The Cardiac Surgery Advanced Life Support Course (CALS): Delivering Significant Improvements in Emergency Cardiothoracic Care

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Background. A 3-day cardiac surgery advanced life support course was designed with a series of protocols to manage critically ill cardiac surgical patients and patients who suffer a cardiac arrest. We sought to determine the effect of this course on the management of simulated critically ill and cardiac arrest patients.

Methods. Twenty-four candidates participated in the course. Critically ill patients were simulated using intubated mannikins, with lines and drains in situ, and a laptop with an intensive care unit monitor simulation program. Candidates were tested before and after the course with rigidly predesigned clinical situations. Candidates were split into groups of 6, and cardiac arrests were simulated in the same fashion, with all required surgical equipment immediately available. All scenarios were videotaped, and after blinding, an independent surgeon assessed the times to achieve predetermined clinical endpoints.

Results. The time to successful definitive treatment was significantly faster postcourse for the critically ill patient scenarios: (565 secs [SD 27 secs] precourse, compared with 303 secs [SD 24 secs] postcourse; $p < 0.0005$). In addition, the times taken to achieve a wide range of predetermined objectives, including airway check, assessing breathing, circulation assessment, treating with oxygen, appropriate treatment of the circulation, and requesting blood gases, chest radiographs, and electrocardiograms, were also significantly faster in the postcourse scenarios. Times to successful chest reopening and internal cardiac massage were also significantly improved in cardiac arrest patients: (451 secs [SD 39 secs] precourse and 228 secs [SD 17 secs] postcourse; $p = 0.011$).

Conclusions. Structured training and practice in the management of critically ill cardiac surgical patients and patients suffering a cardiac arrest leads to significant improvements in the speed and quality of care for these patients.

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Protocols for the management of patients who suffer an in-hospital cardiac arrest are well established in patients on general medical and surgical wards. These protocols allow all staff members to participate fully in the cardiac arrest with speed and confidence; and even if resuscitation is not successful, a well-managed cardiac arrest allows the staff and relatives of the patient to be satisfied that everything possible has been done to save the patient.

Among patients after cardiac surgery, however, although cardiac arrest is not a rare event with an incidence of approximately 0.5% to 2% [1–4], no established protocol or structured training program exists that is tailored to the special needs of such patients. Staff members are often well trained in basic life support and defibrillation, but once chest reopening is required, the lack of a protocol means that staff must await for expert assistance before potentially life-saving maneuvers.

In Europe and the USA, there are major changes to the make-up of staff members being called to attend critically ill patients, postcardiac surgery. The European working time directive together with falling caseloads have resulted in fewer cardiac surgical trainees. That means that there are fewer senior cardiothoracic residents available to cover the wards and intensive care. In their place, intensive care or anesthetic trainees, noncardiothoracic junior staff members, and nurse practitioners are increasingly being asked to attend patients, but these staff members are often very low on experience of the issues particular to our specialty.

We, therefore, created a series of protocols for the critically ill cardiothoracic patient and set up a 3-day course to teach these skills. This study sought to evaluate the improvements in clinical skills taught by this course, both for the management of the critically ill patient and also for patients suffering a cardiac arrest.

Material and Methods

Construction of Cardiac Surgical Unit Advanced Life Support (CALS) Course Protocols

A group of cardiothoracic surgeons and anaesthetists (J.D., S.A., J.J., A.L.) derived a series of protocols for the

