniques with rapid neuromuscular blockade reversal (e.g., Sugammadex).	Shortened ICU stay, reduced ventilation-associated complications, and quicker mobilization.
Enhanced Recovery After Surgery	Incorporates early mobilization, minimal invasive monitoring, and non-opioid-based pain management.	Improved overall recovery, reduced hospital length of stay, and better patient satisfaction.

General Anesthesia Doses and Special Considerations in Cardiac Surgery

In cardiac surgery, the administration of general anesthesia requires careful consideration of the patient's cardiovascular status, comorbidities, and surgical procedure (26,27). The goal is to maintain hemodynamic stability while ensuring adequate sedation and muscle relaxation for optimal surgical conditions (28). Table (5) shows the key anesthetic agents, their doses, and special considerations for use in cardiac surgery.

Table 5: Doses of Common General Anesthesia Agents in Cardiac Surgery. Adapted from (Gropper, M. A. (Ed.). (2019). Miller's Anesthesia (9th ed.). Elsevier (22).

Anesthetic Agent	Induction Dose	Maintenance Dose	Notes
Propofol	1.5–2.5 mg/kg IV (depending on patient response)	4–12 mg/kg/hr (TIVA) or 0.5–2.5 mg/kg/hr (maintenance)	Commonly used for induction and maintenance; quick onset.

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Etomidate	0.2–0.3 mg/kg IV	Continuous infusion 0.03–0.05 mg/kg/min for maintenance	Preferred in hemodynamically unstable patients.
Ketamine	1–2 mg/kg IV	0.25–0.5 mg/kg/hr for maintenance	Used for patients at risk of hypotension; also provides analgesia.
Isoflurane	-	0.5–1.5 Minimum Alveolar Concentration (MAC) (inhalational)	Inhalational agent; maintains hemodynamic stability.
Sevoflurane	-	0.5–2.0 MAC (inhalational)	Preferred for its myocardial protection properties.
Dexmedetomidine	Loading dose: 1 mcg/kg IV over 10–20 minutes	Maintenance: 0.2–0.7 mcg/kg/hr	Used for sedation and analgesia; preserves hemodynamic stability.
Rocuronium	0.6–1.2 mg/kg IV	0.1–0.2 mg/kg every 20–40 minutes as needed for maintenance	Preferred for muscle relaxation; rapid onset.
Vecuronium	0.08–0.1 mg/kg IV	0.02–0.08 mg/kg IV every 20–40 minutes for maintenance	Alternative to Rocuronium, less cardiovascular effects.
Sugammadex	2–4 mg/kg IV (based on neuromuscular blockade depth)	-	Reverses muscle relaxation induced by Rocuronium or Vecuronium.

The table (5) provides a general guide for commonly used general anesthesia agents and their dosing in cardiac surgery. The actual doses may vary based on the patient's clinical condition, comorbidities, and response to anesthesia (29).

General Anesthesia and Modern Patient-Centered Care Approaches

The absence of advanced technologies in cardiac surgery and anesthesiology presents significant challenges, including reduced procedural precision, increased risk of complications, and prolonged recovery times (30). Surgeons face difficulties in achieving optimal visualization and control during complex procedures, while anesthesiologists struggle to maintain hemodynamic stability without advanced monitoring tools like transesophageal echocardiography (30). These limitations hinder workflow efficiency, elevate stress, and compromise critical decision-making, emphasizing the vital role of modern technologies in ensuring the safety and effectiveness of cardiac surgical care (30).

DISCUSSION

Patient-centered and tailored approaches have, over the years, seen a **significant shift toward personalized care**, where anesthesia is increasingly tailored to individual patient needs. This approach might account for 70–80% of progress in general anesthesia techniques in cardiac surgery, as it improves outcomes by addressing specific cardiovascular conditions, age, comorbidities, and other patient factors (31). The choice of anesthetic techniques in cardiac surgery is critical for optimizing patient outcomes. Induction agents such as propofol, etomidate, and ketamine are selected based on cardiovascular stability, as highlighted in recent guidelines emphasizing patient-specific approaches (32). Maintenance strategies balance hemodynamic stability and myocardial protection, with evidence supporting the use of inhalational agents or TIVA for reduced complications (33). Effective neuromuscular blockade with agents like rocuronium and sugammadex supports enhanced recovery protocols, aligning with multimodal strategies to minimize postoperative risks (34). Tailored anesthetic management ensures safety and faster recovery (35).

Pulmonary artery catheters provide precise hemodynamic control, making them essential for high-risk cardiac surgery cases, especially in assessing pulmonary pressures and cardiac output (36). Transesophageal echocardiography offers real-time cardiac imaging, enhancing intraoperative decision-making, particularly in valve surgeries (37). Cerebral oximetry ensures brain oxygenation monitoring, reducing neurological complications during surgery (38). Non-invasive cardiac output monitoring serves as a safer option, broadening accessibility to a wider patient population (39). Together, these tools enable comprehensive monitoring, optimize surgical management, and improve outcomes, ensuring maximal benefit tailored to patient-specific needs (40).

Myocardial protection in cardiac surgery, optimized through volatile anesthetics and ischemia-reperfusion management, has been shown to reduce intraoperative myocardial damage and improve long-term heart function (41). Anticoagulation strategies, balancing anticoagulants and reversal agents, effectively decrease perioperative bleeding and thromboembolism risk (42). Multimodal analgesia, including non-opioid analgesics and regional techniques, provides enhanced pain control and reduces opioid use, promoting faster recovery (43). Early extubation protocols with rapid reversal of neuromuscular blockade reduce ICU stays and complications (44). Enhanced recovery pathways (ERAS) further optimize patient recovery, shortening hospital stays and improving satisfaction (45).

Propofol is favored for its rapid onset, while etomidate is ideal for hemodynamically unstable patients (46). Ketamine is effective for hypotension-prone patients, offering both hemodynamic stability and analgesia (47). Inhalational agents like isoflurane and sevoflurane provide hemodynamic stability and myocardial protection (48). Agents like dexmedetomidine, rocuronium, and sugammadex optimize sedation, muscle relaxation, and recovery (2). Advances in pharmacology, including the use of dexmedetomidine for sedation and sugammadex for neuromuscular blockade reversal, have significantly improved intraoperative management and postoperative recovery (49). Monitoring technologies like TEE and cerebral oximetry are now integral to surgical procedures, improving decision-making and reducing complications (50). Multimodal analgesia and early extubation strategies are central to enhanced recovery protocols, leading to shorter ICU stays and faster rehabilitation (51). The ongoing comparison between TIVA and inhalational anesthesia emphasizes the need for further research to refine patient-specific strategies (52).

CONCLUSION

General anesthesia remains a cornerstone of cardiac surgery, with continual advancements enhancing the safety and effectiveness of these complex procedures. The evolving techniques in cardiac anesthesia, driven by patient-specific strategies, have led to improved outcomes in high-risk surgeries. Tailoring anesthetic agents like propofol, etomidate, and ketamine ensures cardiovascular stability during induction, while maintenance agents such as inhalational agents and TIVA support hemodynamic control and myocardial protection. Advanced monitoring technologies, including TEE and cerebral oximetry, enhance intraoperative decision-making and reduce complications. Enhanced recovery protocols, including multimodal analgesia and early extubation, contribute to faster recovery, shorter ICU stays, and better patient satisfaction. Continued research is essential to optimize anesthesia strategies for diverse patient populations.

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