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Review Article

Prolonged Stay in ICU after Cardiac Surgery: Challenges –A Review

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ABSTRACT

Prolonged stay in the intensive care unit (ICU) following cardiac surgery has become a topic of increasing concern in the medical community. While advancements in surgical techniques and perioperative care have improved the outcomes of cardiac surgeries, some patients still experience extended ICU stays due to various complications and comorbidities. This review article aims to explore the reasons behind prolonged ICU stays after cardiac surgery, their impact on patient outcomes, and the strategies and innovations that healthcare providers can employ to mitigate these challenges.

Keywords: Intensive care unit, Cardiac surgery, Prolonged length of stay

INTRODUCTION

Cardiac surgery has seen a demographic shift in the patient profile, with many presenting in their latter part of life with multiple comorbidities. Patients with multiple comorbidities are undergoing cardiac surgeries and having favorable outcomes, which can be attributed to advances in surgical techniques, anesthesia, and perioperative care.

Although there is no standardization with respect to the definition of a prolonged length of stay (LOS) in intensive care unit (ICU) in a cardiac surgery patient, a retrospective multicenter cohort study by Sha defines an extended ICU LOS in such patients as anything more than or equal to 5 days.[1] Another retrospective observational analysis by Almashrafi *et al.* also mentions the same (LOS > five days) as a prolonged ICU stay.[2] Prolonged stay in the ICU after cardiac surgery is reported in around 4–11% of the entire patient cohort. This is known to utilize a significant proportion of the ICU resources, leading to additional healthcare costs and cancellation of scheduled surgeries as a result of extended ICU bed occupancy. This is also known to negatively impact the mental and social life of the patients and relatives apart from the financial burden.

Continuous monitoring of factors affecting the ICU LOS after cardiac surgery helps design patient care services and streamlines patients' movement more efficiently. Integrating the surveyed data about such factors into patient care services directed at bettering patient outcomes is important as it will ensure better usage of the resources in the hospital and lessen the financial burden.

If we look at the surgical procedures *per se*, a combined valve replacement/repair plus a coronary artery bypass grafting (CABG) or a valve replacement/repair is found to have a prolonged LOS

in the ICU. Higher acute physiology and chronic health evaluation scores and non-elective surgeries also add to the brunt of such patients.

The most common predictors observed for a prolonged LOS are as follows:[2,3]

Increased age	Blood transfusion
Atrial fibrillation	Surgical site infection
Chronic obstructive pulmonary disease	Delirium
Low ejection fraction	Increased cardiopulmonary bypass time
Renal dysfunction	
Non-elective surgeries	
Complexity of surgery	
Insulin-dependent diabetes mellitus	
Critical preoperative state	
Right ventricular dysfunction	

INDEPENDENT PREDICTORS OF ICU LOS

Of all the basic demographic variables, age has been found to be a consistent factor associated with prolonged LOS. Surgical characteristics such as cardiopulmonary bypass (CPB) time and blood transfusion were found to be predictive of ICU LOS.[3]

Consistent factors which have been found to be associated with a prolonged LOS in various studies are increased age, chronic obstructive pulmonary disease (COPD), renal failure, atrial fibrillation (AF), low ejection fraction, NYHA classIII–IV, non-elective surgery, prior cardiac surgery, and inotropic support.[3]

ENHANCED RECOVERY AFTER CARDIAC SURGERY (ERACS)

ERACS is a multimodal transdisciplinary care program for patients who undergo surgery to ensure a smooth perioperative course with the aim of reducing complications and ensuring an early and uneventful discharge from the hospital and a return to normal life activities. It is known to reduce the overall complication rate to <50% and decrease the LOS in the hospital. Although there are published protocols for non-cardiac surgeries, an evidence-based protocol for cardiac surgery is yet to emerge, which can be uniformly practiced.

