Seminars in Cardiothoracic and Vascular Anesthesia
2015, Vol. 19(2) 87–94

DOI: 10.1177/1089253214568529
scv.sagepub.com
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How Should We Manage Arrest Following Cardiac Surgery?

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Abstract

Perioperative arrest occurs in thousands of cardiac surgical patients annually, yet standard resuscitation methods are ineffective or potentially harmful. These "high risk, low volume" events typically occur in well-monitored patients in the highly specialized environment of the operating room or intensive care unit, with a short list of likely causes of arrest, making a protocolized approach to management feasible and desirable. An evidence-based guideline for resuscitation specific to the cardiac surgical patient was first published by Dunning et al in 2009 and adopted by the European Resuscitation Council the following year. It emphasizes important deviations from advanced cardiac life support, including immediate defibrillation or pacing of arrhythmias *before* external compressions, if feasible within 1 minute, and avoidance of epinephrine due to potential rebound hypertension. In standard fashion, the rapid exclusion of reversible causes of arrest is followed by chest reopening within 5 minutes. This approach is now standard of care in most European countries and is under review for use in the United States by the Society of Thoracic Surgeons. The anesthesiologist, as either team leader or participant, plays a critical role in optimally managing arrests after cardiac surgery. Their familiarity with this new standard is essential to optimal patient outcomes.

Keywords

cardiac surgery, circulatory arrest, perioperative mortality, postoperative complications, critical care

Anesthetic management of the cardiac surgical patient poses unique challenges due to preexisting cardiovascular disease and associated comorbid conditions, combined with highly specialized procedures utilizing hypothermia, anticoagulation, and cardiopulmonary bypass. Cardiac emergencies in such patients are not uncommon, with up to 8% experiencing a perioperative arrest.[1,2] Survival of these arrests can be as high as 79%, but significant variability in outcomes exists.[3] LaPar et al reported that 10-year failure-to-rescue rates in 4138 arrests ranged from 50% to 83% among the 17 study hospitals.[1] Although advanced cardiac life support (ACLS) has long been the acknowledged resuscitation standard for the majority of adults in the United States, this approach is suboptimal and potentially harmful in patients with a recent sternotomy. In these patients, reasons for postoperative arrest are relatively few and differentiated by electrical (arrhythmia) or mechanical causes (tamponade, profound hypovolemia due to bleeding, or tension pneumothorax). In all these scenarios, institution of external cardiac massage (ECM) is associated with a greater burden of adverse neurologic outcomes when compared to internal massage.[4] Additionally, potential harm from ECM is increased after recent sternotomy, warranting a modified approach if safer resuscitation strategies exist. Specialized monitoring promotes immediate recognition of arrest in an environment with readily available resources of personnel and equipment, including those needed for emergent resternotomy. In contrast to the 2010 resuscitation guidelines issued by the American Heart Association (AHA), which failed to offer specialized guidance for cardiac surgical arrests,[5] the European Resuscitation Council fully endorsed the approach introduced by Dunning et al.[6,7] This protocol, designed exclusively for management of arrest after cardiac surgery, considers the unique features of these patients and the environment where these events are likely to occur in recommending important deviations from ACLS. The Society of Thoracic Surgeons has appointed a resuscitation task force that is expected to approve this protocol as the optimal resuscitation strategy for patients in the United States in 2015. Below, we describe this protocol and contrast key differences from standard ACLS techniques.

