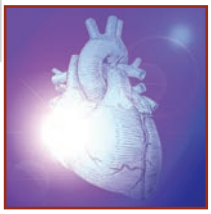

Multidisciplinary Review of Code Events in a Heart Center

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Objective To identify a cause for clinical deterioration, examine resuscitation efforts, and identify and correct system issues (thus improving outcomes) via a multidisciplinary code-review process soon after cardiopulmonary arrest.

Methods Retrospective analysis of code events in a tertiary pediatric heart center from September 2010 to December 2013 and review of surgical-cardiac data from January 2010 to December 2013.

Results A multidisciplinary team reviewed 47 code events, 16 of which (34%) were deemed potentially preventable. At least 2 issues were identified during 66% (31/47) of cardiopulmonary arrests reviewed. Key issues identified were related to communication (62%), environment/culture/policy (47%), patient care (including resuscitation, 41%), and equipment (38%). About 60% of reviewed arrests resulted in educational initiatives (eg, mock code, in-service education) and 47% resulted in a new policy or modification of existing policy. Less common were changes in equipment (32%) or modification of staffing needs (11%). Changes most frequently occurred in the unit specific to the event (68%) but some changes occurred throughout the Heart Center (32%) or across the hospital system (13%). Survival to discharge after cardiopulmonary arrest has improved over time ($P=.03$) to 81% for cardiac surgical patients in our center.

Conclusion A multidisciplinary code-review committee can identify deficiencies and lead to educational initiatives and improvements in care. When coupled with a hospital-wide "code blue" review process, these changes may benefit the institution as a whole. (*American Journal of Critical Care.* 2016;25e90-e97)

doi: http://dx.doi.org/10.4037/ajcc2016302

Cardiopulmonary arrests in hospitalized children are rare events reported to occur in 1.06 of every 1000 pediatric admissions.[1] However, the incidence of cardiopulmonary arrest within pediatric critical care settings is nearly 10-fold higher, with 9.4 cardiopulmonary arrests per 1000 admissions, and the rate is even higher in dedicated pediatric cardiac intensive care units (40-60/1000 admissions).[2-4] Achievement of optimal outcomes for life-threatening events depends on rapid identification of deteriorating condition, high-quality resuscitation, and optimal performance of a multidisciplinary team. Ideally, the goal is to prevent cardiopulmonary arrest with interventions initiated by a rapid response team or in cases where cardiopulmonary arrest is imminent, the intensive care unit team.[5,6]

Hospitals commonly use the morbidity and mortality review conference to review adverse events. These meetings typically take place long after an event and include only physicians. The time elapsed between the event and the review may result in loss of details and potentially missed opportunities to identify system errors. Additionally, exclusive participation of physicians may result in a failure to identify areas for improvement in all staff. A final bias of the typical morbidity and mortality conference is the predominant focus on deaths, thereby overlooking other "near-miss" situations, the analysis of which could help to identify areas for improvement in patient care.

Focused, event-specific debriefings are another technique often used to review code events. Numerous approaches have been proposed, including immediate debriefings to review team performance.[7-10] Such reviews focus on the quality of cardiopulmonary resuscitation (CPR) and team-related issues. Efforts to improve team performance during a cardiopulmonary arrest promote optimal results from such high-intensity, low-frequency events.[11,12] Although these types of reviews occur very shortly after the resuscitation, they tend to be focused primarily on issues related to resuscitation and overlook system-based issues.

Our Heart Center was dissatisfied with our morbidity and mortality review process because of the inability to find causes of cardiopulmonary arrests and the difficulty in identifying systematic failures that could be corrected. With the support of senior leaders, we established a multidisciplinary "code-review" team in June 2010. The primary objective of this team was to identify system flaws that might be improved and to report these issues to Heart Center leaders. The secondary objectives of this team were to (1) identify a cause for each cardiopulmonary arrest, (2) comment on potential preventability of the cardiopulmonary arrest, and (3) review the quality of resuscitative efforts. We hypothesized that our multidisciplinary code-review process would enable us to identify a cause for clinical deterioration, examine resuscitation efforts, and identify and correct system issues and thus improve outcomes.

Focused, event-specific debriefings are a technique often used to review code events.

