

# Standards for Resuscitation After Cardiac Surgery

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Of the 250 000 patients who undergo major cardiac operations in the United States annually, 0.7% to 2.9% will experience a postoperative cardiac arrest. Although Advanced Cardiac Life Support (ACLS) is the standard approach to management of cardiac arrest in the United States, it has significant limitations in these patients. The European Resuscitation Council (ERC) has endorsed a new guideline specific to resuscitation after cardiac surgery that advises important, evidence-based deviations from ACLS and is under consideration in the United States. The ACLS and ERC recommendations for resuscitation of these patients are contrasted on the basis of the essential components of care. Key to this approach is the rapid elimination of reversible causes of arrest, followed by either defibrillation or pacing (as appropriate) before external cardiac compressions that can damage the sternotomy, cautious use of epinephrine owing to potential rebound hypertension, and prompt re-sternotomy (within 5 minutes) to promote optimal cerebral perfusion with internal massage, if prior interventions are unsuccessful. These techniques are relatively simple, reproducible, and easily mastered in Cardiac Surgical Unit–Advanced Life Support courses. Resuscitation of patients after heart surgery presents a unique opportunity to achieve high survival rates with key modifications to ACLS that warrant adoption in the United States. (*Critical Care Nurse*. 2015;35[2]:30-38)

**A**dvanced Cardiac Life Support (ACLS) is the standard approach to management of cardiac arrest in the United States and guides patients' resuscitation in a wide variety of clinical situations, but it has serious shortcomings after cardiac surgery. Here we review key differences and supporting evidence between ACLS and guidelines recently adopted by the European Resuscitation Council (ERC), counterpart to our American Heart Association (AHA), that are specific to resuscitation after cardiac surgery (see Table). The ERC's guideline<sup>1</sup> incorporates all key recommendations from the detailed cardiac surgery guideline initially published by Dunning et al,<sup>2</sup> advising important, evidence-based deviations from ACLS that warrant consideration in the United States. The key conceptual differences between ACLS and European guidelines are found in the different environments in which patients experience cardiac arrest; whereas ACLS is designed broadly for both out-of-hospital and in-hospital cardiac arrest,<sup>3</sup> the ERC guideline addresses the highly specific population of patients with a recent sternotomy who experience cardiac arrest in the intensive care unit (ICU),

## CE Continuing Nursing Education

This article has been designated for CE credit. A closed-book, multiple-choice examination follows this article, which tests your knowledge of the following objectives:

1. Identify cardiopulmonary resuscitation risks after cardiac surgery
2. Contrast European Resuscitation Council and American Heart Association arrest guidelines
3. Describe standards of postsurgical arrest management

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**Table** Recommendations for management of cardiac arrest: ACLS versus CSU-ALS

**ACLS recommendations for arrest**

**CSU-ALS recommendations for postoperative cardiac surgical arrest**

<b>Ventricular fibrillation or pulseless ventricular tachycardia</b>	
Immediate external cardiac massage	Defibrillate first if available within 1 minute
External cardiac massage → single shock → external cardiac massage × 2 minutes before repeating shock	Three stacked shocks before external cardiac massage
<b>Asystole or profound bradycardia</b>	
External cardiac massage → vasopressor	DDD pacing at maximum outputs if available within 1 minute → external cardiac massage
<b>All pulseless cardiac arrests</b>	
Epinephrine 1000 µg every 3-5 minutes; vasopressin 40 units may be used for first or second dose	No epinephrine or vasopressin during arrest Reduce epinephrine dose to 100 µg <i>prearrest</i>
Use specific roles under direction of team leader	Use 6 key roles during arrest management (see Figure 1) Rapid re sternotomy (<5 minutes) if no response to initial therapies

Abbreviations: ACLS, Advanced Cardiac Life Support; CSU-ALS, Cardiac Surgical Unit–Advanced Life Support.

