

RESUSCITATION AFTER CARDIAC SURGERY AWARENESS, AN EGYPTIAN MULTICENTRE SURVEY

Authors and Institutions

Moslem Abdelghafar¹

Department of Cardiothoracic Surgery, Wythenshawe hospital, Manchester, UK.

Taher Abdelmoniem²

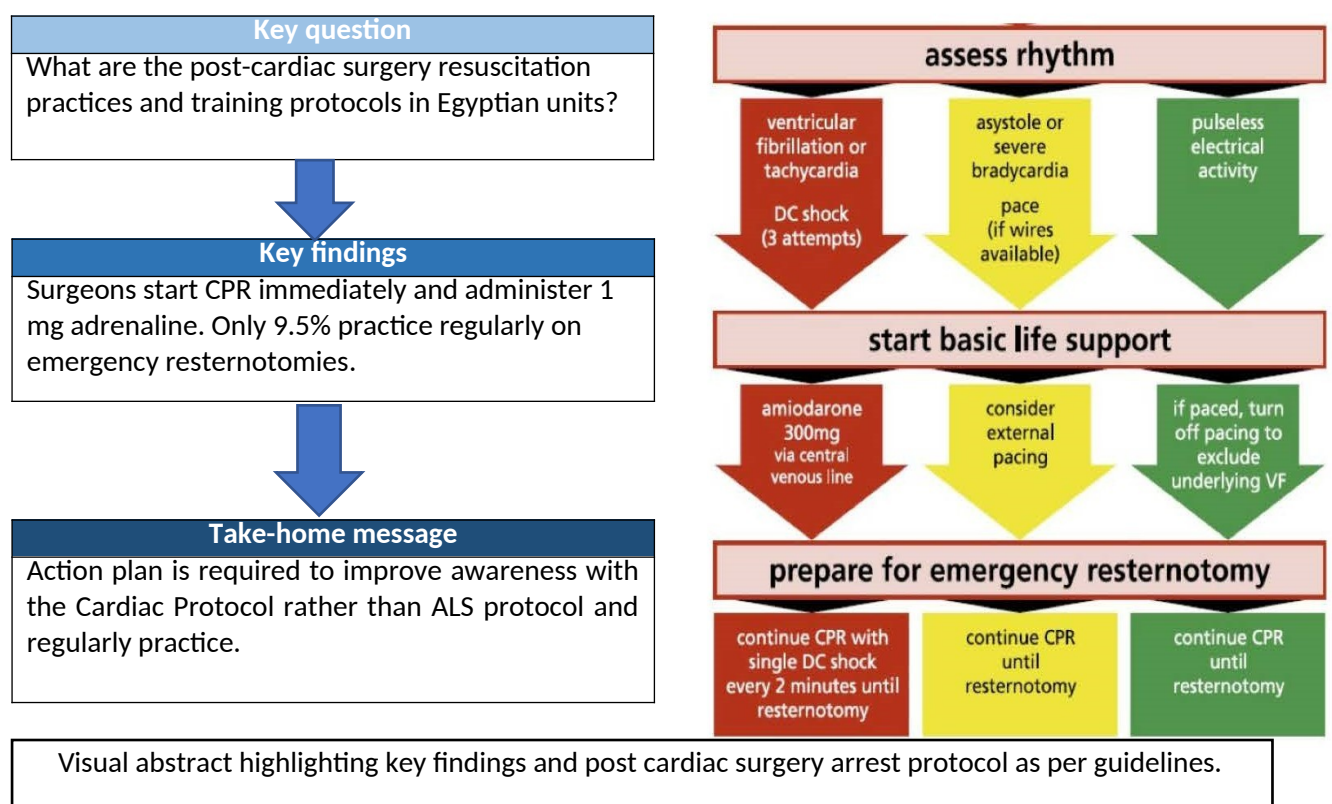
Department of Cardiac Surgery, National Heart Institute, Giza, Egypt.

Alaa Mohamed³

Department of Cardiothoracic Surgery, El-Hussine Hospital, Al-Azhar University, Cairo, Egypt.

Mohamed Abdalla⁴

Department of Cardiac Surgery, Shebein ELKom teaching hospital, Shebein ELKom, Egypt.



Abstract

Cardiac surgery patients have different resuscitative needs than other patients who experience in-hospital cardiac arrest, this was addressed in the guidelines. However, it is unknown how widely the guidelines are practiced, or a training protocol is followed in different cardiac surgery units in Egypt.