Methods

Heart Center Demographics

The Heart Center includes 5 cardiac anesthesiologists, 3 cardiothoracic surgeons, a 20-bed cardiothoracic intensive care unit (CTICU), and a 24-bed step-down cardiology unit and performs approximately 400 cardiovascular surgeries per year. The CTICU is staffed 24 hours per day, with in-house coverage provided by 8 advanced practice nurses (APNs) and 8 dedicated cardiac intensivists as well as nurses and respiratory therapists. The code team responding for cardiac and respiratory arrests for Heart Center patients consists of (1) a cardiac intensive care physician, (2) an APN, (3) a respiratory

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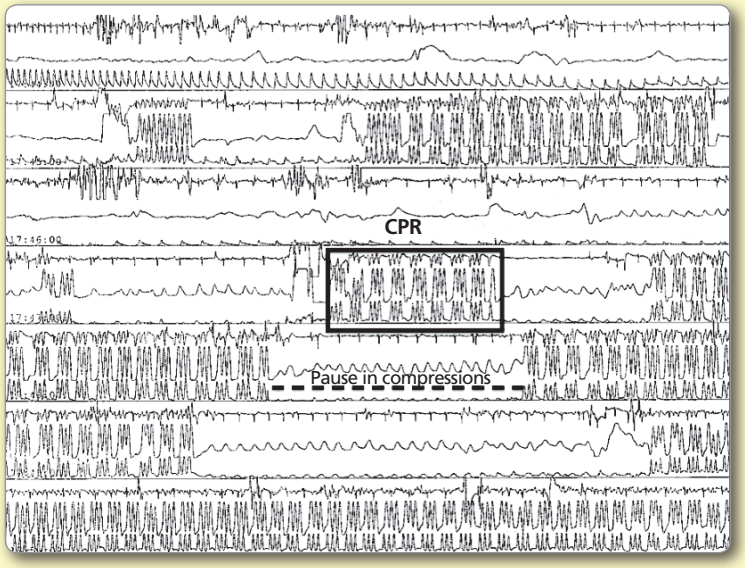

Figure 1 Typical trend screen printout used for reviews. Within each row, the telemetry demonstrates electrocardiogram tracing on top, respiratory channel in middle, arterial blood pressure tracing on bottom. Each row represents 1 minute of time. Compression quality and time off chest can be estimated.

Abbreviation: CPR, cardiopulmonary resuscitation.

therapist, (4) a charge nurse, (5) pharmacists, (6) pastoral care, and (7) bedside nursing providers regardless of the patients' location in the hospital.

Type of Cardiopulmonary Arrest Reviewed

A cardiopulmonary arrest was defined as an activation of the code system with initiation of circulatory (chest compressions) and/or respiratory (bag-mask ventilation or placement of an advanced airway) support in close proximity to the events. The following code events were to be reviewed: (1) any cardiopulmonary arrest outside of the CTICU for patients on the cardiology service and (2) any cardiopulmonary arrest within the CTICU that was considered "unanticipated."

Composition of the Code-Review Team

The code-review team consists of a core group of members: 2 cardiothoracic intensive care physicians, 1 cardiologist, 1 cardiac anesthesiologist, an advanced practice nurse, a cardiothoracic surgeon, nursing leaders from the CTICU and the cardiac step-down unit, the Heart Center nurse educator, a clinical pharmacist, a respiratory therapist, and a quality improvement coordinator. Additional team members are added specifically for each event and may include the charge nurse on the unit at the time of the cardiopulmonary arrest, bedside care personnel, fellows and residents involved in the care of the patient, or subspecialty members of the heart center (eg, member of adult congenital team, interventional cardiologist, extracorporeal membrane oxygenation [ECMO] leaders).

The code-review team consists of a multidisciplinary core group.

Review Process

After a cardiopulmonary arrest, either the APN or 1 of the 2 CTICU attending physicians is notified of the event by caregivers and is responsible for coordination of data collection and interviews of staff members. Either the APN or 1 of the CTICU attending physicians then assumes primary responsibility for the review and is responsible for data collection, leading the review meeting (including presenting data), and reporting findings. Primary data gathered include telemetry (Figure 1), content from the electronic medical record, radiographs, electrocardiograms, echocardiograms, and laboratory information. Data collection occurs within the first 72 hours. The review leader (APN or physician) arranges a meeting of the core group and includes any auxiliary members with the goal of meeting within 7 days of the event. The event is reviewed during a single 1-hour meeting with input and discussion from all participants. The meeting occurs in a location where all clinical data can be rapidly obtained to answer any questions from participants. The review is always started with a reminder that all discussions take place in a nonpunitive, blame-free environment and begins with a brief clinical summary of events.