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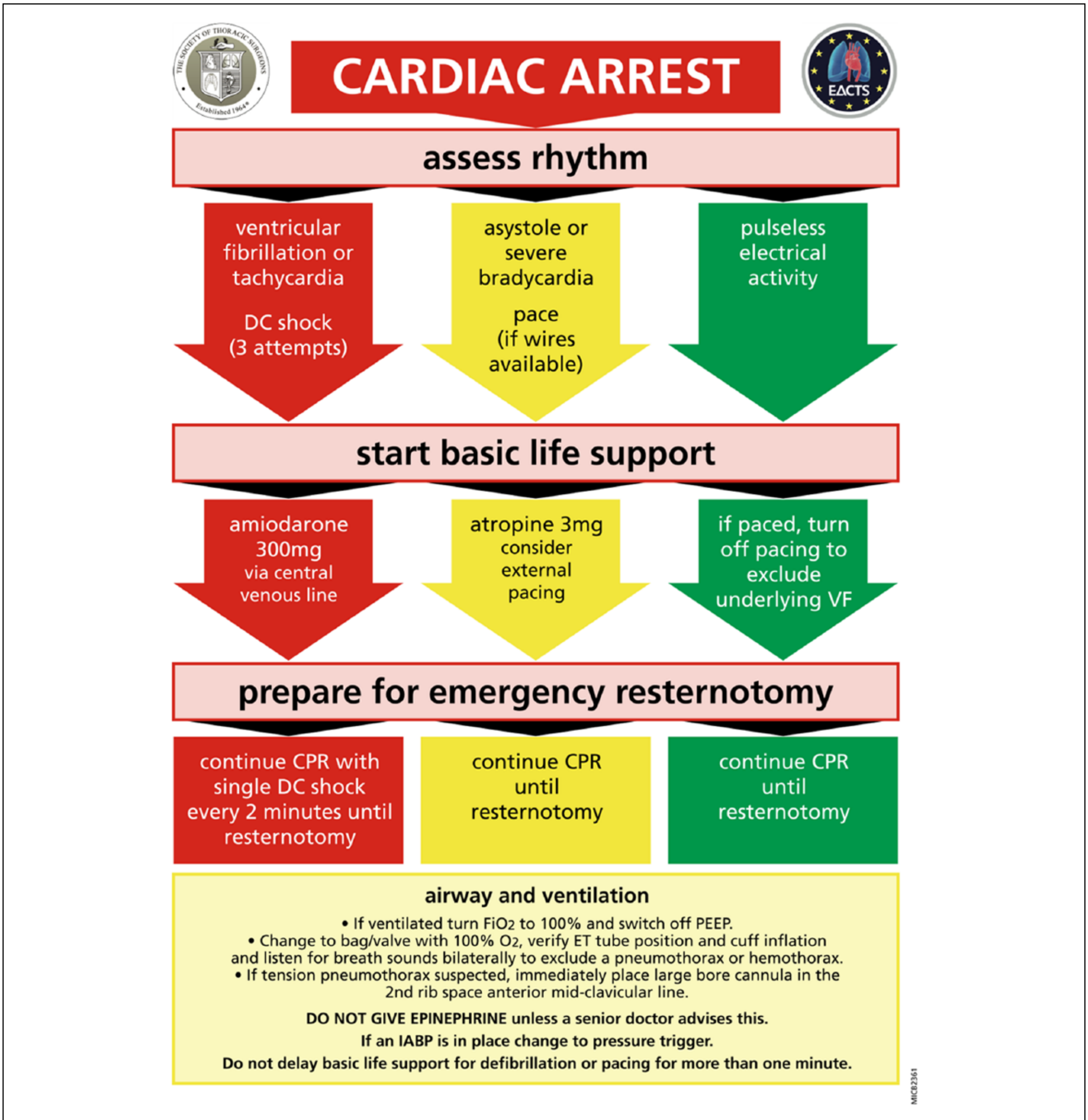

Figure 1. Protocol for arrest management after cardiac surgery. From Dunning et al,[6] with permission.

Protocol for Arrest Management After Cardiac Surgery

The protocol for arrest management after cardiac surgery is illustrated in Figures 1 and 2.[6] The European Resuscitation Council now recommends its use in preference to standard ACLS for an arrest in the postoperative cardiac surgical patient.[7] Important features of arrest management for the anesthesiologist and intensivist are highlighted below, including initial strategies for arrhythmia management using defibrillation or pacing, limited use of epinephrine, and conduct of an emergency resternotomy.