up to 5000 US patients per year. Of critical importance is the rapid exclusion of reversible causes of cardiac arrest such as tension pneumothorax, endotracheal tube mal-positioning, and infusion errors that can occur in this environment. If perfusion is inadequate in the absence of readily reversible causes, re sternotomy within 5 minutes is the optimum strategy for neurologically intact recovery.<sup>1,2</sup>

Cardiac surgical patients present a unique opportunity for high survival thanks to optimal monitoring and immediate recognition of cardiac arrest from predictable causes, coupled with highly trained practitioners in an environment conducive to specialized interventions such as emergency re sternotomy. In contrast to survival rates of 18% to 39% cited for in-hospital cardiac arrest,<sup>4,5</sup> Dimopoulou et al<sup>6</sup> reported that 79% (23/29) of their cardiac surgery patients who had a cardiac arrest survived to discharge, with 55% of these patients still alive at 4-year follow up. In the following pages, we contrast AHA and

ERC recommendations for resuscitation of patients after cardiac surgical arrest, on the basis of essential components of care including cardiopulmonary resuscitation (CPR), defibrillation, management of asystole, use of epinephrine, and conduct of re sternotomy.

### Cardiopulmonary Resuscitation

Immediate external cardiac compressions (ECC) at a rate of 100/min and a depth of 2 inches (5 cm) are advocated by the AHA for virtually all adult cardiac arrests, but several important features of postoperative heart patients warrant consideration of a different approach. In contrast to ACLS strategies that advise compressions first, airway assessment and interventions can be performed rapidly in intubated ICU patients and may prove invaluable in quickly eliminating reversible causes of cardiac arrest. Manual ventilation of the patient with a bag-valve-mask device using 100% oxygen will determine appropriate endotracheal tube placement and the absence of pneumothorax or ventilator issues as reversible causes of cardiac arrest, while promoting optimal oxygenation. In addition, even brief external compressions can pose significant risks of cardiac damage shortly after heart surgery, as noted in multiple case reports of massive hemorrhage subsequent to CPR in these patients.<sup>7,8</sup>

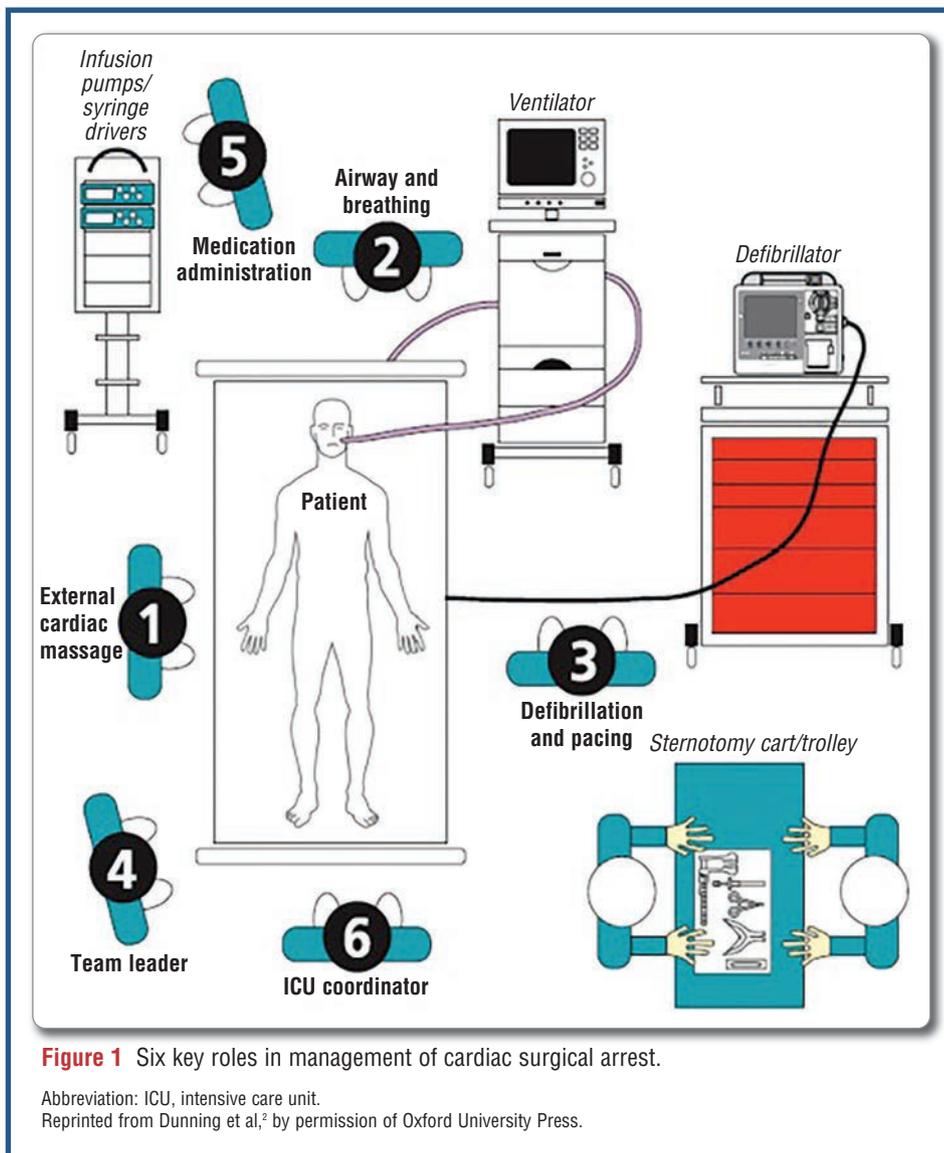
A recent meta-analysis<sup>9</sup> in noncardiac surgery patients receiving ECC identified a high rate of complications, including pericardial injury (8.9%), fractured sternum (15%), and rib fractures (32%), as well as additional