PREOPERATIVE ERACS STRATEGIES

Hemoglobin A1C (HbA1c) measurement for risk stratification

Optimal glycemic control with a target HbA1c level of <6.5% has been found to decrease the incidence of sternal wound infections, events of ischemia, and related complications. Although there is no strong evidence-based guideline to tell what is the preoperative HbA1c cutoff value, various literature suggests a value <7% as an achievable goal. A clear demonstration of the long-term survival benefit is demonstrated in a recent retrospective review. However, it is difficult to extrapolate these data to cardiac surgery. Halkos *et al*. prospectively analyzed the relationship between HbA1c values and post-operative outcomes in 3555 patients.[4] They found an increase in in-hospital mortality by fourfold when the HbA1c levels were above 8.4%. Furthermore, there was an increased odds for the occurrence of myocardial infarction (MI), deep sternal wound infection, and cerebrovascular accident.[4] Another large study by Carson *et al*. examined 41,663 people with diabetes with 1,05,123 non-diabetic patients and found that the 30-day mortality and in-hospital morbidity were significantly higher to the tune of 23–37% in people with diabetes.[5] Tight perioperative glucose control improves the post-operative outcome.[4,5] Routine HbA1c testing is recommended, and if the value is more than 7%, they should be treated as diabetics.[6]

Preoperative albumin measurement for risk stratification

There is an increased risk of mortality and morbidity in patients with a low serum albumin concentration. Hypoalbuminemia is found to be a prognosticator of preoperative risk, correlating with increased length of time on a ventilator, acute kidney injury (AKI), infection, longer LOS, and mortality. A preoperative serum albumin concentration of <3 g/dL may have an implication on the morbidity following cardiac surgery, especially on CPB. Its non-oncotic properties, such as immunomodulation, antibiotic transportation, endothelial stabilization, and anti-inflammatory effects, may have a role in critically ill cardiac patients. Albumin molecules also have been found to have antioxidant properties, which may be an advantage in recovery from the early inflammatory insult following a CPB, especially for a prolonged duration.[7,8]

Correction of nutritional deficiency

In patients undergoing cardiac surgery, supplemental nutritional therapy targeting albumin levels (>3 g/dL) may improve the outcomes. This may require at least 7–10 days of intense nutritional therapy. This becomes all the more important when the patients have a history of weight loss of more than 10–15% in the past six months, have a body mass index (BMI) of <18.5 kg/m^2, and a serum albumin level of <3 g/dL without any hepatic or renal dysfunction.[1]

Prehabilitation

An interprofessional multimodal approach focusing on bettering the nutritional and physical status of a patient

is found to have a positive impact on bettering the post-operative complication rates in surgeries. This includes education about the disease and disease progression and outcomes, nutritional support, anxiety reduction, and social support. The same model has been extensively studied and practiced in colonic surgeries and is being extrapolated to cardiac surgery and is found to have a positive impact. The training of inspiratory muscles with spirometry exercises betters the post-operative respiratory complication rates.[1,9] This requires a coordinated approach between the anesthesia and surgical team and the physiotherapy department, classifying the patients into discrete groups based on the preoperative physical status and listing the patients for cardiac surgery accordingly.

Patient engagement tools

Making use of the patient-smartphone interaction platform to improve the patient-healthcare interaction is desirable. The cost to the end user is often negligible. Digital health in cardiac surgery may be commonly applied in post-operative screening of possible or expected complications on a time-to-time basis. This, when integrated with the hospital database of the patient and the use of similar applications at the hospital level, will help in alerting the hospital about such a patient. Telehealth visits have been in use, especially post-COVID. This also ensures patient education, and patients often remain more active in self-care.[10]

Smoking and alcohol

Tobacco smoking and alcohol consumption are known risk factors for post-operative complications involving respiratory tract, wound healing, metabolic derangements, and infections. Abstinence for four weeks minimum is found to have a favorable post-operative outcome, which may not be possible in urgent or emergency surgeries.[1]