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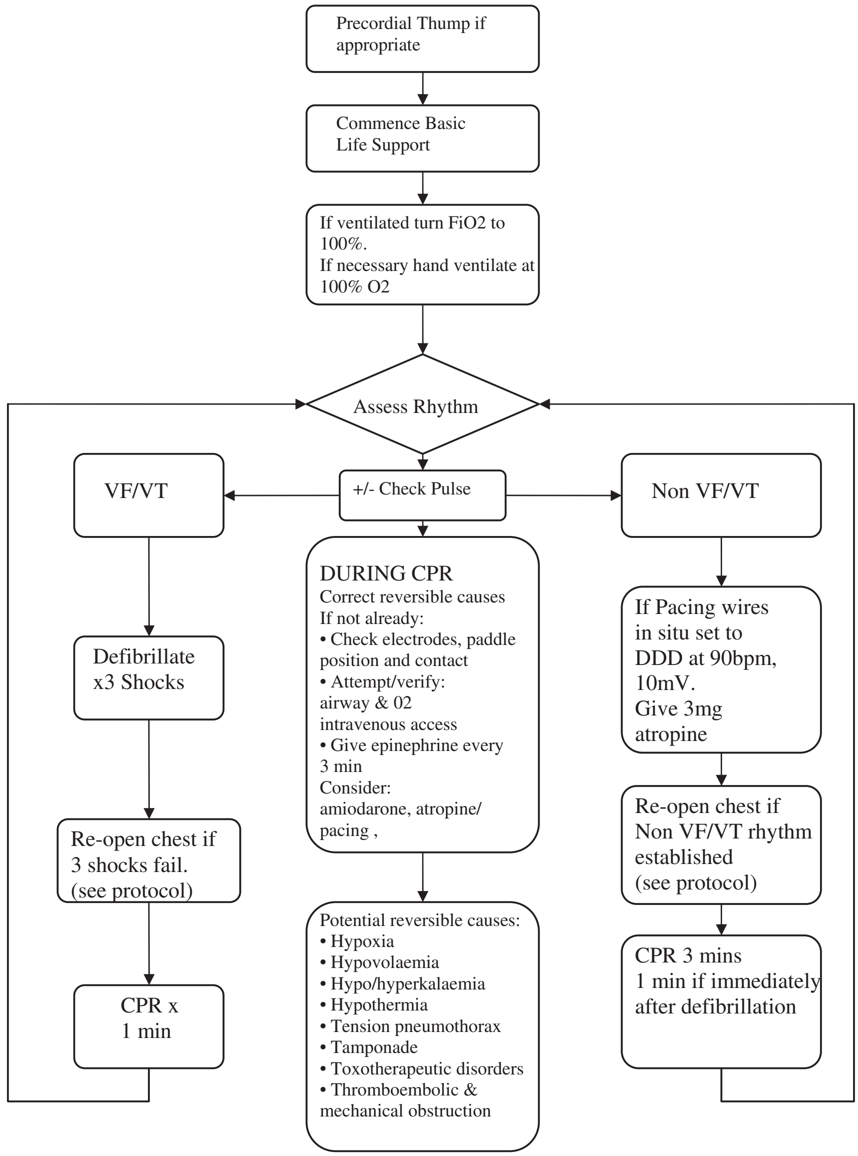

Fig 1. Initial management of cardiac arrest. (BLS = Basic Life Support; CPR = cardiopulmonary resuscitation; DDD = dual chamber sensing and pacing; VF/VT = ventricular fibrillation/tachycardia.)

management of cardiac arrests or critical illness in cardiothoracic surgical patients, based on existing guidelines from Advanced Cardiac Life Support (ACLS), the European Resuscitation Council guidelines, publications from the cardiothoracic literature, and their own clinical experience. A protocol for patients who suffer a cardiac arrest was derived (see Figs 1 and 2). Further protocols for hypotension, vasodilatation, low cardiac output, arrhythmias, respiratory failure, and renal failure were derived. A 3-day course was then constructed, comprising lectures, practical skills stations, and "real-time" patient scenario reconstructions. At the heart of the protocols to treat critically ill cardiothoracic surgical patients was a reproducible and rigid methodology to identify significant pathology in an ABC (Airway, Breathing, Circulation) fashion, similar to that taught on Advanced Trauma Life Support courses and Care of the Critically Ill Surgical Patients courses [5, 6].

Candidate Testing

Before any training, candidates attending the course were tested by asking them to manage patient scenarios of patients who had recently become acutely unstable. A mannikin (Resusci Anne, Laerdal Medical Corp) was used to simulate the patient which was intubated, had central lines, chest drains, urinary catheters and syringe drivers placed in the same fashion as a typical patient shortly post cardiac surgery. A laptop computer with an intensive care monitor simulator program was used to present real time clinical data, and a trainer presented the case, ran the laptop computer, and gave any clinical data as required if the correct information was requested. All scenarios were

