Keynote Lecture Series

Small incisions still require great anesthesia: anesthesiology techniques to enhance recovery in robotic coronary bypass grafting

Danny Feike Hoogma[1,2], Wouter Oosterlinck[2,3], Steffen Rex[1,2]

[1]Department of Anesthesiology, University Hospitals of Leuven, Leuven, Belgium; [2]Department of Cardiovascular Sciences, Biomedical Sciences Group, University of Leuven, Leuven, Belgium; [3]Department of Cardiac Surgery, University Hospitals of Leuven, Leuven, Belgium

Correspondence to: Danny Feike Hoogma, MD. Department of Anesthesiology, University Hospitals of Leuven, Herestraat 49, 3000 Leuven, Belgium. Email: Danny.hoogma@uzleuven.be.

Robotic coronary artery bypass grafting (CABG) has emerged as a promising minimally invasive surgical technique for the treatment of coronary artery disease. This paper provides an in-depth analysis of the anesthetic management for robotic CABG. Challenges associated with robotic CABG are discussed and various anesthetic techniques, perioperative elements and pain management modalities that can contribute to enhanced patient recovery are explored.

Keywords: Robotic coronary artery bypass grafting (robotic CABG); quality of recovery (QoR); pain management; enhanced recovery; patient satisfaction

Submitted Nov 21, 2023. Accepted for publication Apr 22, 2024. Published online Jun 26, 2024.
doi: 10.21037/acs-2024-rcabg-0048
View this article at: https://dx.doi.org/10.21037/acs-2024-rcabg-0048

Introduction

Robotic coronary artery bypass grafting (CABG) is a state-of-the-art surgical approach that offers significant advantages over traditional open-heart surgery, including reduced surgical trauma, smaller incisions, shorter hospital stay, and quicker recovery times (1). Anesthetic management plays a crucial role in achieving successful outcomes, patient comfort and ultimately enhancing quality of recovery (QoR).

Patient-centered outcomes are increasingly important in the current era. Early assessment of QoR is an important aspect of evaluating the success of the procedure and the patient's overall (long-term) outcome (2). The QoR-40 is a 40-item recovery score evaluating five dimensions: physical comfort, emotional state, physical independence, psychological support and pain. A five-point Likert scale is used to rate each item with a possible score of 200 for excellent QoR or 40 for extremely poor QoR (3). Myles *et al.* (2) have suggested that earlier and effective interventions could improve the outcome after cardiac surgery.

In the early 1990s, Engelman *et al.* (4) made the first steps to enhance recovery and overall outcomes of the cardiac surgical patient. They demonstrated that a 'fast-track' postoperative management was associated with a significant improvement in recovery and even a reduction in hospital length of stay (LOS) (4). Nonetheless, is was not until 2019 that the first Enhanced Recovery After Cardiac Surgery (ERACS) guidelines were published (5). These guidelines are a comprehensive set of evidence-based interventions and best practices aiming to improve outcomes for patients undergoing cardiac surgery (5). These strategies provide the clinician, patient and healthcare personnel with a structured approach to perioperative care, covering many aspects of preoperative optimization, intraoperative homeostasis and postoperative rehabilitation. Increased compliance with these interventions has already been shown to be associated with shortened hospital stay and reduced postoperative complications (6).

Unfortunately, many daily used strategies to enhance recovery are not discussed in the current ERACS guidelines but are also considered to significantly improve postoperative outcomes (7-9). In the current paper, we will address multiple (graded and non-graded) elements that in our practice have aided in the care of patients undergoing robotic CABG surgery. These include preoperative evaluation and education, surgical positioning of the patient, airway management, multimodal anesthesia, perioperative analgesia, fluid management and (chest) drain management.

Preoperative considerations

A comprehensive preoperative assessment is essential for determining the patient's eligibility for robotic CABG. Efforts to optimize the patient's medical condition should be undertaken to reduce perioperative risks and enhance outcomes. Recent evidence suggests that dedicated patient educational programs can improve mental well-being and quality of life after cardiac surgery (10). These educational programs cannot only improve the level of self-management, but also the return to normal activities. The quality of communication between patients and surgical team empowers the patient, facilitates treatment discussions and is needed to assure correct informed consent (11). In addition, illustrations and 3D printed models can further improve patient's satisfaction and reduce perioperative anxiety (12). In robotic assisted surgery, patient empowerment and preoperative education may benefit the outcome measures (13).