INTRAOPERATIVE STRATEGIES

Surgical site infection (SSI) reduction

Reducing SSI requires a multidisciplinary approach involving surgeons, nurses, anesthesiologists, infection control teams, and the active participation of the patients themselves. Adherence to evidence-based guidelines and continuous quality improvement efforts are the cornerstone of achieving this goal. Reducing SSI is a crucial aspect of patient safety and post-operative care. SSI can lead to complications, prolonged hospital stays, increased healthcare costs, and patient discomfort. Some of the strategies to reduce SSI apart from following strict hand hygiene and aseptic techniques are as follows:[11]

Preoperative patient preparation

- Properly assess and optimize the patient's overall health before surgery
- Patients with risk factors, such as diabetes or obesity, should have their conditions well-managed.

Appropriate antibiotic prophylaxis

Choosing the appropriate antibiotic based on the type of surgery and local resistance patterns is to be considered. A cephalosporin antibiotic is to be administered within an hour before the incision is made. Re-dosing is to be done whenever the surgery duration exceeds four hours. It may be stopped within 48 hours after cardiac surgery.[11]

Hair removal and skin preparation

Avoid shaving the surgical site; instead, use clippers or depilatory creams to remove hair if necessary. It has been found in a meta-analysis that clipping is found to significantly reduce the incidence of SSI.[12] The use of chlorhexidine – an alcohol-based solution for skin preparation before surgery should be ensured. Preoperative bathing with chlorhexidine is known to bring down the bacterial count in the wound significantly.[1]

Intranasal mupirocin

It is found that 18–30% of all patients undergoing surgery are carriers of *Staphylococcus aureus*, and they have three times the risk of *S. aureus* SSI and bacteremia. Topical therapy with mupirocin ointment has been demonstrated to reduce such infection incidence.[13]

Post-operative normothermia is known to reduce the incidence of SSI. Other measures such as minimizing tissue trauma during surgery, strict aseptic techniques, optimal wound closure with staples, sutures or adhesive strips, and subcuticular sutures may help in reducing SSI. In-hospital active surveillance and reporting of the incidence of infection, with a strict antibiotic stewardship protocol, ensures responsible use of antibiotics to prevent antibiotic resistance. The data on SSI should be regularly analyzed to identify areas of improvement in surgical protocols and patient care. Continuous staff training on best practices for infection prevention should be done.

Rigid sternal fixation

Wire cerclage of the sternal ends is commonly practiced in cardiac surgery for sternal closure. This ensures approximation of the edges, but it has been found that the side-to-side movement of the sternal edge is not prevented with the wire cerclage. The use of rigid plate fixation is an

alternative that has been studied and found to be beneficial, especially in high-risk groups like those with high BMI, COPD, and a history of chest wall radiation. There is a reduced incidence of mediastinal wound complication and better sternal adherence, as per a meta-analysis.[14]

Hyperthermia

Temperature monitoring and normothermia are essential aspects of cardiac surgery, especially on a CPB. Prospective studies have demonstrated that a core temperature exceeding 37.9°C is known to cause cognitive impairment, infection, and renal impairment, all of which increase the LOS in ICU.[15,16] Post-operative hyperthermia within 24 hours after the surgery may cause cognitive impairment, which may even persist up to 4–6 weeks after a CABG surgery. Normothermia with continuous surface warming should be adhered to.[15]

Blood transfusion

Inappropriate transfusion of packed red blood cells (RBCs) and blood products such as fresh frozen plasma and platelets is known to have a negative impact on the patient's recovery and prolong the ICU LOS. Transfusion practice in the Operating room and ICU should be point-of-care test-driven. The use of thromboelastography or rotational thromboelastometry has been found to help in avoiding unnecessary preoperative or intraoperative blood transfusion. Blood salvage techniques and the use of tranexamic acid or epsilon aminocaproic acid for correcting ongoing bleeding once surgical hemostats are done should be encouraged intraoperatively.