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during cardiac catheterization or in the early post-operative period following cardiac surgery (when chest compressions could disrupt vascular sutures), consider delivering up to 3-stacked shocks before starting chest compressions.

Given the potential for harm from even brief compressions, it is reasonable to defer ECC momentarily for more definitive therapies, as long as they are timely: In an arrest after cardiac surgery, external cardiac massage can be deferred until initial defibrillation or pacing (as appropriate) have been attempted provided this can be done in less than 1 minute.<sup>2</sup>

cases of chamber rupture, prosthetic valve dehiscence, vascular dissection, and more. After sternotomy, there is additional risk from displacement of the sternum with external compressions, as cardiac tissue or bypass grafts can be damaged or lacerated by bone edges or sternal wires. The actual incidence of these events is unknown, but they are potentially preventable and often fatal, warranting careful consideration before even brief compressions if other therapies offer benefit.

Finally, a short duration of CPR (1-3 minutes) before defibrillation of ventricular tachycardia or fibrillation (VT/VF) has not been shown to improve outcomes. The 2010 AHA guideline<sup>10</sup> states: "With in-hospital SCA [sudden cardiac arrest], there is insufficient evidence to support or refute CPR before defibrillation." In contrast, the ERC guideline<sup>1</sup> states,

The ERC guideline further recommends gauging the effectiveness of ECC by using the arterial pressure waveform, ensuring generation of a systolic blood pressure greater than 60 mm Hg for optimal cerebral perfusion.<sup>1</sup> If external compressions fail to restore an adequate blood pressure, the chest should be reopened immediately, as this may indicate tamponade or extreme hypovolemia from internal bleeding.