Defibrillation and Pacing Strategies

One of the most important differences between the cardiac surgical arrest protocol and ACLS is its prioritization of defibrillation in arrhythmia management.[6] Ventricular

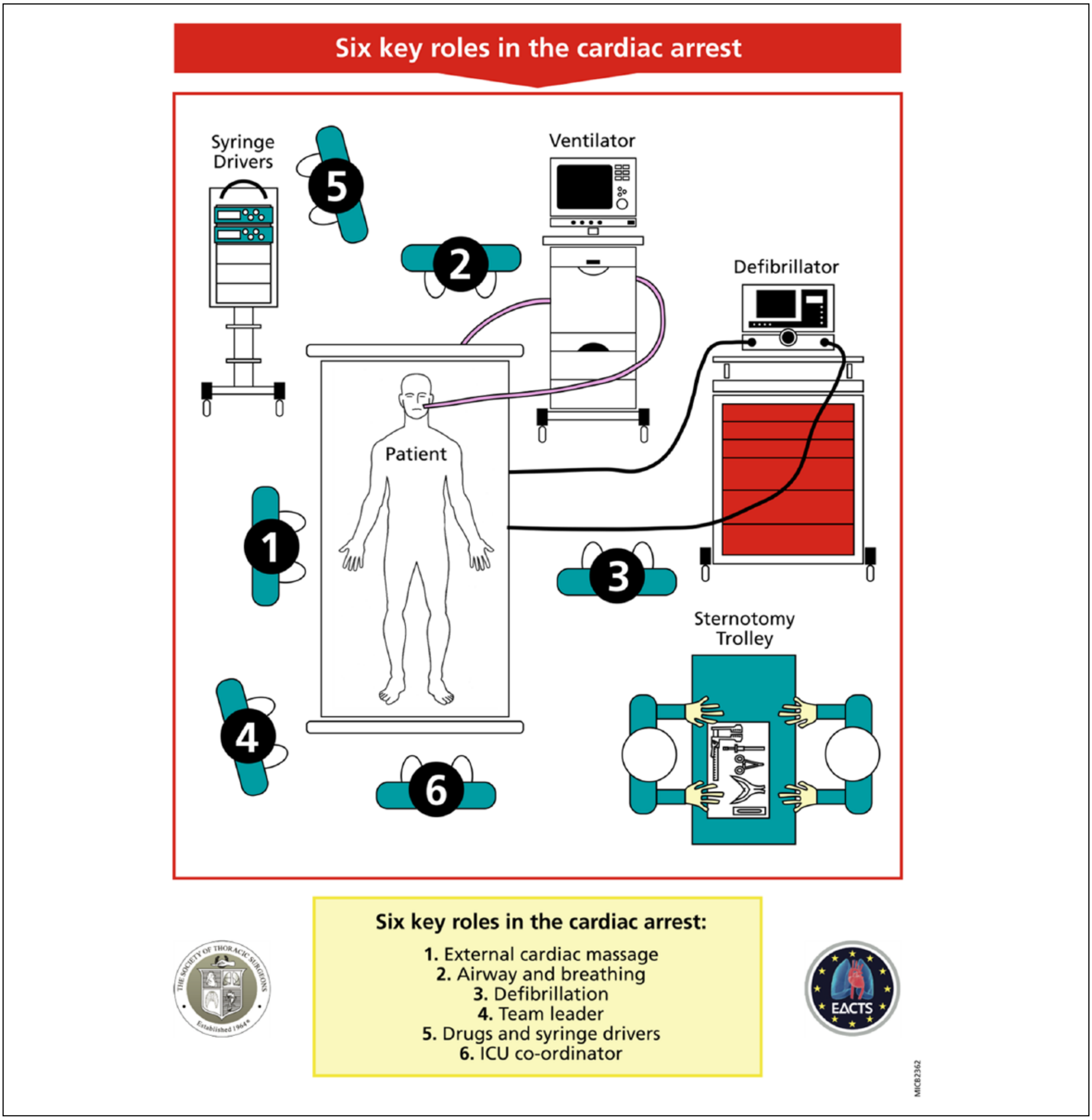

Figure 2. Provider roles for cardiac surgical arrest management.From Dunning et al,[6] with permission.