POST-OPERATIVE STRATEGIES

Glycemic control and insulin infusion

Hyperglycemia in the preoperative period is known to increase morbidity due to its varied effects on physiology. It has been attributed to oxidative stress, prothrombotic effects, glucose toxicity *per se,* and inflammation. Multiple randomized controlled trials do support the same on varied patient cohorts. A strict post-operative glycemic control is known to improve the post-operative outcomes. Using epidural analgesia in cardiac surgery is also known to ensue good post-operative glycemic control in such patients.[17,18] Tight blood glucose control between 80 mg/dL and 110 mg/dL, at the same time avoiding hypoglycemia, is known to have a positive impact on post-operative outcomes. Still, subsequent studies have not been able to replicate those findings.[16] Due to the higher incidence of hypoglycemia, blood glucose should be maintained between 110 mg/dL and 200 mg/dL.

Pain management

Parenteral opioids have been the mainstay in pain management in cardiac surgery, which has its own set of side effects, such as sedation, respiratory depression, nausea, and ileus. A multimodal analgesia approach using non-opioid or opioid-sparing techniques due to their additive or synergistic effects will ensure equipotent analgesia, at the same time bringing down the side effects of opioids, which would help in early discharge from the ICU and hospital. The use of non-steroidal anti-inflammatory drugs and selective cyclooxygenase-2 inhibitors have their own complications of renal dysfunction and thromboembolic events after cardiac surgery. The safest non-opioid analgesic prescribed is paracetamol, which may be given intravenously and converted to oral formulations once the gut function recovers. Tramadol is a common analgesic used after cardiac surgery, which has opioid as well as non-opioid effects, bringing down the requirement of morphine by almost 25% and improving pain scores. Pregabalin and gabapentin also have been tried and are found to reduce the opioid requirement drastically. A pregabalin administered one hour before and up to 2 days postoperatively is known to improve the pain scores compared to the placebo. Dexmedetomidine, an α-2 adrenergic agonist, is showing a lot of promise in analgesic management, bringing down the opioid requirement significantly, also with its favorable pharmacokinetic profile in decreasing the incidence of AKI after cardiac surgery.[19-21] We have demonstrated earlier extubation and discharge from the ICU in cardiac surgical patients by thoracic epidural analgesia.[22]

Delirium screening

An acute confusional state is characterized by disorganized thinking, inattention, or fluctuating mental status and is associated with reduced in-hospital and long-term survival. Detection of delirium at an early stage with a systematic screening tool, such as the confusion assessment method for ICU or the ICU delirium screening checklist, should be considered to improve the outcomes. This should be done at least once per nursing shift. The most common causes of delirium, such as pain, hypoxemia, a low cardiac output state, and sepsis, should be identified and treated accordingly.[23] We found a lesser incidence of delirium post-cardiac surgery using dexmedetomidine.[24]

Hypothermia

Hypothermia after cardiac surgery is found to be deleterious as it is associated with an increased risk of bleeding, infection, and arrhythmias, leading to prolonged LOS in the ICU. Persistent hypothermia is the failure to return to or unable to maintain a temperature of 36°C for 2–5 h after an ICU admission of a patient after cardiac surgery. Measures such

as raising the ambient temperature, using warm intravenous fluids, and using Bair Hugger forced air warming blankets should be encouraged to mitigate this issue.[25]

Chest tube patency

An efficient mediastinal and pleural tube drain management is essential after cardiac surgery as a clogged drain might lead to collection of blood in the pericardial or pleural sac, leading to cardiac tamponade or hemothorax, respectively. Furthermore, retained shed blood in the mediastinal space would hemolyze and trigger an oxidative inflammatory pathway, which is found to cause further pleural or pericardial effusion and is also associated with AF.[1] The most common chest tube manipulation strategy used in ICUs is chest tube milking or suctioning out the clots from the chest tube. The effectiveness of the first method is found to be questionable, as suggested by a meta-analysis of randomized controlled trials. It is found to be harmful and ineffective while suctioning out the clots by a breach in the sterile barrier, which is again something that can lead to infections and may damage the internal structures. Active chest tube clearance methods may be used to manage the chest tube systems, and once the drainage levels become visibly serous, the drains should be removed as early as possible.[1,26,27]