Intraoperative considerations

"Before anything else, preparation is the key to success."—Alexander Graham Bell

Preparation and positioning: exposure for surgery and monitoring

A close collaboration between anesthesia and surgery is required. Standard American Society of Anesthesiologist (ASA) monitoring and electroencephalography monitoring should be used in all patients to ensure adequate monitoring. Prior to induction of general anesthesia, a large bore intravenous line and invasive right (because of positioning) radial arterial blood pressure measurement line should be placed. Following induction of anesthesia and intubation, a central venous catheter is placed for central venous pressure measurements and infusion of drugs. Some practitioners additionally place a central venous introducer sheath, which is rarely necessary in this patient population. The use of transesophageal echocardiography (TEE) is mandatory in any minimally invasive cardiac surgical procedure (14). Finally, the patients should be positioned in supine position with the table slightly tilted towards the right to optimize exposure of the left hemithorax.

Airway management and hemodynamics

Robotic CABG usually requires perioperative single lung ventilation of the right lung, although, this is not a prerequisite (15). For single lung ventilation, many anesthesiologists have traditionally favored the use of a double-lumen tube (DLT) (16,17). There are indeed several advantages, including a low risk for displacement, use of positive pressure in the non-ventilated lung and improved lung collapse. Nonetheless, a DLT is known to be associated with an increased incidence of sore throat and hoarseness, which can decrease QoR (18). Likewise, the incidence of serious complications such bronchial rupture is increased. Moreover, the placement of a DLT is difficult if not impossible/contraindicated in patients with a difficult airway. Therefore, we systematically use a single lumen endotracheal tube (SLT) and the Rüsch EZ-blocker™ (Teleflex, Ireland) in every robotic CABG patient to achieve lung separation and single lung ventilation. As with the DLT, fiberoptic evaluation is used to confirm adequate positioning of the bronchus blocker. We suggest placing the EZ-blocker only after positioning the patient. Prior to the placement of the blocker (i.e., starting with endotracheal intubation), we ventilate the patient with 100% oxygen to facilitate later lung collapse (19). Before inflating the left-sided blocking balloon, the patient is disconnected from the ventilator to allow lung collapse. After inflation of the balloon, ventilation is resumed. Notably, the use of a SLT with EZ-blocker reduces anesthesia times as it omits the requirement to replace a DLT with a SLT should postoperative ventilation be required in the post anesthesia care unit (PACU).

At the start of the surgical procedure, a left-sided tension pneumothorax is created to enhance surgical exposure and vision. This can affect hemodynamics in hemodynamically unstable patients. In case of severe arterial hypotension, close collaboration between surgeon and anesthesiologist is required to interrupt insufflation. Ventilation is maintained with a tidal volume of 4–5 mL/kg at a rate of 18–20 per min, targeting a pH >7.3.

Multimodal anesthesia: it is not only opioids

Multimodal, balanced, and short-acting anesthesia is one of the key-components in many fast-track protocols (4). The current ERACS guidelines describe multiple interventions for postoperative analgesia, however, they do not mention intraoperative anesthesia management (5). Anesthesia requires not only analgesia, it must also guarantee hypnosis and amnesia while maintaining hemodynamic stability (5). Historically, high-dose opioids were used to achieve the aforementioned goals (20). Unfortunately, this came at the cost of prolonged postoperative ventilation and intensive care unit (ICU) stay (20). This burden on resources stipulated significant practice changes including the use of low-dose and/or short-acting opioids combined with either intravenous or inhaled anesthetics in cardiac surgery, allowing 'early' extubation. Currently, the evidence is neutral regarding superiority of either intravenous anesthetics or inhaled anesthetics in terms of postoperative outcomes, therefore this is often left at the discretion of the anesthesiologist while considering specific patient factors (21,22). Notably, total intravenous anesthesia has been demonstrated to have more environmental sustainability (23).

Based on our personal experience, we suggest using a total intravenous based multimodal anesthesia regimen including remifentanil, dexmedetomidine and propofol (electroencephalography guided). This approach allows for early extubation, either on table or within two hours after surgery (24).

Chest tubes: active management starts intraoperatively

Management of chest drains remains a challenge in the postoperative course of the patient following cardiac surgery. Despite being essential, these drains can elicit significant postoperative pain, affecting respiratory recovery, ambulation and oral intake, ultimately reducing QoR (25). Decisions about chest drain management are largely driven by tradition, and unfortunately, it is frequently forgotten that active chest drain management should be part of the ERACS program (25).

A small volume of pericardial or pleural blood is to be expected following robotic CABG surgery and drainage is considered an essential step in reducing certain complications, including effusions, tamponade, and atrial fibrillation (26). Management should already commence intraoperatively by evaluating the number, location, and size of the drains. Unfortunately, evidence regarding these factors is limited due to inconsistencies in study design (26). In addition, most studies in ERACS fail to report on chest drain management.