Methods

A 21-question survey is created and included: Participants demographics, Prevalence of cardiac arrest, Cardiac arrest protocol, Emergency re sternotomy technique, Training protocols. Survey was disseminated through social media messaging platforms during the period between November 2020 and January 2021.

Results

95 responses were from 11 centres across Egypt. 68.5% of the respondents were surgeons, 76.8% of participants were junior surgeons.

For patients who go into VF after cardiac surgery, respondents would attempt a median of 3 shocks with only 24.2% commencing defibrillation shocks before external cardiac massage, while the

majority initiating CPR immediately and performing emergency resternotomy in a median time of 10 mins. 56.8% would give 1 mg of adrenaline as soon the cardiac arrest was established. If a surgeon was not available, only 36.8% of respondents would allow any trained personnel to perform the emergency resternotomy. Only 9.5% practice regularly on emergency sternotomies. 75% think tailored training is important and staff should be oriented about it in the future.

Conclusion

An action plan is required to improve the awareness of the junior surgeons with the Cardiac Advanced Life Support Protocol.

Keywords: Cardiac surgery, Resuscitation, Training, Education

Word count: 3941 words

Corresponding Author: Moslem Abdelghafar. Mobile number: +44 759 752 7951.

E-mail: Moslem_fathy@hotmail.com.

Postal address: 10 Maple gardens, M20 4NN, Manchester, UK.

Abbreviations and acronyms

ACLS	Advanced Cardiac Life Support
AHA	American Heart Association
ALS	Advanced Life Support
CPR	Cardiopulmonary Resuscitation
EACTS	European association of cardiothoracic surgery
ECM	External cardiac massage
ERC	European resuscitation council
ICU	Intensive care unit
ROSC	Return of spontaneous circulation
PEA	Pulseless electrical activity
STS	Society of Thoracic Surgeons
VF	Ventricular fibrillation
VT	pulseless Ventricular tachycardia

Introduction

Every year, over 250,000 patients have cardiac surgery in some 450 centres in Europe [1] and more than 400,000 patients undergo cardiac surgery in the United States at approximately 1,200 medical centres [2-4]. During the past decade, there has been an increasing recognition that cardiac surgery patients have different resuscitative needs than other medical and surgical patients who experience in-hospital cardiac arrest. The special resuscitative needs of cardiac surgery patients were addressed in the 2010 European Resuscitation Council (ERC) Guidelines for Resuscitation in the section reviewing cardiac arrest in special circumstances and the 2010 American Heart Association (AHA)

Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care in Special Situations. [5-6]. However, it's unknown how widely the guidelines are practiced, or a training protocol is followed in different units in Egypt. This national survey aims to identify the views and common practice of Egyptian cardiac surgery teams regarding resuscitation after cardiac surgery.

Methods and Materials.

A 21-question survey is created (Table 1) based on the original survey used by the European Association of Cardiothoracic Surgery (EACTS) guidelines committee.[7] Questions included the following topics: Participants demographics, Prevalence of cardiac arrest in the intensive care unit, Cardiac arrest with ventricular fibrillation or non-shockable rhythm, Emergency resternotomy technique, Training and arrest protocols. Survey dissemination was through social media platforms and mobile messaging applications and emails during the time period between November 2020 and January 2021. Ethics approval and informed consent have been waived by the institutional review board.

Demographics

The first eight questions were used to obtain demographic data on the expertise of the respondent, the size of the unit and the prevalence of cardiac arrest and emergency resternotomy in the unit where the respondent worked.

Data cleaning

Prior to analysis the data from all respondents were analysed independently and excluded if the multiple choice, numerical or text responses indicated that the survey had been incorrectly completed or if multiple respondents came from the same email address. Respondents were excluded if there were no responses to over 50% of the questions or if the numerical data responses were impossible (i.e., more arrests than operations performed in that unit).

Statistical analysis

Continuous data are presented as median, mean, standard deviation and range, or only as median if the data was significantly skewed using the Kolmogorov—Smirnov test. Categorical data was

presented as percentages. Data was presented and analysed using SPSS 13.0 (Statistical Package for the Social Sciences, SPSS Inc Chicago, USA).

(Table 1. depicting survey questions.)