fibrillation (VF) or pulseless ventricular tachycardia (VT) occurs in 30% to 50% of postoperative cardiac arrests and is typically a witnessed event.[3] Current ACLS algorithms advocate cardiopulmonary resuscitation (CPR) as the first priority, followed by a single shock, then 2 additional minutes of CPR before a second defibrillation is attempted.[5] Chan et al demonstrated that survival of in-hospital cardiac arrest fell from 39% to 22% if defibrillation occurred beyond 2 minutes, emphasizing the importance of immediately applying this therapy for optimal outcomes.[8] Although the benefit of brief CPR prior to defibrillation has been demonstrated in arrests persisting greater than 4 to 5 minutes, the AHA acknowledges that no such benefit has been shown for in-hospital cardiac arrest, stating that there is no evidence to support or refute this approach for such witnessed events.[9]

Additionally, a recent meta-analysis in the general population showed that CPR poses considerable risks, including pericardial injury or rib fractures in 9% and 32%, respectively, as well as myocardial lacerations, ruptured chambers or papillary muscle, prosthetic valve dehiscence, and embolic events.[10] In patients with a recent sternotomy, ECM poses even greater potential for tissue damage from sharp sternal edges or wires. Numerous case reports have documented acute right ventricular lacerations, followed by massive bleeding, with application of as few as 5 chest compressions.[11,12]

The number of shocks that should be delivered is also critical to arrhythmia management. A meta-analysis identified an average success rate of 78% for the first shock, followed by 35% and 14% for the second and third shocks, respectively.[13] Defibrillation of a witnessed cardiac surgical arrest in less than 1 minute would presumably improve these results. The European Resuscitation Council now recommends 3 sequential shocks following cardiac surgery and for any witnessed arrest where the patient is already connected to a defibrillator, with the rationale that "it is unlikely that chest compressions will improve the already very high chance of return of spontaneous circulation when defibrillation occurs early in the electrical phase, immediately after onset of VF."[7] After considering the potential risks versus benefits of ECM after cardiac surgery, the protocol recommends that for witnessed VF/VT arrests, 3 sequential attempts at defibrillation should be made without intervening CPR, as long as this can be performed in less than 1 minute.[6] Additionally, the council recommends use of 150 J of energy when using biphasic defibrillation. In situations where a delay in defibrillation beyond 1 minute is anticipated, immediate CPR should be performed until defibrillation can take place.

ACLS recommendations for asystolic arrest include CPR and use of a vasopressor, but the availability of temporary pacing wires after cardiac surgery leads to an additional deviation from their approach.[5] The timely application of external pacing poses a unique therapy that offers great benefit with little, if any, harm (particularly in the absence of a competing rhythm). While the AHA offers no specific guidance for managing asystolic arrests in the postoperative cardiac surgical patient, the cardiac surgery arrest protocol advocates the following strategy: for asystolic arrest or profound bradycardia, institute temporary pacing at a rate of 90 bpm, maximal atrial and ventricular outputs, in an asynchronous mode (DOO) without intervening CPR, if available within 1 minute.[6] These settings can be readily achieved using the emergency button of most devices in general use, although adjustment of rate will be needed. Failure to effectively capture the myocardium after instituting these settings warrants immediate CPR; consideration may then be given to use of a chronotrope or transcutaneous pacing, depending on availability. In patients who arrest with a paced rhythm, the pacemaker should be paused briefly to exclude the possibility of a shockable rhythm (eg, fine VF) that is masked by pacing artifact (Figure 3).

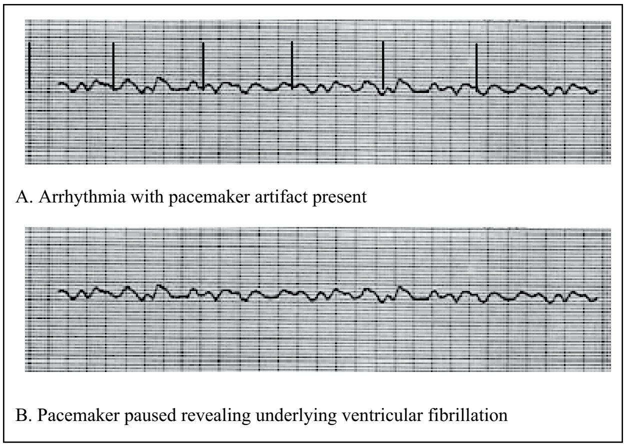

Figure 3. Electrocardiogram of arrhythmia with and without pacemaker artifact.