During the postoperative course, several elements should be considered when implementing an active chest drain management. A recent randomized trial by St-Onge *et al.* (27) identified that chest drain management with active clearance significantly reduced re-exploration rates when compared to conventional management (27). In contrast are the results of the study by Ntinopoulos *et al.* (28) who compared similar approaches and identified a reduced chest tube output using active clearance, but without any difference in outcome (28). The debate regarding timing of chest drain removal is ongoing, especially as current enhanced recovery guidelines for thoracic and cardiac surgery state that these chest drains should be removed early (5,29). The timing must be balanced by the risk-benefit ratio, which unfortunately is mainly based on 'a gut' feeling with limited evidence to support these decisions.

In our center, we have changed our chest drain management in robotic CABG surgery. Considering the presence of an open pericardium, limited drainage volume and low re-exploration rates we have reduced the number, size and length of our chest drains to only one chest drain (19 Fr) placed in the seventh intercostal space. To ensure evacuation of retained blood, negative pressure (−15 cmH_2O) is used. We have demonstrated that in this population a median duration of 18 h until chest drain removal is possible and safe (30). Drains are only left in place if output exceeded 300 mL or if output in the previous 6 h exceeded at any moment 100 mL/h.

Postoperative care

Multimodal analgesia regimen: opioids and non-opioids

In the past decade, analgesic management has changed drastically due to several innovations. In addition, the current opioid crisis and implementation of enhanced recovery pathways in cardiac surgery have paved the way for a multimodal analgesic approach in an attempt to reduce postoperative pain, promote early ambulation, early oral intake and improve recovery (5,6,8). Advancements in surgical and technological techniques allow the cardiac surgeon to use a robotically assisted thoracoscopic approach for CABG surgery, thus reducing the surgical trauma and length of incision. Consequently, the origin of postoperative

Table 1 Perioperative multimodal analgesic strategy at the University Hospitals of Leuven

Time of treatment	Drug	Dosing	Duration
Intraoperative	Dexamethasone	5 mg IV 2/d	First 48 hours
	Dexmedetomidine	0.5 μg/kg/h IV	Until weaning
	Remifentanil	0.1–0.2 μg/kg/min IV	Until weaning
	Metamizole	15 mg/kg q6 IV	Start of robotic phase
	Acetaminophen	15 mg/kg q6 IV	End of surgery
	Ropivacaine	20 mL 0.5% local	Infiltration chest tubes
	Morphine	0.1 mg/kg IV	End of surgery
Postoperative	Acetaminophen	15 mg/kg q6 IV/PO	Scheduled until POD 2
	Metamizole	15 mg/kg q6 IV/PO	After 24 h only as needed
Rescue	Morphine	0.1 mg/kg q4 SC	If NRS for pain >4 until POD 1
	Morphine	1–2 mg IV	If NRS for pain >6 in PACU
	Ibuprofen	10 mg/kg IV	For 48 hours
	Ketamine	0.15 mg/kg IV	At PACU
	Ropivacaine	10–20 mL 0.5% local	At PACU (infiltration chest tube)

IV, intravenous; PO, peros; POD, postoperative day; SC, subcutaneous; NRS, Numerical Rating Scale; PACU, post anesthesia care unit.

pain has shifted from somatic (i.e., ribs, intercostal nerves and muscles) to primarily visceral (i.e., pleural and pericardial) related pain (30-32).

Current ERACS guidelines suggest using a multimodal opioid-sparing strategy consisting of education and multiple non-opioid drugs (5). However, other authors suggest also adding loco-regional techniques to this package (7,33). Currently, evidence regarding the choice of drugs is limited but generally consists of pregabalin, nonsteroidal anti-inflammatory drugs, acetaminophen, dexmedetomidine, dexamethasone and/or methadone with an opioid as rescue treatment (34). Regarding regional analgesic techniques, recommendations vary between epidural, spinal, paravertebral, intercostal or fascial plane blocks (34). The use of these fascial plane blocks has gathered much attention, mainly because they are promoted to be easy and safe (35). However, randomized clinical trials have suggested that in the setting of multimodal analgesia, these fascial plane blocks appear to have limited to no incremental benefits (30,36-38).

In our center, we are using a multimodal analgesic strategy which includes a combination of non-opioid analgesics administered together with local infiltration of chest tube insertion sites in all our adult cardiac surgical patients. This strategy is continued postoperatively for those transferred to our PACU (*Table 1*).

Early extubation: the most threatening medical condition has been treated

Since the early 1990s, the concept of fast-track anesthesia was introduced which focused among others on early extubation (4). The increase in surgical volume, resource demands and adjustments in anesthetic and surgical techniques have further fostered this transition (1).