Pharmacological thromboprophylaxis

A patient, after cardiac surgery, remains in a hypercoagulable state, increasing the risk of vascular thrombotic events, which may be a deep venous thrombosis to a fatal pulmonary embolism (PE). Hence, effective thromboprophylaxis in the form of either anticoagulation or mechanical thromboprophylaxis – compression stockings and/or intermittent pneumatic compression devices should be prescribed until a patient is in hospital or until they are effectively mobilized. Prophylactic dose of anticoagulation should be considered from the 1st post-operative day itself unless contraindicated. A meta-analysis by Ho *et al*. suggests that chemical thromboprophylaxis could reduce the vascular thrombotic risk without increasing the bleeding risk in such post-operative cardiac surgical patients.[28,29]

Extubation strategy

Prolonged mechanical ventilation after cardiac surgery is known to be associated with long-term hospitalization, morbidity, and associated increase in hospital costs. Some of the common reasons are attributed to the complications like dysphagia and ventilator associated pneumonia. Fast-tracking protocols tailored to every ICU should be ensured in aiding early extubation of a post-cardiac surgical patient within six hours of ICU admission. Although early extubation has shown to be an effective strategy in bringing down the complications, the overall outcomes in a post-cardiac surgery patient depend on the intraoperative clinical variables like intra aortic, duration of surgery, blood transfusion, opioids, intraaortic balloon pump, etc. Hence, a direct association of early extubation with a significant reduction in complications have not been clearly demonstrated.[30,31]

Acute Kidney Injury and prevention

AKI is found to complicate 22.3 % of all cardiac surgical procedures as per a meta-analysis by Hu *et al*., of which 2.3% end up receiving renal replacement therapy (RRT).[32] Of all the strategies, the most effective one is to identify such potential at-risk patients before the surgery and ensure therapies or strategies to reduce the incidence of AKI. Although not used on a routine basis, urinary biomarkers such as urinary neutrophil gelatinase-associated lipocalin, tissue inhibitor of metalloproteinase-2, or insulin-like growth factor binding protein 7 are helpful in identifying patients who are at high risk of developing AKI.[33,34] Discontinuing angiotensin-converting enzyme inhibitors I and angiotensin-II antagonists for 48 hours before surgery, avoiding hyperglycemia and radiocontrast agents close to surgery, close monitoring of the patient's volume status and hemodynamics, and avoiding nephrotoxic medicines are few effective and proven strategies which may be implemented in bringing down the incidence of AKI.

Goal-directed fluid therapy (GDT)

Using monitoring techniques in aiding fluid therapy, vasopressor, and inotrope administration with a standardized algorithm helps in bettering the patient outcomes following cardiac surgery. The most commonly used end parameters are cardiac output, cardiac index, systemic venous oxygen saturation, and urine output. At the same time, calculating oxygen debt and oxygen consumption and serial monitoring of serum lactate levels helps in tight monitoring of the ongoing hemodynamic state and ensures a patient-tailored fluid administration. GDT has consistently demonstrated an improvement in the overall survival rates and hospital and ICU LOS across surgical specialties and not just in cardiac surgery.[35,36] In a randomized prospective, multicenter trial of GDT after cardiac surgery, we have demonstrated earlier extubation and a favorable postoperative outcome with a reduced ICU LOS in high-risk cardiac surgical patients.[37]

POST-CARDIOTOMY VENTRICULAR DYSFUNCTION (PCVD)