### Defibrillation

Immediate defibrillation of "shockable" rhythms is of unquestioned importance to survival and, once available, takes priority over all other therapies. When hospitalized patients with VT/VF, a majority of whom were in an ICU, were defibrillated within 2 minutes, survival nearly doubled from 22% to 39% ( $P < .001$ ).<sup>4</sup> Significantly higher

survival rates of 54% to 79% are achievable in patients undergoing cardiac operations, in part owing to prompt treatment of potentially reversible causes.<sup>1</sup> Anthi et al<sup>11</sup> cited acute destabilizing VT/VF as the cause of cardiac arrest in 45% of their patients, and 27% were attributed to mechanical events such as tamponade or pneumothorax. Half of these arrests occurred during the first 3 postoperative hours (almost 90% were within 12 hours) when patients typically are intubated with continuous electrocardiographic and hemodynamic monitoring and presumably are near manual defibrillators and personnel trained in their use.

The sequencing of defibrillation and ECC is of critical importance in these patients. Several detailed reviews have shown no benefit from CPR before defibrillation in out-of-hospital arrest when response times were 3 to 5 minutes or less, lending support to immediate defibrillation after heart surgery, where shorter response times should further negate the need for intervening compressions.<sup>12,13</sup> Yet current ACLS algorithms advocate “a brief period” of ECC before defibrillation of VT/VF, with delivery of a single shock followed by a 2-minute cycle of CPR before repeating defibrillation attempts.<sup>3</sup> In a recent large, randomized trial<sup>14</sup> in patients who had experienced an out-of-hospital cardiac arrest, researchers investigated the optimum CPR duration (30-60 seconds vs 3 minutes) before rhythm analysis and shock by an automated external defibrillator, and they reported no significant differences but a trend toward better survival in the subset of VT/VF patients with shorter CPR duration.

Unfortunately, current ACLS algorithms are derived primarily from studies that used automated external defibrillators in out-of-hospital arrest, situations that are clearly different from a witnessed event in an intubated ICU patient after sternotomy. For inpatient cardiac arrest, the AHA acknowledges “the benefit of delaying defibrillation, to perform CPR before defibrillation, is unclear.”<sup>10</sup> In contrast, the ERC advocates immediate delivery of 3 stacked shocks for VT/VF arrest after cardiac surgery or when a manual defibrillator is already connected.

Although there are no data supporting a 3-shock strategy in any of these circumstances, 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 the onset of VF.<sup>1</sup>

In ventricular fibrillation or pulseless ventricular tachycardia, 3 sequential shocks should be given without intervening CPR. In VF or pulseless VT, emergency re-sternotomy should be performed after 3 failed attempts at defibrillation.<sup>2</sup>

When defibrillation occurs soon after the onset of VT/VF, neurological recovery is more likely regardless of diagnosis or subsequent revascularization, and defibrillation without delay is the accepted standard of care. Strategies that optimize electrical therapy for VT/VF prior to potential disruption of the sternotomy are reasonable for these patients. Additional recommendations by the AHA for in-hospital cardiac arrest that are appropriate after heart surgery include allowing nonphysicians to defibrillate and use of hands-free pads.<sup>5</sup> These strategies offer important benefit both within and outside of the ICU that can significantly reduce time to defibrillation and potentially reduce mortality.

## Asystole

Management of asystole or profound bradycardia is facilitated by the rapid institution of cardiac pacing, which is readily available after heart surgery. These rhythms may be transient or permanent and are more common following aortic valve or arrhythmia surgeries that are near the conduction system. Temporary single- or dual-chamber pacing wires are typically placed epicardially during most cardiac operations for management of bradyarrhythmias. When perfusion is inadequate because of a slow heart rate, ACLS algorithms call for immediate CPR followed by administration of epinephrine.<sup>3</sup>

After heart surgery, the presence of temporary pacing capabilities

offers more definitive therapies that can be applied easily and without delay by staff trained in their use. The AHA generally endorses use of postoperative pacing wires to “reverse symptomatic bradycardia or asystole,”<sup>15</sup> but the ERC offers additional directives:

For asystole or severe bradycardia, connect the epicardial pacing wires and set to DDD at 90 [beats per minute] at the maximum atrial and ventricular output voltages.<sup>2</sup>

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If the conduction system fails to respond to external pacing or chronotropic agents, the ERC guideline for a “nonshockable” rhythm recommends continuing ECC until prompt emergency re sternotomy can be performed. However, it is essential to rapidly exclude the possibility of a shockable rhythm (ie, fine VF) masked behind non-capturing pacemaker spikes, to avoid delaying defibrillation in lieu of fruitless pacemaker adjustments. For any cardiac arrest with pulseless electrical activity where the temporary pacemaker is in use, this device should be paused briefly to exclude VF before reopening the patient’s chest.