Robotic CABG surgery resolves the 'threatening' cardiac condition, as such, these patients have no medical reasons to be sedated nor ventilated postoperatively (1,39). Multiple studies have already demonstrated that early extubation, in the operating room or within 2 h, reduces ICU stay, without increasing postoperative complications (1,40). In addition, bypassing the ICU after robotic CABG surgery is associated with a significant reduction in cost and hospital LOS (40).

In our center, ERACS patients are usually transferred, while sedated (with dexmedetomidine and remifentanil) and intubated, to our PACU. By using a nurse-driven extubation protocol, they are weaned from the ventilator within 30–60 min after arrival at the PACU (30). During their postoperative stay in our PACU, two to three sessions of 30–60 min continuous positive airway pressure are applied (41).

Fluid management: overload and outcome

Fluid overload after cardiac surgery is common and associated with an increased incidence of postoperative complications, including increased incidence of acute kidney injury and hospital LOS (5). Goal-directed fluid therapy (GDFT) is an intervention recommended by the ERACS guidelines aiming at optimizing tissue perfusion by identifying the optimal treatment, either fluids, inotropes or vasopressors (5). This requires the continuous evaluation of standard hemodynamic parameters (i.e., blood pressure, central venous pressure, heart rate) and in addition, several quantifiable goals, including central or systemic venous oxygen saturation, urinary output, lactate levels and hematocrit (42). Finally, cardiac ultrasound is, certainly amongst minimally invasive procedures, an indispensable tool to improve GDFT and outcome (7,42). Although clinicians frequently apply this concept in clinical practice, specific goals are often lacking (42). In addition, interpreting and calculating fluid-balances has shown to be difficult and variable (42,43). Therefore, it is recommended to assess weight gain, as this is easier to interpret (42,43).

Return to preoperative status: activate the patient

Early enteral nutrition and mobilization are considered by many clinicians as essential interventions to improve postoperative recovery (6,7). Nonetheless, current ERACS guidelines have not (yet) incorporated these interventions (5). A scheduled prophylactic post-operative nausea and vomiting (PONV) strategy can aid in the early resumption of oral intake and improved patients satisfaction and QoR (44). Consequently, these patients are more likely to ambulate, further enhancing recovery and reducing postoperative complications (6,45,46). In addition, these interventions might also reduce fluid overload.

A frequently forgotten element in recovery are chest drain(s) for which an active management should be employed, encouraging early removal (26). Even more, all lines, except for the peripheral intravenous (IV) access, can usually be removed the morning after surgery (30).

In our center, we ensure scheduled PONV prophylaxis (i.e., dexamethasone 5 mg q12 IV and ondansetron 4 mg q6 IV), which allows patients to resume oral intake (water) only 30 min after extubation. By the evening, patients are ambulated, sitting on the side of their bed. By the morning after surgery, patients are seated in an armchair, consuming a light breakfast (6). Thereafter, chest drains, central and arterial lines and in-dwelling catheter are removed and they are transferred to the ward (with nurse to patient ratio 1:8) (6,30).

Discharge criteria

Patients' speedy recovery should be a top priority of any ERACS program. That is why during their stay with us, we encourage patients to rest in their armchair during daytime hours and avoid bed rest. With the help of physiotherapy, we encourage patients to ambulate as much as possible. To facilitate early ambulation, we continue postoperative analgesia with IV or oral acetaminophen for 48 h. If required we can supplement this with oral metamizole, ibuprofen or contramal. To ensure a smooth and safe recovery, central continuous electrocardiogram (ECG) monitoring is used, allowing us to detect and treat any abnormalities promptly. Our discharge criteria include a clear chest X-ray, respiratory and hemodynamic stability, decreasing C-reactive protein (CRP) levels and physical fitness (ability to walk up >22 stairs and use a home trainer). Generally, patients reach these criteria on postoperative day 3 or 4.

Conclusions

This paper highlights the critical role of a close collaboration between anesthesia, surgery and nurses to optimize care in patients during robotic CABG surgery. The implementation of enhanced recovery guidelines and multimodal strategies can potentially contribute to a smoother recovery process, improved patient satisfaction and QoR. However, more evidence is needed regarding patient reported outcomes in this population.

Acknowledgments

Funding: None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Cite this article as: Hoogma DF, Oosterlinck W, Rex S. Small incisions still require great anesthesia: anesthesiology techniques to enhance recovery in robotic coronary bypass grafting. Ann Cardiothorac Surg 2024;13(5):409-416. doi: 10.21037/acs-2024-rcabg-0048