During the review, the group focuses on several key areas where systems could have failed. These areas include (1) communication, (2) patient care, (3) equipment, and (4) environment/culture/policy issues. Communication issues included any communication, whether verbal, pager, cell phone, or other means of data transfer between providers (APN, attending physician, fellow, bedside nurse). These issues could involve information related to patients' status, laboratory values, or activation of auxiliary teams (eg, the ECMO activation process). Issues related to patient care, reflecting a knowledge gap or inadequate skills, were defined as deviations from the standard of care at any level (including attending physician). Equipment issues involved any life-support devices, pumps, or monitoring used before or during the cardiopulmonary arrest (eg, the airway cart did not contain all laryngoscope blade sizes). Finally, environment/culture/policy issues can include hospital- or unit-specific findings. One example is a hospital policy for constant attendants that did not address situations where the patient was more than 18 years of age.

At the conclusion of the review, findings are summarized and disseminated to Heart Center

leaders, nursing leaders, the quality improvement section, and the hospital-wide code-review committee with a goal of completion in another 7 days.

After approval from the institutional review board, we retrospectively reviewed deidentified quality improvement findings from 47 cardiopulmonary arrests occurring between September 2010 and December 2013. All reviews were summarized by 3 individuals, with findings from reviews categorized into different domains including the type of cardiopulmonary arrest (cardiac vs respiratory), the cause of cardiopulmonary arrest (airway compromise, acute respiratory insufficiency, arrhythmia, hypotension/hypoperfusion, or metabolic/electrolyte abnormality as previously defined[13]), preventable aspect of the cardiopulmonary arrest, communication issues, care-related issues, equipment issues, or environment/culture/policy issues. Outcomes from the code review were grouped into categories consisting of new education, equipment change, staffing change, or policy change. The magnitude of each issue was classified as unit-specific, Heart Center–specific, or hospital-wide. Discrepancies were settled by discussion, and final categorization was agreed upon by unanimous consensus.

Additionally, we queried our local surgical database that tracks complications (including cardiopulmonary arrest) for all postoperative patients. We focused on the global measure of survival to discharge for patients during the same time span as our review process. This method was used to independently validate that our process improvements were resulting in clinical improvement for our population of patients.

Results

A total of 47 cardiopulmonary arrests occurring between September 2010 and December 2013 were reviewed. The median time from the cardiopulmonary arrest event to review was 5 days (range, 1-21 days). Most events reviewed by our process involved chest compressions (42/47, 89%). Twenty-one events (45%) occurred in patients already intubated, and 24 patients (51%) were intubated as a result of the code event. Two patients (4%) were not intubated but were treated with noninvasive positive pressure ventilation after initial bag-mask ventilation.

Basic demographic findings for the cardiopulmonary arrests that were reviewed are summarized in Table 1. The majority of events reviewed occurred in the CTICU and involved patients between 1 month and 1 year of age. Nearly two-thirds of the patients reviewed (62%) had 2-ventricle physiology, with the remaining 38% of patients having single-ventricle physiology. The majority of patients (64%) were postoperative. The most common causes for a cardiopulmonary arrest involved hypotension/hypoperfusion (22/47, 47%) or acute respiratory insufficiency (15/47, 32%).

Table 1
Demographics for codes reviewed

Characteristic	No. (%) of codes[a]
Total	47 (100)
Cardiac disease category	
Single-ventricle physiology	18 (38)
2-ventricle physiology	29 (62)
Age of patients	
<28 days	10 (21)
1 month to 1 year	19 (40)
1-8 years	15 (32)
>8 years	3 (6)
Location where cardiopulmonary arrest occurred	
Cardiothoracic intensive care unit	31 (66)
Step-down unit	11 (23)
Other	5 (11)
Reason for admission	
Operative	30 (64)
Catheterization	6 (13)
Medical/nonintervention	11 (23)
Cause of cardiopulmonary arrest	
Airway compromise	4 (9)
Acute respiratory insufficiency	15 (32)
Arrhythmia	5 (11)
Hypotension/hypoperfusion	22 (47)
Metabolic/electrolyte abnormality	1 (2)

[a]Because of rounding, percentages may not total 100.