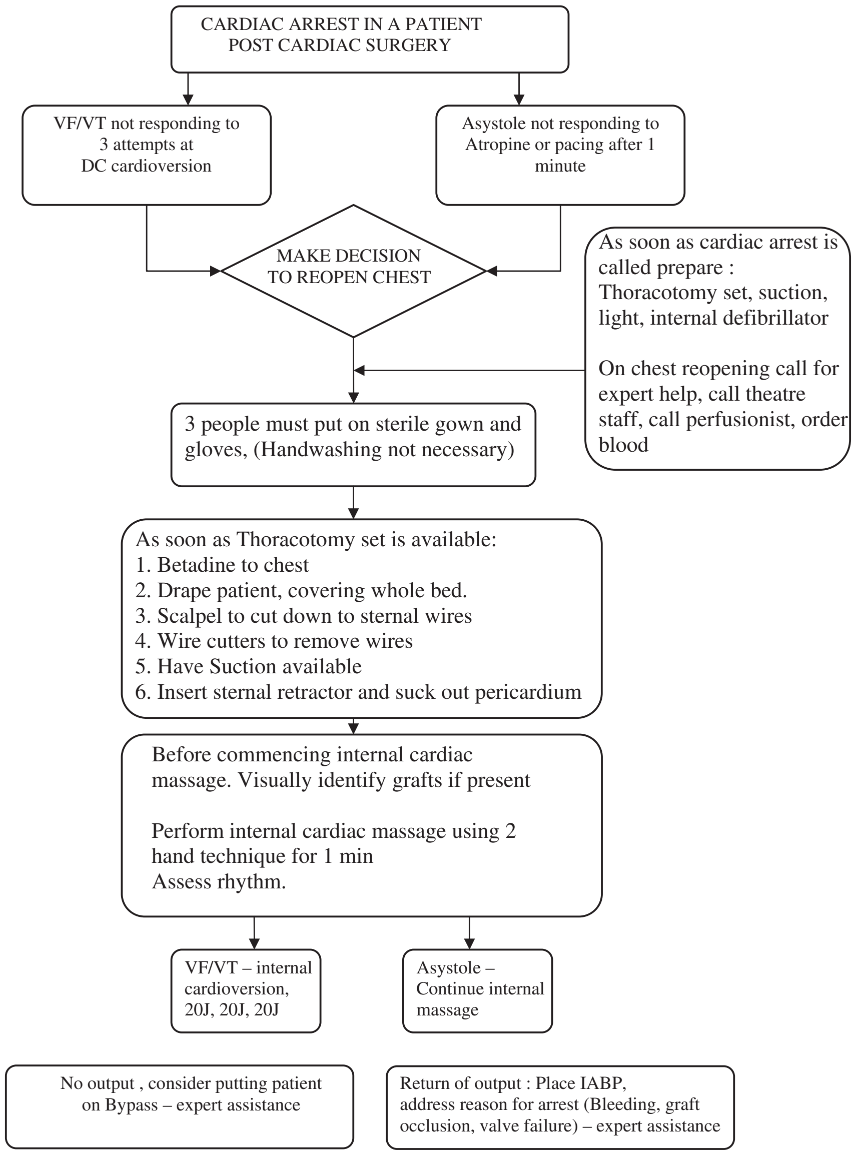

Fig 2. Chest reopening protocol. (IABP = intra-aortic balloon pump; DC = direct current; VF/VT = ventricular fibrillation/tachycardia.)

videotaped for subsequent analysis. Each scenario was run according to a rigid framework to ensure reproducibility.

At the end of the course, each candidate was again asked to manage a patient scenario, and the same trainer performed the reconstruction. These were again videotaped.

Before any cardiac arrest training, the candidates were split into groups of 6, in a skill mix similar to that found on an intensive care. They were asked to perform a resuscitation on a patient who arrests shortly post cardiac surgery. A mannikin was used, and in addition to the full intensive care unit mock-up, a thoracotomy set, gowns and gloves, drapes, and internal defibrillators were available in the room for use. The scenarios were again videotaped, and the arrest scenario was repeated at the end of the course in the same groups.

Critically Ill Cardiac Surgical Patient Scenarios

Eight scenarios were constructed for the purpose of testing reflecting common emergencies in cardiothoracic surgery (Table 1). The initial clinical status and all possible subsequent changes to status depending on treatment by the candidate were agreed in advance, and intensive care unit monitor screens were created to reflect all these changes. An endpoint of correct definitive treatment was agreed so that the time to correct definitive treatment could be determined. All candidates were split into groups of 4, and the scenarios were randomly allocated so that they were used equally as either precourse or postcourse scenarios. Candidates did not observe a scenario in the precourse test that they then took in the postcourse test.