It may be defined as a new onset or worsening heart failure that requires the administration of inotropes and/or mechanical circulatory support devices during the weaning period from CPB. Apart from the most common causes,

such as advanced age, recent MI, renal failure, emergency procedures, and prolonged aortic cross-clamping, the causes of PCVD *per se* are multifactorial, most often comprising surgical tissue trauma, ischemia-reperfusion injury, beta-receptor down regulation, coronary air/atheroma embolization, activation of inflammatory mediators, etc. Incidence of PCVD *per se* varies from 20% to 60%; it may be self-limiting, resolving after a transient insult, and sometimes may end up in a low cardiac output syndrome (LCOS) state having negative prognostic implications. LCOS after cardiac surgery remains a matter of concern and occurs in 5–15% of patients. It is known to be associated with multiple organ dysfunction (MODS) and may cause prolonged hospital stay and proportional increased morbidity and mortality.[38-40]

NON-OCCLUSIVE MESENTERIC ISCHEMIA (NOMI)

NOMI is a rare yet serious complication after cardiac surgery first described by Ende in the year 1985.[41] It can turn out to be a silent menace in the colon, especially the ileum and the distal jejunum being more commonly affected. There is no obvious major occlusion of an artery, yet there can be signs and symptoms of intestinal ischemia. Hence, early identification of the disease and risk stratification of the patients becomes very important. The clinical signs of NOMI could vary from abdominal pain to more pronounced oliguria, rise in lactate levels, and hypotension. It may even progress to intestinal ischemia, which may lead to a breach in the mucosal layer, ending up with bacteremia and MODS. Renal insufficiency, diuretic therapy, and age >70 years are some of the most common preoperative risk factors. The most prominent post-operative risk factors are hypovolemia, cardiogenic shock, administration of α-adrenergic agonists, and use of intra-aortic balloon pump. A prolonged duration of CPB >100 min and duration of surgery exceeding 240 min, hypotension, apart from norepinephrine support exceeding 0.1 mcg/kg/min, were found to be risk factors during the intraoperative period as per a study by Groesdonk *et al*. Catheter angiography is the gold standard in the diagnosis, though contrast multi detector row computed tomography may be used to detect intestinal malperfusion. Most often, it is conservatively managed. A high index of suspicion and early intervention are key to the management of NOMI.[42,43]

NEW-ONSET AF (NOAF)

AF is the most frequent adverse event after cardiac surgery and is found to occur in up to 25% of patients after isolated CABG, 30% after isolated ventricular procedures, and 40–50% in combined procedures. It is found to be associated with postoperative stroke, sternal and respiratory tract infections, renal dysfunction, and gastrointestinal dysfunction. It is often associated with longer LOS in ICU and hospital and proportionately increased readmission rates as well. Attributed etiologies are multifactorial and may be due to atrial substrate changes (within first six days, post-operative), re-entry circuits, sympathetic tone, inflammation, and oxidative stress-raised C-reactive protein, interleukin-6, tumor necrosis factor- , dyselectrolemia, etc. Advanced age is found to be the most consistent risk factor across multiple studies, while history of COPD, prior history of AF, obesity, chronic renal failure, rheumatic heart disease, increased left atrial volume, abnormal left ventricular systolic and diastolic function, and male gender are the other identified risk factors. Management includes identifying the trigger and correcting the associated causatives. Dyselectrolemia management use of appropriate anti-arrhythmics such as beta-adrenergic blockers, amiodarone, and calcium channel blockers routinely corrects the NOAF. The use of corticosteroids such as methylprednisolone, hydrocortisone, and dexamethasone has been studied across varied studies. It is summarized to be a class IIb recommendation in the SCA/EACTA 2019 practice improvement advisory for AF prophylaxis but is not widely used. Electrophysiological strategies like overdrive atrial pacing may be tried. The use of posterior pericardiotomy as a surgical strategy for draining the pericardial fluid, which could possibly be a trigger for the development of AF, is also advocated. Off-pump CABG has comparatively a lesser inflammatory response compared to CPB and theoretically could have a lesser incidence of AF post-surgery, but the real-world extrapolation in terms of the incidence of AF is not convincing as per randomized controlled trials. Anticoagulation should be considered in AF lasting for more than 48 h or of unknown duration as in any non-surgical patient, and a transesophageal echocardiogram may be done to rule out any intracardiac thrombus.[44-46]