The primary issues identified during the review process, in order of frequency, involved communication (62%), a policy or procedure that was lacking or not followed (47%), resuscitation (41%), or equipment (38%). Multiple issues were identified in 66% of our reviews (31/47). Approximately 34% of events (16/47) were deemed as potentially preventable cardiopulmonary arrests. A trend toward decreased preventability of code events over time was not significant (50% potentially preventable in 2010, 40% in 2011, 33% in 2012, and 28% in 2013, $P = .85$).

> The primary issue identified during the review process was communication.

Educational initiatives were the most frequent interventions (28/47, 60%) with additional in-service training for staff. There were also changes in policy (22/47, 47%), equipment (15/47, 32%), or staffing (5/47, 11%) as a result of the review findings. The findings were classified as unit-specific (ie, CTICU or step-down unit) in 68% of reviews, Heart Center–wide (ie, CTICU, step-down unit, and procedure areas) in 32%, and hospital-wide (affecting all areas of inpatient care) in 13% of reviews. Table 2 outlines specific changes within our service that have resulted

Table 2
Examples of specific changes developed as a result of our code-review process

Breadth of change	Description of change
Unit-specific	Communication tool developed for acceptable saturations in cyanotic patients Changes to postoperative order set to include preordered intravenous fluid bolus for resuscitation Increased cerebral saturation monitoring and standardized operating room and cardiothoracic intensive care unit (CTICU) systems Reeducation on intraosseous drill locations in unit and recommendations for use Development of airway cart for CTICU with increased stock of equipment available at bedside Clarification of the role of the unit clerk to assist in communication during critical events in the CTICU Standardization of new procedure room equipment to mirror cardiac operating room setup Education for CTICU staff on location of universal protection equipment in step-down unit Changes in equipment stocked on unit (central catheter and chest tube kits reevaluated to improve size ranges) Standardized location of immediate postoperative patients within the CTICU to improve proximity for caregivers Improved availability of inhaled nitric oxide by having a unit setup within the CTICU respiratory department Standardized end-tidal carbon dioxide monitoring on extubated patients with a nurse-controlled anesthesia pump Standardized pain-control protocol developed in conjunction with pain team for extubated patients Improved availability of blood products for patients at high risk for postoperative bleeding-through worked out with blood bank
Heart Center–specific	Implemented protocol for initial admission to CTICU for all single-ventricle and shunt-dependent children Reeducation of staff on pediatric early warning system scoring Monthly care conferences established to provide consistent long-term planning for long-term patients Standardized interventional catheterization to CTICU handoff procedure with template notes in electronic medical record Development of standardized screening for respiratory viruses preoperatively in high-risk surgical patients Protocol development for transfer of care from CTICU to operative staff for emergency procedures Hands-on skills update for all staff on resuscitation basics including bag-mask ventilation and chest compressions Expansion of mock-code scenarios to step-down unit Clarification of night operating room staff and role in activation of extracorporeal cardiopulmonary resuscitation Ability for staff to practice drawing up code medications during mock codes to improve efficiency and skills Improved rapid availability of equipped and stocked bed space in CTICU for emergent transfers Standardized monitoring during transfer of postcatheterization patients to postanesthesia care unit Team dynamics training during education days for staff to work on improving teamwork during cardiopulmonary resuscitation
Hospital-wide	Changes in code-team alerts to indicate cardiac patients Education for operating room staff and opening of new hospital units Identified deficiency in reporting of critical laboratory test results with point-of-care testing Reeducation of extracorporeal membrane oxygenation team on new equipment specifics CTICU physician to serve as medical control for transport and direct admission of cardiac patients, regardless of accepting unit

from the review process. Often, after the education was completed, knowledge and performance were tested by using simulated patient crises to ensure resolution of the identified issue.

Our cardiac surgical database was reviewed during the same time frame as an independent validation of clinical impact for our patients. We identified a total of 79 cardiopulmonary arrests in cardiac surgical patients from 2010 to 2013, with a yearly occurrence ranging from 3.2% to 6.2%. Cardiopulmonary arrest in our surgical population most commonly occurred in patients younger than 28 days of age (48%, 38/79), followed by patients between 29 days of age and 1 year (43%, 34/79), and with the fewest cardiopulmonary arrests in patients older than 1 year of age (9%, 7/79). Overall survival to discharge during 2010 to 2013, after cardiopulmonary arrest, was 44% for patients with single-ventricle physiology (15/34) and 61% for patients with 2-ventricle physiology (28/46). Figure 2 shows a marked improvement in survival ($P = .03$) for all cardiac surgical patients with a cardiopulmonary arrest over time at our institution, coinciding with the initiation of our review process.