Epinephrine

Despite widespread use, epinephrine and other vasopressors are not recommended in cardiac surgery arrests for 2 reasons: they have not been shown to be efficacious, and there is concern for rebound hypertension. The AHA acknowledges that epinephrine has not been shown to improve neurologically intact survival in any population to date, although return of spontaneous circulation has been reported.[5] These findings were confirmed in a recent meta-analysis of vasopressors in cardiac arrest.[14] Despite the lack of demonstrated benefit and additional reports of worsened neurologic outcomes with its use, epinephrine remains in the AHA algorithms for VT/VF, asystole, and pulseless electrical activity at a dose of 1 mg repeated every 3 to 5 minutes.[5] Potential adverse effects of this medication are well documented, including proarrhythmia and increased myocardial oxygen demand. In a witnessed arrest after cardiac surgery, there is even greater risk of harm due to the potential for rebound hypertension. In a case report by Webb, only 100 mcg of epinephrine was given for an arrest caused by a tension pneumothorax. Drug administration was followed by prompt evacuation of pleural air and restoration of a pulse, but subsequent malignant hypertension resulted in massive bleeding that required an emergency resternotomy.[15] This situation is not unusual and warrants the following level C recommendation: neither epinephrine nor vasopressin should be administered during cardiac arrest unless advocated by a senior clinician experienced in its use.[6] The use of epinephrine may be beneficial, however, before cardiac arrest in patients with poor output or hypotension, but dosages ≤100 mcg are recommended to avoid this phenomenon.[6,7]

Table 1. Key Roles During Postoperative Cardiac Arrest Management.

Role	Essential Functions
1. Initial rescuer	Identify arrest
	Summon help
	Attempt defibrillation or pacing (as appropriate)
	If ineffective, initiate external massage
2. Airway	Increase FiO2 to 100%
	Remove positive end-expiratory pressure
	Assess for airway and breathing
	Exclude misplaced endotracheal tube or tension pneumothorax
3. Defibrillation and pacing	Connect defibrillator
	Administer 3 sequential shocks at 150 J and any additional defibrillations
	Once draped, switch to internal defibrillator paddles and reduce to 20 J
	Initiate and manage temporary pacemaker
4. Team leader	Direct overall code management
	Confirm cause of arrest
	Direct and confirm appropriate therapies
	Initiate timely preparations for resternotomy
5. Medication administration	Administer amiodarone for ventricular tachycardia or ventricular fibrillation
	Stop all other infusions
	Ensure no epinephrine given unless directed by senior clinician
6. Critical care nursing coordinator	Coordinates personnel—emergency responders and notifies surgeon, others
	Coordinates equipment—ensures availability of resources for resternotomy
7. Resternotomy provider (sterile)	Don sterile gown and gloves (if not sterile)
8. Resternotomy provider (sterile)	Apply all-in-one sterile drape (if undraped)
	Cut skin (scalpel)
	Remove wires (wire cutter, needle driver)
	Place retractor under sternum and open widely
	Initiate suction
	Initiate internal massage
	Initiate internal defibrillation

Conduct of a Cardiac Surgical Arrest

Basic Life Support

Recognition of a cardiac arrest after cardiac surgery is typically immediate in the operating room or intensive care unit (ICU) environment. A review of monitor tracings will reveal a simultaneous loss of pulsatility in the arterial, central venous, pulmonary artery, and SpO2 tracings. Palpation for a pulse is unnecessary and time-consuming in this situation, warranting immediate activation of the arrest protocol. In potential "prearrest" situations where the blood pressure falls precipitously but pulsatile waveforms remain, help should be summoned and corrective strategies immediately instituted. For a true arrest, appropriate personnel are notified and interventions taken to immediately correct life-threatening arrhythmias with defibrillation (VF/VT) or pacing (asystole) prior to external compressions, as previously described. If delay longer than 1 minute is likely or if these therapies fail, ECM should be started immediately and performed in standard fashion. However, the availability of an arterial line offers important feedback about the effectiveness of compressions. A systolic blood pressure >60 mm Hg should be targeted for optimal cerebral perfusion; failure to achieve this parameter during ECM is an indication for immediate chest reopening.[6] An end-tidal carbon dioxide level >10 mm Hg has been shown to correlate with return of spontaneous circulation and provides additional feedback about the effectiveness of resuscitation efforts, without specific recommendations for cardiac surgical patients. Six essential roles are needed for optimal management of a postoperative cardiac arrest (Figure 2). The critical tasks and responsibilities assigned to these roles, as well as the resternotomy team, are listed in Table 1. Training for cardiac surgical arrest management should be organized around performance of these key role functions.