For the cardiac arrest scenarios, a ventricular fibrilla-

Table 1. Moulage Scenarios

Scenario	Initial Scenario	Definitive Treatment
Bleeding	65-year-old 2½1/2 hours post-CABG, p110, BP 85/60, CVP-1, SaO_2 90%. 800 ml in drains.	Colloid then blood boluses, return to theater
Ischemia	60-year-old 5 hours post-CABG, p110 BP 80/45, CVP 20, SaO_2 80%	Adrenaline, PA catheter, IABP, return to theater
Tamponade	75-year-old 45 mins post-CABG, p120 BP 70/50, CVP 20, SaO_2 85%	Adrenaline +/− IABP, PA catheter, Echo, return to theater
Respiratory failure	78-year-old 1 day post-AVR. Extubated, p120 BP 135/70, CVP 9, SaO_2 86%	High flow oxygen, CPAP, then return to ICU and intubation
High output failure	70-year-old 8 hours post-AVR, p120 BP 90/40, CVP 8, SaO_2 94%	Noradrenaline, PA catheter, return to ICU
Ventricular tachycardia	65-year-old 3 hours post-CABG, p240 BP 65/45, CVP 16, SaO_2 90%	DC cardioversion, post-cardioversion ECG
Supraventricular tachycardia	68-year-old 6 hours post-CABG, extubated, p180, BP 100/60, CVP 14, SaO_2 90%	DC cardioversion
Acute mitral regurgitation	67-year-old 2 hours after difficult mitral repair, p130 BP 75/45, CVP 25, SaO_2 85%	Adrenaline, PA catheter, Echo and return to theater

BP = blood pressure (mm Hg); CABG = coronary artery bypass graft surgery; CPAP = continuous positive airway pressure; CVP = central venous pressure; DC = direct current; ECG = electrocardiogram; Echo = echocardiography; IABP = intra-aortic balloon pump; ICU = intensive care unit; p = pulse; PA = pulmonary artery; SaO_2 = oxygen saturation.

tion arrest and an asystolic arrest were simulated with equal frequency before and after the course.

Scenario Assessment

All tests were videotaped and assessed after the course. An independent cardiothoracic surgeon (J.N.) who has no involvement in any part of the course was asked to assess each videotape. Each video was numbered and the assessor was blinded as to whether the scenario was performed before or after the course. He assessed the time to a series of predetermined objectives (Tables 2 and 3).

Statistical Analysis

The times to achievement of the set objectives are presented as means together with their standard deviation. To compare pretest and posttest performance, paired t tests were calculated, using a p value of less than 0.05 to indicate a significant difference. If a candidate did not get to a set objective, this was treated as a missing variable. This analysis was performed on SPSS version 11.5 (SPSS, Chicago, Illinois).

Results

Eleven nurse practitioners, 8 senior house officers, 4 registrars, and 1 consultant from a total of 6 UK cardiothoracic units participated as candidates in this course. Two courses were run, each containing 12 candidates.

Critically Ill Cardiac Surgical Patients

Twenty-four precourse and 24 postcourse scenarios were conducted. There was a highly significant difference in the time taken to reach the stage of definitive treatment. During the precourse scenarios, the mean time was 565 s (SD 27 s) compared with only 303 s (SD 24 s) in the postcourse scenarios ($p < 0.0005$). In addition, the times taken to achieve a wide range of predetermined objectives, including checking the airway, assessing breathing, assessing the circulation, treating with oxygen, appropriate treatment of the circulation, and requesting of blood gases, chest radiographs, and electrocardiograms, were also significantly faster in the postcourse scenarios (Table 2). A higher number of these objectives were also missed out entirely in the precourse scenarios compared with postcourse scenarios. Finally, an assessment of a clinical decision that would have led to deterioration of the patient was made. In total, of the 24 precourse scenarios, 15 potentially dangerous decisions were made compared with only 2 in the 24 postcourse scenarios. These dangerous decisions included electing to treat atrial fibrillation with a blood pressure of 60/40 mm Hg with amiodarone, electing to wait for fresh frozen plasma and platelets in a patient bleeding 600 mL in half an hour with no coagulopathy, giving colloid to a patient with left ventricular failure and a central venous pressure of 25, and trying to give digoxin to treat a ventricular tachycardia (190 beats per minute with a blood pressure of 70/40 mm Hg). The two decisions made postcourse that were deemed dangerous were deciding to reopen a patient who was tamponading without requesting an echocardiogram to confirm the diagnosis, and starting adrenaline for a hypotensive patient who had a low blood pressure due to a supraventricular tachycardia.