Right ventricular dysfunction after cardiac surgery

Right ventricular dysfunction after cardiac surgery occurs in 0.1% of the patients after a cardiotomy, in approximately 2–3% of the patients undergoing heart transplantation, and 10–20% of the patients needing left ventricular assist device insertion. The most commonly identified causes are as follows.[47]

Prolonged cardiopulmonary bypass time	Atrial arrhythmias
Right coronary embolism or graft occlusion	Loss of atrioventricular synchrony
Inadequate myocardial protection during surgery	Preexisting pulmonary hypertension
Reperfusion lung injury with secondary pulmonary hypertension	
Protamine-induced pulmonary hypertension	

Management of the right ventricular (RV) dysfunction is focused on identifying the correctibles, such as hypoxemia, hypercapnia, acidosis, raised airway pressures on ventilation, and inotropes such as dobutamine, milrinone, and epinephrine in titrated doses. Treatable precipitants of right-sided heart failure include infection, anemia, thyroid dysfunction, PE, arrhythmia, or non-adherence to prescribed medications. Supraventricular tachyarrhythmias, especially atrial flutter and AF, are common causes of right-sided heart failure in patients with severe pulmonary hypertension. Diuretics are administered if the patient is volume-loaded. There should be a strong suspicion when there is a significant stroke volume variation (SVV) and pulse pressure variation (PPV), but there is no response to intravenous fluids. Hence, the reliability of SVV and PPV in RV dysfunction is questionable. Mechanical ventilation in acute RV dysfunction can turn out to be deleterious. The targets should be to limit the plateau pressure to <27 cm H_2O and keep the driving pressure to <18 cm H_2O. Reversing or preventing hypoxemic pulmonary vasoconstriction also should be ensured.[48]

CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD)

COPD has a major impact on the mortality and morbidity of a patient undergoing cardiac surgery. Reintubation and prolonged mechanical ventilation in such a patient increase the mortality risk by almost 50%, as per a retrospective cohort analysis by Szylińska *et al*.[49] There is an increased incidence of pneumonia, wound infection, stroke, and respiratory failure in the COPD cohort undergoing cardiac surgery. The incidences of AF in non-COPD and COPD patients undergoing cardiac surgery are variable, as per literature evidence.[50]

The EUROSCORE-European system for cardiac operative risk evaluation also includes COPD and such chronic lung diseases using long-term steroids and inhaled bronchodilator therapy as an independent risk factor for surgical mortality. Preoperative optimization, thoracic epidural analgesia, early weaning and fast-tracking, and early mobilization of such patients should be ensured for a good postoperative outcome.

ACUTE KIDNEY INJURY (AKI)

Cardiac surgery-associated AKI is a recognized complication having very high morbidity and mortality, increasing the odds ratio of operative mortality by 3–8-fold, prolonging the ICU and hospital stay of such a patient. Early diagnosis, identifying the correctable preoperative factors, and use of prophylactic measures perioperatively to optimize renal function become crucial for a better outcome. Pathogenesis of cardiac surgery-associated AKI is multifactorial and is a consequence of multiple intraoperative and postoperative factors.[51]

Apart from factors such as age, pre-existing renal disease, chronic kidney disease, diabetes mellitus, and redo surgeries, the greatest influence on the outcome after an AKI is found to be the complexity and the emergency nature of the surgery. Inflammation triggered by the CPB and hemodilution during CPB are the consistent factors causing AKI. Furthermore, the non-pulsatile flow of the CPB puts the renal system under ischemic risk. Prolonged CPB time, aortic cross-clamp, ischemia-reperfusion injury, and LCOS are some of the identified triggering factors causing renal ischemic insult. Non-oliguric renal failure, wherein there is a rise in serum creatinine, but urine output remains more than 400 mL/24 hours, is the most common form of AKI, occurring in 20% of the patients with an RRT requirement of 1%. In contrast, oliguric renal failure is found in 5–7% of the cases.