94	Demographics
95	1- What's your speciality?
97	(a) Cardiothoracic surgeon
98	(b) Cardiac surgery Anesthesiologist
	(c) Cardiac surgery intensive care specialist
	2- What's your degree of expertise?
	a) Consultant grade
	b) Non consultant/Middle grade/specialist/ in training
	3- What's the name of your hospital?
	Prevalence of cardiac arrest in the intensive care unit
	4- How many cardiac surgical procedures did your unit perform in the past 12 months?
	5- How many patients in the past 12 months do you estimate required closed chest compressions for cardiac arrest in your cardiac intensive care following cardiac surgery?
	6- How many patients in the past 12 months who suffered a cardiac arrest on your cardiac intensive care unit required emergency re sternotomy as part of the resuscitation?
	7- How many patients in the past 12 months who required an emergency re sternotomy also required a return onto cardiopulmonary bypass?
	8- Of all patients who arrested, what percentage of these do you estimate survived to hospital discharge?
	Cardiac arrest with ventricular fibrillation
	9- Regarding patients who go into ventricular fibrillation or pulseless ventricular tachycardia on your cardiac intensive care have you ever experienced successful return to a spontaneous circulation with a precordial thump?
	(a) I have witnessed one or more successful occasions
	(b) I have never witnessed this, but I have heard of success in cardiac surgical patients
	(c) I have never witnessed or heard of success, but I would have a go if I thought it was appropriate
	(d) I have never witnessed or heard of success and I think that it is benign but of little use
	(e) I think that this is a potentially harmful manoeuvre and would not condone its use
	10- If a patient goes into ventricular fibrillation or pulseless ventricular tachycardia on your cardiac intensive care after cardiac surgery do you think that they should:
	(a) Receive immediate external chest compressions followed by defibrillation as soon as available
	(b) Have defibrillation as soon as possible and only commence external chest compression after 1—3 attempts at defibrillation have failed
	11- on your unit if a patient goes into ventricular fibrillation or pulseless ventricular tachycardia what is your preferred sequence of defibrillation attempts?
	(a) I would perform three attempts at defibrillation in a row, then commence chest compressions for 2 min with a single shock after each 2-min cycle
	(b) I would perform single attempts at defibrillation with external chest compressions for 1 min between attempts
	(c) I would perform single attempts at defibrillation with external chest compressions for 2 min between attempts
	(d) I would perform three attempts at defibrillation in a row, with external chest compressions till re sternotomy
	12- For patients in established cardiac arrest when do you think that administration of epinephrine (adrenaline) is warranted?
	(a) As soon as possible
	(b) after 2 min of external massage
	(c) After 3—5 min of external massage
	(d) After 5—10 min of external massage
	(e) Only after continued cardiac arrest despite emergency re sternotomy
	(f) Only in exceptional circumstances and should not be part of routine cardiac arrest management after cardiac surgery
	13- If you had to name a number of defibrillation attempts or a rough time at which you felt that a patient less than 24 h after cardiac surgery in ventricular fibrillation should have emergency re sternotomy what would it be? (number of attempts and number of minutes)
	14- If you had to name a number of defibrillation attempts or a rough time at which you felt that a patient MORE than 24 h after cardiac surgery in ventricular fibrillation should have emergency re sternotomy what would it be? (number of attempts and number of minutes)
	Cardiac arrest where the rhythm is not VF or pulseless VT.

Results

Of 126 responses, 95 were suitable for inclusion. 31 responses were deleted due to duplication or incorrect completion. We have responses from over 11 centres across Egypt, 54.7% of respondents were from one centre, the rest were from other different centres. 68.5% of the respondents were surgeons while cardiac anaesthetists and intensivists formed 12.6% and 18.9% respectively. The majority of participants were non-consultants/middle-grade doctors comprising 76.8%, consultant participation was 23.2%.

The median number of cases performed in the units of respondents was 480 and this ranged from 10 to 3000. The average percentage of cardiac arrests in these units was 7% and the average percentage of emergency resternotomy after cardiac arrest was 2.4%. Respondents reported that the median survival to hospital discharge of all arrests was 33%.

Concerning a precordial thump in ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT), 37.9% of respondents had seen this work at least once. In addition, 15.8% had heard of its

10- If a patient goes into ventricular fibrillation or pulseless ventricular tachycardia on your cardiac intensive care after cardiac surgery do you think that they should:

95 responses



DC shocks in a VF arrest situation.

successful use and an additional 14.7% would have a go even though they have never heard of a success. Only 12.6% felt that this might be harmful & 18.9% think it's of little use.

In patients who arrest with VF or VT, only 24.2% of respondents would commence 1-3 defibrillation shocks then perform external cardiac massage (ECM), with the majority initiating CPR immediately (Figure 1).