Cardiac Arrest Scenarios in the Cardiac Surgical Patient

Four precourse and 4 postcourse cardiac arrest scenarios were conducted. Despite the small numbers of scenarios conducted, there was a highly significant difference between the two groups in the time taken to reach all significant objectives after cardiopulmonary resuscitation

Table 2. Times to Set Objectives for the Critically Ill Cardiothoracic Surgical Patient Scenarios

	Pretest (Missed)	Posttest (Missed)	p Value
Time to airway check	31 secs (9.2) (5 missed)	4.8 secs (1.0) (0 missed)	0.01
Time to breathing check	81 secs (20) (6 missed)	25 secs (3.0) (0 missed)	< 0.0005
Time to circulation check	110 secs (14) (6 missed)	65 secs (5.3) (0 missed)	0.013
Time to drain check	126 secs (16) (3 missed)	87 secs (9.9) (2 missed)	0.112
Time to urine output check	170 secs (24) (7 missed)	97 secs (10) (3 missed)	0.025
Time to treatment with oxygen	198 secs (25) (2 missed)	26 secs (4.0) (0 missed)	< 0.0005
Time to first appropriate treatment of circulation	300 secs (37) (3 missed)	192 secs (17) (2 missed)	0.008
Time to ECG	245 secs (42) (4 missed)	131 secs (15) (0 missed)	0.008
Time to blood gas request	223 secs (34) (0 missed)	112 secs (13) (0 missed)	0.005
Time to CXR request	224 secs (39) (9 missed)	124 secs (16) (3 missed)	0.048
Time to Echo request	438 secs (39) (16 missed)	221 secs (28) (15 missed)	*
Time to PA catheter request	315 secs (34) (7 missed)	236 secs (15) (11 missed)	0.146
Time to reassessment of patient	355 secs (34) (8 missed)	124 secs (14) (0 missed)	< 0.0005
Time to definitive treatment	565 secs (27) (0 missed)	303 secs (24) (0 missed)	< 0.0005
Total number of treatments categorized as dangerous	15	2	

* Too many missing.

CXR = chest radiograph; ECG = electrocardiogram; Echo = echocardiogram; PA = pulmonary artery; secs = seconds.

had been initiated (Table 3). The mean time to chest reopening and internal cardiac massage was 451 s (SD 39 s) in the precourse groups and 228 s (SD 17 s) in the postcourse groups. In addition, although skills taught on previous courses such as the times taken to start cardiopulmonary resuscitation, check the rhythm, and give resuscitative drugs were not highly significantly different, the time to make the decision to open the chest, the time to first incision, and the time to internal massage were very significantly different.

Comment

Numerous pressures on highly experienced cardiothoracic surgeons have led to great changes in the types of clinician called on to attend critically ill cardiothoracic patients. Anesthetic registrars, senior house officers, and increasingly, nurse practitioners are now called on to provide the initial assessment of potentially life-threatening situations. In addition, improvements in surgical technique and postoperative care means that cardiac arrest in the surgical intensive care is much less common. As a result, staff are less familiar with emergency chest reopening when such an arrest occurs. We have demonstrated that a structured teaching course that teaches and practices protocols for critically ill patients and cardiac arrests in cardiothoracic patients significantly improves the quality of care given to these patients and significantly improves the time to definitive treatment.

We also found that the course greatly increases the confidence that candidates have when facing similar patients in their clinical work. To date, one junior registrar that participated in the course has had to manage a cardiac arrest and chest reopening on the intensive care unit. His competent management was widely seen as the reason for the patient surviving this episode, surviving eventually to discharge and beyond.