Airway Management

Current ACLS algorithms have de-emphasized initial intubation and recommend low tidal volumes of approximately 600 mL to avoid hyperventilation.[5] Arrest after cardiac surgery is likely to occur in an intubated patient, and easily correctable events, such as a misplaced endotracheal tube or tension pneumothorax, should be quickly excluded. Thus, the second rescuer should immediately address airway and breathing issues. If extubated, a bag/mask/valve device should be used with 100% oxygen, at a ratio of 2 breaths per 30 compressions. More commonly, patients will be intubated and the FiO2 increased to 100% with removal of positive end-expiratory pressure for augmentation of venous return.[6] Rapid airway assessment includes confirmation of endotracheal tube placement by looking for bilateral chest movement and the presence of condensation in the ventilator tubing, listening for breath sounds and ensuring the absence of air excursion around the endotracheal tube, and palpating the trachea for deviation indicative of a tension pneumothorax. Examination of end-tidal carbon dioxide tracings, if capnography is in use, provides additional information about the respiratory status that may contribute to diagnosis and management. It is recommended that the patient be removed from the ventilator and bagged while breath sounds are being auscultated, to more easily assess respiratory issues and lung compliance. If no issues are identified, the patient may be returned to the ventilator on 100% oxygen without positive end-expiratory pressure. If this assessment reveals a possible tension pneumothorax, immediately place a large-bore cannula in the second intercostal space anteriorly at the midclavicular line.[6]

Medications and Infusions

Following cardiac surgery, fluid and/or medication infusions are universal and could lead to arrest due to inadvertent bolusing of medications or drug errors. The cardiac surgery arrest protocol recommends that all infusions be stopped during an established arrest, with the exception of an infusion line for drug administration.[6] Sedative agents can contribute to vasodilation and myocardial depression, but if there is concern for awareness, their continued use can be considered. Medication administration is recommended only for a VF/VT arrest, warranting amiodarone at a dose of 300 mg via intravenous bolus after 3 failed defibrillation attempts.

Emergency Resternotomy

For a cardiac surgical arrest that does not respond to initial interventions, the final common pathway for all etiologies is a timely emergency resternotomy. It is well documented that internal massage fosters more effective circulation with higher cerebral perfusion pressures than ECM.[4,16] In addition, mechanical causes of arrest are more easily identified and treated. If readily reversible causes of arrest are not identified, rapid resternotomy (within 5 minutes) should be performed.[6] Reopening even a portion of the sternotomy in the presence of tamponade physiology often leads to immediate hemodynamic improvement. If bleeding is present, a source may be localized and corrective interventions rapidly undertaken. Despite training, chest reopening is an unusual event that is highly stressful for providers. Optimal conduct is facilitated by a simplified approach that clearly delineates roles and expectations while fostering teamwork.