125

126 Regarding the sequence of
127 defibrillation attempts
128 interspersed with ECM, 50.5% of
129 respondents would perform
130 three attempts at defibrillation

12- For patients in established cardiac arrest when do you think that administration of epinephrine (adrenaline) is warranted?
95 responses

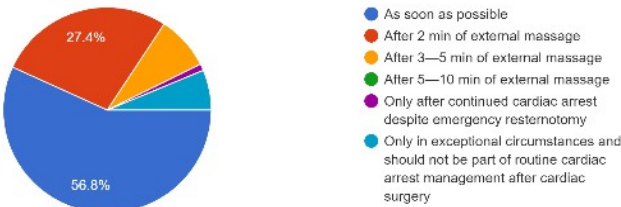


Figure 2 Adrenaline administration patterns after cardiac arrest.

131 without intervening ECM, and 35.8% of these respondents would then perform two minutes of ECM
132 before further attempts. 49.4% would perform single defibrillation attempts interspersed with ECM
133 at 1- or 2-minute intervals, and 56.8% of respondents would give 1 mg of adrenaline as soon the
134 cardiac arrest was established. Only 6.3% of respondents thought that it should be given rarely or
135 not at all. (Figure 2).

136

137 For patients who go into VF in less than 24 hours after cardiac surgery, respondents would attempt a
138 mean of 3 shocks prior to emergency resternotomy, and would hope to do this in a median time of
139 10 mins. They would also perform an emergency resternotomy within 15 min if the rhythm was not
140 VF. While for patients who suffer cardiac arrest more than 24 hours after the surgery results were, a
141 median of 5.6 attempts of defibrillation and a median of 17.6 minutes to perform emergency
142 resternotomy. (Table 2).

143 Table 2.
144

	Number of responses	Median	Range
Number of defibrillations attempts before resternotomy in VF/VT			
Cardiac arrest <24 h	95	3 shocks	14 (min 1, max 15)
Cardiac arrest > 24 h	95	5 shocks	19 (min 1, max 20)
Time to resternotomy where initial rhythm is VF/VT			
Cardiac arrest <24 h	95	10 mins	29 (min 1, max 30)
Cardiac arrest > 24 h	95	17.6 mins	58 (min 2, max 60)
Time to resternotomy where initial rhythm is asystole/PEA			
Cardiac arrest <24 h	95	15 mins	44 (min 1, max 45)
Cardiac arrest > 24 h	95	17.6 mins	44 (min 1, max 45)

145

146 A series of questions were asked on the conduct of an emergency resternotomy in patients who
147 have suffered a cardiac arrest (Table 3). If a surgeon was not immediately available 36.8% of

respondents would be happy for a suitably trained non-surgeon to perform the emergency resternotomy while 58.9% of respondents would not be happy for anyone except a surgeon to perform the resternotomy. Of respondents who would allow a non-surgeon to perform an emergency resternotomy, 33.7% would allow anyone trained for the procedure to do it, 14.4% would allow an anaesthesiologist, 17.9% would allow intensive care doctor, and 12.6% would allow a junior grade doctor to perform an emergency resternotomy. Only 9.5% and 3.2% would allow a theatre scrub nurse and a senior intensive care nurse respectively to do this.

49.4% of the participants have never practised any local training to perform an emergency sternotomy however 34.7% believe it is a must-have. 41% of the respondents state they occasionally practice or talk with the staff about guidance in the event of a cardiac arrest. Only 9.5% practice regularly on emergency sternotomies.

25% assume current training is sufficient and does not need modification or additional patient tailoring, while 75% think tailored training is important and staff should be oriented about it in the future.

70.5% of all respondents advocate the current guidelines for resuscitation published by the ERC, EACTS, and the AHA for use on their patients, however, 5% disagree with the guidelines and have their own local protocol. Meanwhile, 24.2% have not read the guidelines.

Discussion

The incidence of cardiac arrest after cardiac surgery is around 0.7—7% [8-16] and has reduced in recent years. The most remarkable statistic regarding these patients is the relatively good outcome with 17—79% of patients suffering a cardiac arrest surviving to hospital discharge, a far higher proportion than can be hoped for when cardiac arrest occurs in other settings. The reason for this superior survival is the high incidence of reversible causes for the arrest. Ventricular fibrillation (VF) accounts for 25—50% of cases and, in the intensive care unit (ICU) setting, this is immediately

173 identified and treated. Also, tamponade and major bleeding account for many arrests and both
174 conditions may be quickly relieved by prompt resuscitation and emergency resternotomy where
175 appropriate.