Discussion

A great variety of methods have been used to review cardiopulmonary arrest events, and very few publications are available to support a best practice for institutions. Some hospitals use immediate postevent debriefings, which improve team performance.[7-10] Additional reports of multidisciplinary event reviews have been focused specifically on CPR performance, but not on other system factors that could affect patients' outcomes.[14] Other centers have reported using the morbidity and mortality conference as a quality improvement tool. A large conference may limit open discussion and not promote free disclosure of medical errors in a large group of peers. One pediatric center independently developed a

hospital-wide process similar in operation to ours, but at that center, cases are reviewed on the basis of preidentified systematic issues for quality improvement.[15] Our method differs in that we do not preselect cases for review. Interestingly, communication between caregivers remained the most frequently implicated factor in adverse patient outcomes after a cardiopulmonary arrest.[15]

Our method of reviewing cardiopulmonary arrests has helped to identify quality improvement targets as well as areas for optimization in resuscitation. Timely data collection has helped determine potential causes for cardiopulmonary arrests because clinical details are still accurate. Collection of telemetry data and data on trends in vital signs provides a more robust picture of the clinical events than the electronic medical record can provide. The use of high-fidelity data has facilitated identification of causes of cardiopulmonary arrest and has enabled us to review the quality of chest compressions and the "time off the chest," which has been acknowledged as a key to successful resuscitation.[12] Although it was not quantified, we have noted a marked improvement in the quality of chest compressions and a decrease in no-flow time without compressions.

Additionally, the telemetry system allows retrospective identification of the first physiological variable to change, which can be helpful in the identification of a potential cause of a cardiopulmonary arrest. When a cardiopulmonary arrest is preceded by an increase in right atrial pressure that is followed by hypoxia, bradycardia, and hypotension in the absence of cardiac tamponade, an acute pulmonary hypertensive crisis may be a potential cause of the cardiopulmonary arrest. This scenario is different from the scenario where the first change noted is onset of junctional bradycardia followed by hypotension and hypoxia, where a primary arrhythmia may be implicated as the cause. Additionally, high-fidelity data analysis during the code review has helped the group to comment on potential preventability of cardiopulmonary arrests. An acute rhythm change that results in cardiopulmonary arrest in a patient with stable hemodynamics is not likely to have been preventable. However, in a patient with unrecognized gradual hypotension and tachycardia, a cardiopulmonary arrest would potentially have been preventable.

Educational initiatives are often incorporated into our Heart Center's mock-code process to educate staff by using scenarios similar to the cardiopulmonary arrests reviewed. Policy or procedure changes were the next most common recommendation. One example involved a modification of our protocol for activating extracorporeal cardiopulmonary resuscitation to improve communication and facilitate a more rapid response from our team. A subsequent review of cardiopulmonary arrests showed that the communication issues had been corrected. Equipment issues were also identified during the review process. For example, a patient was transported to our new on-unit procedure room for an emergent procedure with cardiac anesthesia, where it was noted that the anesthesia monitors and backstand were set up differently than in other areas. As a result, the anesthesia environment was standardized to optimize patient care during critical resuscitation scenarios. Finally, staffing changes were the least frequent recommendation. In one example, the unit clerk was relocated to the nurses' station closest to a patient experiencing a cardiopulmonary arrest to help facilitate communication rather than remaining at the public entrance.