Apart from withholding the nephrotoxic drugs preoperatively maintaining good hemodynamics, other intraoperative measures that might help in preventing an AKI are off-pump surgeries in CABG, minimizing the bleeding and use of blood conservation strategies, and preventing hyperglycemia. CPB considerations such as optimal perfusion pressures (mean arterial pressure>75–80 mmHg), use of leucocyte-reducing filters, lessening the CPB time, and hemofiltration to reduce the fluid load are found to be effective in reducing the occurrence of AKI.

Oliguric patients should be aggressively treated to prevent further tubular injury and worsening of renal function. If oliguria persists even after stabilization of the hemodynamics, a diuretic may be considered. Furosemide, bumetanide, and thiazide diuretic may be considered. Once oliguria is established while minimizing excessive fluid administration, early initiation of RRT is found to reduce mortality and improve survival.[51,52]

BLOOD TRANSFUSION

Packed RBC transfusion is a recognized risk factor for adverse outcomes after cardiac surgery. It is prudent to avoid unnecessary transfusion as it is associated with increased morbidity, mortality, and healthcare costs. Preoperative optimization, intraoperative blood conservation, judicious use of post-operative transfusions, and minimally invasive techniques should be utilized wherever appropriate to minimize the need for blood transfusions.[49] The transfusion trigger may be tailored to the patient's clinical status rather than just the hemoglobin value. Transfusion may trigger a systemic inflammatory response and adverse immunomodulatory effects through the reduction of circulating lymphocytes. Preoperative treatment with intravenous iron, subcutaneous erythropoietin alpha, Vitamin B12, and folic acid are found to be associated with reduced RBC and total allogeneic transfusions in patients with preoperative anemia undergoing elective cardiac

surgery. The etiology of anemia should be assessed in all elective surgeries preoperatively as it is associated with short- and long-term adverse outcomes. Hence, a proper evaluation and treatment should be ensured.[53]

SUMMARY

Prolonged ICU stays after cardiac surgery can have significant adverse effects on patients, including:

- Increased risk of healthcare-associated infections
- Prolonged mechanical ventilation
- Delayed mobilization and rehabilitation
- Higher mortality rates
- Psychological distress, delirium.

Strategies to reduce prolonged ICU stays

1. Preoperative optimization
    - Identifying high-risk patients
    - Optimizing comorbidities
    - Patient education and shared decision-making
2. ERACS protocols
    - Multidisciplinary approach
    - Early extubation
    - Reduced use of opioids
    - Early mobilization
3. Surgical techniques
    - Minimally invasive procedures
    - Off-pump bypass surgery
    - Hybrid approaches
4. Post-operative care
    - Aggressive pain management
    - Goal-directed fluid therapy
    - Early enteral nutrition
    - Delirium prevention strategies
5. Enhanced monitoring
    - Hemodynamic monitoring
    - Continuous cardiac output monitoring
    - Bedside ultrasound.

INNOVATIONS AND FUTURE DIRECTIONS

a. Telemedicine and remote monitoring for early detection of complications and timely interventions
b. Artificial intelligence and predictive analytics usage for risk stratification and personalized care plans
c. Advanced robotic-assisted surgeries for precision and dexterity
d. Stem cell therapies: Potential for cardiac regeneration.

CONCLUSION

Prolonged stays in the ICU following cardiac surgery present a complex challenge, influenced by a multitude of factors. Addressing these challenges requires a comprehensive, multidisciplinary approach that encompasses preoperative optimization, surgical innovations, and advanced post-operative care strategies. By continually researching and implementing new technologies and protocols, the medical community can work toward reducing the incidence of prolonged ICU stays, thereby improving the overall quality of care and outcomes for patients undergoing cardiac surgery.

Ethical approval

The Institutional Review Board approval is not required.

Declaration of patient consent

Patient consent not required as there are no patients in this study.

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Conflicts of interest

Dr. Yatin Mehta is the member of the Editorial board of the journal.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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