Six key roles have been identified that are essential to performing a timely resternotomy, beginning with the first rescuer who initiates arrhythmia management and performs ECM and a second who manages the airway (Table 1). A third role will be dedicated to managing ongoing defibrillation attempts and pacing, which includes ensuring that internal defibrillator paddles are available on the sterile field with the distal end connected appropriately to the device. They are also responsible for managing the external pacemaker generator during the arrest and must ensure that it is not covered during application of the sterile drape. The fourth role is that of team leader and may be filled by the anesthesiologist or intensivist in the absence of a surgeon. This person confirms the arrest and directs the appropriate implementation of this protocol by all members of the team. A fifth role oversees medication administration, stopping all infusions as previously described. The final person, typically an ICU nursing leader, works closely with the team leader to ensure the appropriate notification and allocation of personnel and resources during the arrest. Two additional sterile personnel will be required to open the chest; if not already gowned and gloved, they should do so immediately upon confirmation of an arrest. A valuable tool to assist the reopening team, particularly in the ICU environment, is a "mini" resternotomy set that includes only the instruments deemed essential for initial reentry. This includes a scalpel (and possibly scissors) to cut through skin and sutures, followed by a wire cutter and heavy needle driver to remove sternal wires. A sternal retractor and sterile Yankauer suction handle and tubing complete the set (Figure 4). The availability of this equipment for ICU personnel promotes optimal surgical technique in a challenging environment. Application of an all-in-one drape to cover the entire patient and bed creates a large sterile field that facilitates hand-off of sterile suction and internal defibrillator paddles without contamination. Infection risk is reduced when reopening occurs following routine preoperative skin decontamination and antibiotic administration; therefore, additional chest preparation is deferred, and rapid resternotomy is the highest priority. Finally, availability of a portable light source in the ICU will improve visibility in chest reexploration. Even when a surgeon is not immediately available, the approach noted here promotes ideal preparation and equipment readiness in a standardized

Figure 4. "Mini" resternotomy set.
Essential instruments needed for emergency resternotomy include retractor, scalpel, wire cutter, needle driver, and sterile suction handle and tubing. Emergency sternal reexploration tray; photo courtesy of MÖlnlycke Health Care.

fashion as providers are summoned. Team training and practice using this protocol have been shown to reduce time to chest reopening, and Maccaroni et al credited this approach with an increase in survival-to-discharge rates from 36% to 64% over a 4-year period.[17]

Special Circumstances: Minimally Invasive Approaches and Mechanical Support Devices

With increasing frequency, cardiac surgeons are using nontraditional incisions, such as a left thoracotomy, "mini" incision, or port access approaches, as well as unique chest closure devices that require specialized instruments (eg, Talon). Such patients pose a special circumstance where the previously described approach to resuscitation requires modification. Comprehensive instructions for reentry in the presence of these varied approaches are not feasible, nor is there a literature base to offer such guidance. Sternal reentry in the majority of these cases would be facilitated by a median sternotomy incision (which may require a sternal saw) or possibly initiation of femoral cardiopulmonary bypass. For these nontraditional cases, the surgeon is advised to communicate appropriate emergency procedures to the team upon completion of the procedure, as well as encourage the timely use of echocardiography for differentiating causes of acute postoperative compromise and needed interventions.[6]

Patients with a left ventricular assist device pose additional challenges in arrest management, beginning with the timely recognition of arrest in patients with a nonpalpable blood pressure. Despite concerns about disruption of cannulae or damage to the pump with ECM, a recent literature review identified 3 reports of CPR performed in 10 left ventricular assist device patients. They demonstrated that standard CPR was safe, but all devices were implanted at least 50 days prior to compressions.[18] Additional research is needed to determine the optimal approach for resuscitation in left ventricular assist device patients. For arrest in patients with an intraaortic balloon pump, changing the device to a pressure mode trigger with 1:1 counterpulsation provides maximal augmentation during massage.[6]

Summary

High survival rates are feasible in patients who arrest after cardiac surgery because there are often reversible causes of arrest, which occur in the specialized environment of the operating room or ICU. An evidence-based protocol specific to the population of patients who arrest after cardiac surgery has now been endorsed as standard of care in Europe and is undergoing approval by the Society of Thoracic Surgeons.[7] In an arrest after cardiac surgery where risks from compressions are increased, the rapid defibrillation or pacing of life-threatening arrhythmias takes priority over external massage. Epinephrine and other vasopressors at standard doses are not recommended, due to concerns for rebound hypertension and lack of efficacy; however, epinephrine at doses less than 100 mcg may be appropriate for hypotensive patients who maintain a spontaneous circulation. An essential component of this protocol is the recommendation for emergency resternotomy within 5 minutes of arrest if unresponsive to initial therapies. Important initial steps to achieve this goal include use of a "mini" resternotomy set, elimination of epinephrine from emergency orders, and team training using the standardized approach described in this protocol. With this much-needed guideline comes the opportunity to standardize management of cardiac surgical emergencies across institutions, with defined benchmarks for processes that create optimal outcomes.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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