## Epinephrine

Use of epinephrine can cause catastrophic hypertension in postoperative heart patients, contributing to hemorrhage and the need for immediate reopening, which warrants extreme caution and modifications to standard administration.<sup>1,2</sup> For pulselessness from any dysrhythmia, ACLS algorithms advocate administering 1 mg of epinephrine every 3 to 5 minutes, despite a lack of evidence that doing so improves survival, particularly in cardiac arrests of short duration.<sup>3</sup> Cardiac surgery with cardiopulmonary bypass elicits a powerful hormonal response that triggers the release of endogenous catecholamines, and patients often receive additional inotropes or vasopressors for hemodynamic stabilization. Undesirable epinephrine effects of particular concern include increased myocardial oxygen demand and stimulation of dysrhythmias.<sup>2,3</sup> After cardiac surgery, this “standard” epinephrine dosing can contribute to profound rebound hypertension with potential disruption of grafts and suture lines and subsequent hemorrhage. In reviewing the special circumstance of postoperative cardiac arrest, the AHA acknowledges the potential for vasopressor-induced bleeding, but cites

insufficient evidence on epinephrine dose, antiarrhythmic use, and other routine pharmacological interventions to recommend deviating from standard resuscitation guidelines when cardiac arrest occurs after cardiac surgery.<sup>15</sup>

A careful review of the ACLS guideline identifies that for VT/VF, an initial defibrillation attempt followed by 2 minutes of CPR should precede any epinephrine dosing.<sup>3</sup> Therefore, the recommendation to initially withhold epinephrine in VT/VF arrest appears consistent with the

European guideline: “Neither adrenalin nor vasopressin should be given during the cardiac arrest unless directed by a senior clinician experienced in their use.”<sup>2</sup>

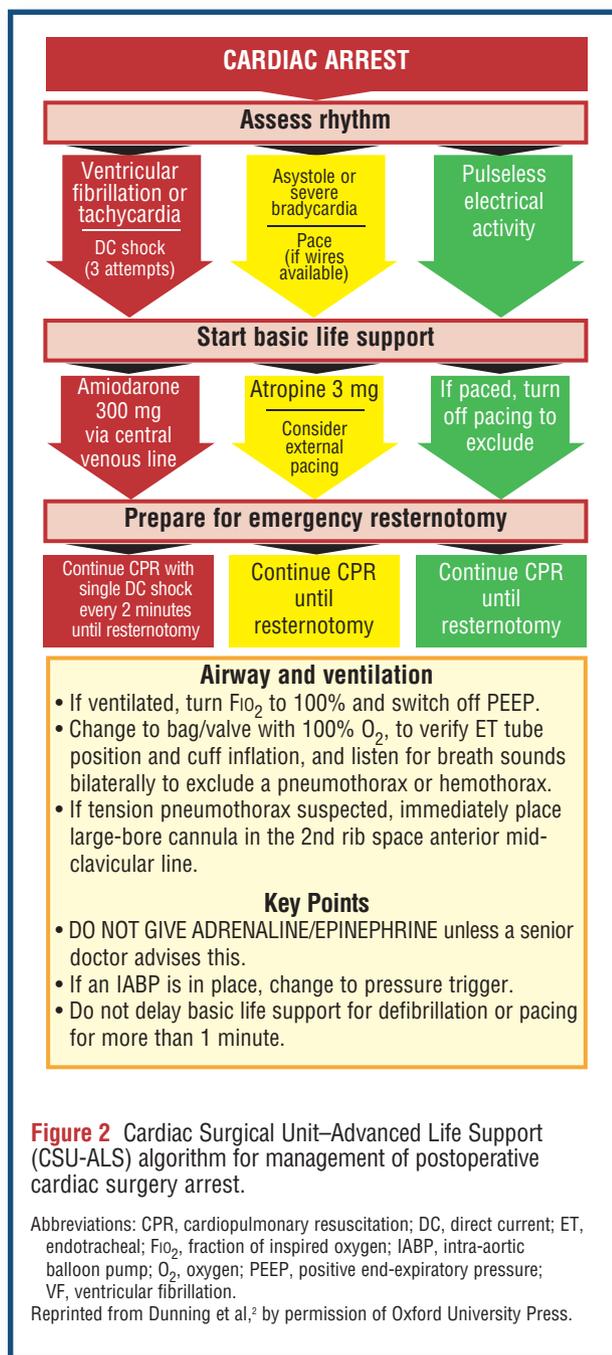
Although epinephrine is not indicated during cardiac arrest, it may be useful prior to cardiac arrest to support the circulation and distinguish patients who are inotrope responsive. In these situations, the ERC guideline advocates reduced doses of 100 µg or less, whenever epinephrine is used in a postoperative cardiac surgical patient.<sup>1,2</sup> In addition, consideration should be given to discontinuing all infusions during an established cardiac arrest (with the possible exception of sedation) to exclude medication errors as an easily reversible cause of cardiac arrest.