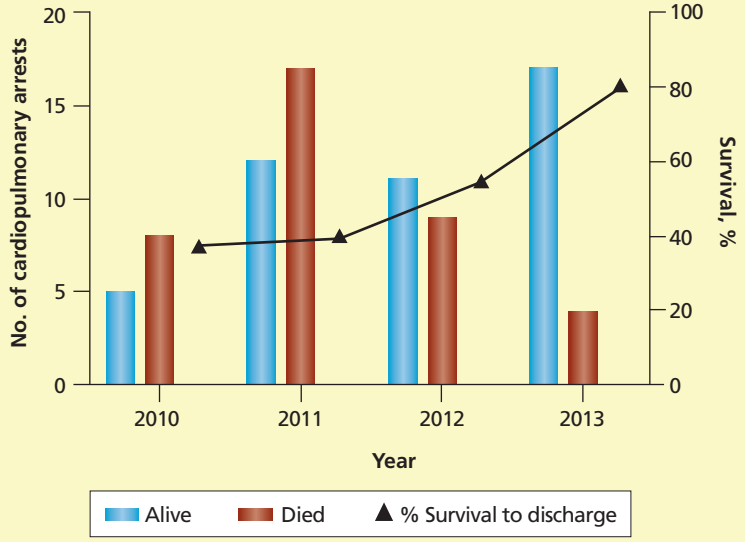

Figure 2 Cardiac surgical patients with a cardiopulmonary arrest by year with number of patients on the left axis and percentage survival of all cardiac surgical patients with a cardiopulmonary arrest on the right axis.

> Practice changes made due to the review process, have resulted in more positive outcomes.

Pasquali et al[16] suggest that the low mortality rate in high-performing cardiac surgical centers is not due to fewer complications, but rather to the ability of staff in those centers to deal with complications. They defined a "failure to rescue" rate as the ability to prevent a clinically important deterioration (ie, death or permanent disability) from a complication.[16] Review of cardiac surgical data at our institution demonstrates that our overall incidence of cardiopulmonary arrests is similar to the incidences reported in other published data series[3,4,17] at 3% to 6% per year. The Get With The Guidelines–Resuscitation database

report[13] from 2011 reported a subgroup of cardiac surgical patients with a survival to discharge of 37%, which was similar to our experience in 2010 and 2011. Over time, our survival rate after cardiopulmonary arrest has improved each year with survival to discharge reaching 55% in 2012 and 81% in 2013, exceeding reported survival rates of 37% to 48% in this specific population.[13,17] This survival rate would suggest that our heart center has lowered our failure-to-rescue rate specifically related to cardiopulmonary arrests in the cardiac surgical patients. Additionally, we have noticed a downward trend, which is not yet significant, in the percentage of cardiopulmonary arrests deemed "potentially preventable." We hope that in the coming years we will be able to demonstrate a decreased incidence of cardiopulmonary arrests in addition to our improved rescue rate.

Our findings have not been limited to our cardiac units but also have affected the entire hospital system. The hospital-wide code-activation system has been modified to clearly define cardiac patients so that specialists in cardiac intensive care can comprise the code team. Additionally, deficits in reporting results of point-of-care testing were identified and corrected. Finally, the ECMO team was reeducated on new systems that have been deployed in all the intensive care units. The expansion of our findings throughout the hospital system highlights the focus of the review process on system issues rather than individual errors.

The potential limitations of this method involve time commitment from the core group of individuals. Data collection and staff interviews frequently take 3 to 6 hours for each case. Additionally, scheduling a time when key participants are available in close proximity and at short notice requires dedication and commitment from our team. The initial reviews did not include a pharmacy representative or respiratory therapist, but after several reviews, this deficiency in the process was noted and corrected. We also do not review every cardiopulmonary arrest in the CTICU, and as a result, other areas for improvement may have been missed. Our review process had CPR performance as a secondary goal, and thus our findings may be due to improved CPR rather than identification and correction of other systematic issues. Finally, although our improvement in outcomes shadows the time course where we started our review process, other factors may account for the improvement, which may include the transition to a dedicated stand-alone CTICU in January 2012 and an institutional quality and a patient safety initiative to reduce preventable harm hospital-wide that began in 2009.[18]

Conclusion

We have implemented a multidisciplinary code-review committee specific for Heart Center patients in our institution. Our process has identified deficiencies in patient care and led to educational initiatives and interventions not only within our cardiac units but also throughout the hospital system. As a result of practice changes implemented because of the review process, we have seen trends toward decreasing preventable cardiopulmonary arrests, improved CPR performance, and increased survival to discharge in our surgical cardiac patients after a cardiopulmonary arrest to rates considerably higher than in other published reports. When coupled with a hospital-wide code-review process, this focused multidisciplinary review may benefit the institution as a whole.

ACKNOWLEDGMENTS
The authors acknowledge the contributions of hospital leaders in promoting a blame-free environment that allowed a robust review process and thank all Heart Center staff for their active participation in the code-review process.

FINANCIAL DISCLOSURES
None reported.

eLetters
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