Wahba and associates [7] reported that the survival after chest reopening was approximately 50% after reopening due to cardiac arrest in 29 patients, and Fairman and colleagues [4] reported 50% restoration of circulation in 79 emergency reopenings. Anthi and colleagues [8] reported a 79% survival among 29 cardiac patients who suffered an arrest on the intensive care unit. Therefore, emergency reopening is a valuable and successful inter-

Table 3. Times to Set Objectives for the Cardiac Arrest Scenarios

	Precourse Mean (SD)	Postcourse Mean (SD)	Paired t Test p Value
Time to initiating CPR	71 secs (23)	13 secs (3.8)	0.114
Time to rhythm check	74 secs (11)	42 secs (5)	0.044
Time to first drug administration	120 secs (14)	86 secs (17)	0.093
Time to first decision to open chest	221 secs (34)	83 secs (4)	0.026
Time to incision	404 secs (40)	176 secs (8.9)	0.009
Time to internal cardiac massage	451 secs (39)	228 secs (17)	0.011

CPR = cardiopulmonary resuscitation; secs = seconds.

vention if performed efficiently in patients suffering cardiac arrest.

In a 6-year review of chest reopenings at Papworth, 79 chest reopenings after cardiac arrest were identified. They found that if the chest was reopened within 10 minutes of the arrest, 48% of patients survived to discharge, compared with only 12% if the reopening took longer than this [1]. In addition, they found survivors among patients having a chest reopening more than 24 hours after surgery and a survivor after an arrest and reopening outside of the cardiac intensive care.

At the Royal Brompton and Harefield Hospitals, a 4-year audit identified 72 patients after cardiac surgery who required open cardiac massage. Initially, 46% of patients survived, although only 12% survived to discharge [9]. As a result of this audit, they suggested a protocol whereby all patients after cardiac surgery who suffer a cardiac arrest should be reopened within 5 minutes, or after two loops of unsuccessful external massage if the rhythm is ventricular fibrillation or pulseless ventricular tachycardia or one loop of unsuccessful external massage if the rhythm is not ventricular fibrillation/tachycardia. No specific protocols for the method of chest reopening were suggested, however.

New guidelines for the management of patients who suffer a cardiac arrest after cardiac surgery have recently been published by the European Resuscitation Council [10]. They support our view that early chest reopening should be performed "immediately if there is no output with external compressions or if there is a shockable rhythm refractory to cardioversion." In addition, they state that chest reopening should be regarded as a relatively straightforward procedure and should be performed within 10 minutes of the arrest. They also state that there should be "training of non-surgical medical staff to open the wound and remove sternal wires, while a surgeon is summoned."

While we have demonstrated important improvements in the times taken to achieve a successful outcome in real-life clinical simulations, we have not investigated the reasons for this improvement. It is possible that the improvements are just a result of candidates becoming used to the format of our testing scenarios or as a result of having 3 days to discuss and learn about critically ill patients rather than as a direct result of our course protocols and training. Considerable effort was made to mimick "real-life" situations, however, and thus it is difficult to imagine that these improvements in care would not translate into genuine improvements in patient management on the ward. Furthermore, the time for which these improvements in care remain with candidates has not been established. It may be hypothesized that only by regularly practicing these scenarios either in genuine clinical cases or using patient simulations will these new clinical skills remain with candidates. Finally, the cardiac arrest situation is a complex clinical scenario, and it remains to be seen how candidates using our protocols in real life are able to interact with staff who are unaware of these protocols when attempting to rapidly and safely reopen a patient suffering a cardiac arrest.

Courses in cardiac arrest for medical patients, Advanced Trauma Life Support for trauma patients, and Care of the Critically Ill Surgical Patient are now well established. These courses are now mandatory requirement in their fields and have greatly improved the care of critically ill patients in these fields. We are confident that this course will also greatly improve the quality of care for critically ill cardiothoracic surgical patients. The protocols are easily applicable internationally, and we hope that, as in other specialties, this course will provide a "common language" for the management of these patients. Thus, if widely adopted, clinicians moving between hospitals will easily fit into potentially complex resuscitation scenarios, and senior clinicians will have increased confidence that initial resuscitation will have been competently managed.

In conclusion, a cardiac surgery advanced life support course significantly improves the quality and speed of care received by critically ill cardiac surgical patients. In addition, emergency chest reopenings after cardiac arrest are performed significantly more quickly after training and practice in a widely applicable protocol for such an event.

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