## Resternotomy

Key to the successful resuscitation of cardiac arrest in these patients is the need to perform emergency re sternotomy early, especially in the context of tamponade or haemorrhage, where external chest compressions may be ineffective.<sup>1</sup>

After promptly excluding reversible causes of arrest and performing defibrillation or pacing, as appropriate, immediate ECC is indicated (Figure 2). The team must then focus on achieving rapid re sternotomy and internal massage by a skilled provider for restoration of optimal perfusion. Reopening the chest immediately in an ICU, rather than transporting to an operating room, allows earlier institution of internal cardiac compressions, which are often essential to neurological recovery. Hallmark studies<sup>2,16</sup> have repeatedly demonstrated that external compressions are a poor substitute for internal massage, consistently delivering cerebral perfusion pressures that are 3- to 4-fold less than those of internal compressions and rarely exceed the 15 mm Hg end point required for neurological survival. Reexploration and direct visualization enable identification of potentially reversible causes of cardiac arrest such as hemorrhage, bypass graft abnormalities, or cardiac tamponade and can be used to rule out additional causes of profound cardiac failure.

Persistent bleeding from mediastinal chest tubes is the most frequent reason for reopening the chest postoperatively and occurs in 1% to 3% of patients.<sup>17</sup> Bleeding can also precipitate cardiac tamponade, a rapidly fatal condition evidenced by inadequate cardiac filling resulting from blood and clot collections around the heart and great vessels, which often (but not always)



is accompanied by increasing intracardiac pressures that equilibrate and persistent hypotension despite fluids and medications. In the presence of significant bleeding or tamponade, ECC will be ineffective for mechanical reasons and rapid surgical correction is the standard of care.<sup>1,2</sup> Improved survival is reported with prompt reoperation after cardiac surgical arrest: Mackay et al<sup>18</sup> reported a 48% survival rate when emergency re sternotomy was performed within 10 minutes, as opposed to 12% when time to chest reopening was more prolonged.

Internal cardiac massage is superior to external cardiac massage. In patients with a recent sternotomy in whom resuscitative efforts are likely to last more than 5 to 10 minutes, emergency re sternotomy is indicated in order to perform internal cardiac massage even if a reversible cause from re sternotomy seems unlikely.<sup>2</sup>

## Standardizing the Approach to Cardiac Surgical Arrests

The ERC guideline for management of postoperative cardiac arrest offers the most specific and appropriate evidence-based approach to these events that is currently available and should be adopted as the standard of care in the United States. The European Association for Cardio-Thoracic Surgery (EACTS) developed this guideline after an in-depth literature review and evidence grading by using standard criteria, followed by web-based surveys sent to surgeons internationally and refinement during the conduct of numerous resuscitation courses. The evidence-based guideline provided by Dunning et al<sup>2</sup> was the first to specifically address management of cardiac arrest after cardiac surgery and was promptly endorsed in the global ERC resuscitation standards<sup>1</sup> the following year. The EACTS and ERC currently recommend this approach in preference to standard resuscitation protocols for cardiac arrests after cardiac surgery.

In addition to the management principles identified here, the guideline by Dunning et al provides a comprehensive approach to the personnel, practices, and equipment necessary to consistently perform emergency re sternotomy within 5 minutes, eliminating wasted seconds that are nonbeneficial (Figures 1 and 2). Key to this approach is a readily available “mini” sternotomy set that includes only the essential instruments for reentry (large drape, scalpel, wire cutter, heavy needle holder, retractor, and suction) as well as staff preparation.<sup>2</sup> Ongoing practice with the multidisciplinary team in simulated open chest resuscitations is strongly recommended to ensure that personnel working with these patients are familiar with specialized procedures to quickly and safely reopen a chest in the ICU. Institutional expectations during these “high-risk, low-volume” situations should be well defined and rehearsed to achieve rapid reopening with optimal survival rates. Hands-on practice with emergency carts, internal defibrillators, and possibly sternal saws (for “mini” or robotic approaches) allows

ICU nurses to be familiar with their use while maintaining sterile technique. This population may be well suited to “specialty-specific emergency response teams,” as advocated by the AHA for pediatrics and maternal-fetal cardiac arrests.<sup>5</sup> Although most experienced US cardiac surgery programs are well aware of ACLS’ limitations and work around them, rarely are written protocols to guide a different approach available. Potential confusion and delays during these emergencies can occur in the absence of clear guidelines, which creates liability and limits our ability to attain the high survival rates that are achievable in these patients.

For the first time, a more appropriate algorithm for management of cardiac arrest after cardiac surgery exists that is evidence based and easily taught in a reproducible fashion. In collaboration with European guideline developers, courses in Cardiac Surgical Unit–Advanced Life Support are being offered through venues such as the American Association for Critical-Care Nurses’ National Teaching Institute to promote standardization, increase providers’ knowledge and comfort, and improve patients’ outcomes. These courses, currently certified by the ERC but not yet by any US governing body, offer a standardized approach to postoperative cardiac arrest that is gaining acceptance rapidly among US providers.

## Summary

The AHA has called for research to improve our understanding of in-hospital cardiac arrest and reduce knowledge gaps; cardiac surgery is a good place to start.<sup>5</sup> Dunning et al<sup>2</sup> have generated a clearly defined, evidence-based protocol for cardiac surgical arrests that offers a much needed standard of care for these high-risk events. Additional research and new evidence are welcomed to further refine this guideline in the years ahead, but this is a tremendous first step in defining best practices in postoperative cardiac emergencies that produce optimal outcomes for patients. The avoidance of standard resuscitation techniques for these highly specialized situations is a critical concept that will save lives and shape our practice for years to come. **CCN**

Financial Disclosures  
None reported.



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To learn more about cardiovascular surgery, read “Tissue Oxygen Saturation and Outcome after Cardiac Surgery” by Sanders et al in the *American Journal of Critical Care*, 2011;20:138-145. Available at [www.ajconline.org](http://www.ajconline.org).

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### Facts

Advanced Cardiac Life Support is the standard approach to management of cardiac arrest in the United States and guides patients' resuscitation in a wide variety of clinical situations, but it has serious shortcomings after cardiac surgery. This article reviews key differences and supporting evidence between Advanced Cardiac Life Support and guidelines recently adopted by the European Resuscitation Council (ERC), counterpart to our American Heart Association, that are specific to resuscitation after cardiac surgery (see Table).

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