176 Prompt recognition and treatment by ICU staff trained in the recognition and management of these
177 arrests improved survival. Practicing protocol-based arrest management has been shown to reduce
178 by 50% the time to chest reopening and reduce complications resulting from the resternotomy after
179 cardiac surgery [17-22].

180
181 EACTS endorsed resuscitation guidelines for this special group, this is further followed by the
182 European Resuscitation Council and American Heart Association in 2010 and finally endorsed in the
183 STS expert consensus in 2017. Our survey gives an insight into current practices in the Egyptian
184 cardiac surgery centres and the degree of orientation and adoption of guidelines.

185 In our study, 68.5% of the respondents were cardiac surgeons, of which are 76.8% middle grade/
186 resident/ junior doctors. This is representative of first responders to cardiac arrest call in a routine
187 practice thus it's crucial to identify knowledge and practices to evaluate the quality and safety of
188 patient care.

189
190 Our respondents will act in a VT/VF cardiac arrest situation as follows, 75% will start CPR, 57% will
191 give adrenaline immediately, almost 50% will perform single attempts of defibrillation between
192 external cardiac massage either at 1- or 2-minute intervals. They will undertake a median of 3 shocks
193 or 10 minutes to perform an emergency resternotomy if within 24 hours of the surgery. These
194 figures increased if the surgery was more than 24 hours ago, with a median of 5 shocks and 17.5
195 minutes to emergency resternotomy. All of which are more in line with Advanced Life Support (ALS)
196 or Advanced Cardiac Life Support (ACLS) protocols and not the protocol dedicated for cardiac
197 surgery and advocated by current guidelines.

198
199 The current guidelines advocate, once cardiac arrest is identified, to assess the rhythm first and not
200 to commence chest compressions as in ALS protocol, reason being the possibility of presence of
201 shockable rhythm such as VF or pulseless VT in 25 – 50% of cases [22]. If a shockable rhythm is
202 identified, chest compressions could be delayed for up to 1 minute to deliver 3 shocks as this might
203 spare the traumatic chest compressions to a fresh sternotomy wound and avoid complications of
204 cardiac/graft injury.

205
206 In the cardiac surgical patient, the efficacy of defibrillation reduces by 10% for every minute delay, in
207 addition, success rates for immediate sequential shocks for VF or pVT decline from 78% with the first
208 shock to 14% with the third, therefore immediate defibrillation with three sequential attempts at
209 150 Joules is advised.[24] While in sever bradycardia or asystole, it is advisable before starting chest
210 compressions to turn the pacing to emergency setting or DDD mode, 90 beats, maximum amplitude.

211
212 No study concluded benefit or harm of administering adrenaline during resuscitation of the
213 postoperative cardiac surgical patient however, the risk of administering adrenaline in conventional
214 doses is with profound hypertension, bleeding, or tearing of vessel anastomoses on return of
215 spontaneous circulation (ROSC), which can precipitate catastrophic harm or further cardiac arrest.
216 [25] Therefore the recommendation to administer adrenaline is to be delayed until reversible causes
217 of arrest are excluded and directed by a senior clinician experienced in their use. Adrenaline remains
218 a useful drug in peri-arrest situations in smaller doses.

219
220 Of concern, almost 60% would not prefer anyone but the surgeon to perform a resternotomy, not
221 junior surgical trainees or non-surgeon colleagues even if trained for it. Nonetheless, 40% would
222 allow anyone trained for emergency sternotomy to perform it in case of cardiac arrest, of note the
223 highest percentage is 17.9% for the intensive care doctors. This could be due to the fact that junior
224 surgeons in the majority of cardiac units in Egypt are the ones actually managing cardiac intensive

225 care, thus being familiar with surgical problems and have enough skills to perform an emergency
226 sternotomy. Senior intensive care or theatre nurses whether were accepted to perform emergency
227 resternotomy by only 13% of the respondents, we believe the reason being the lack of training or
228 fear of medicolegal pursuits and claims.

229 Despite 70.5% of respondents advocate the current guidelines for resuscitation, only 50% of answers
230 indicate there is either occasional discussion with the team on a cardiac arrest protocol (41.1%) or
231 regular training (9.5%). The remaining 49.4% of the respondents concur there is no training available
232 however, 75% believe in its importance and would endorse it in their units.

233
234 An immediate postcardiac arrest care algorithm can offer structured guidance to facilitate the
235 identification and treatment of the potential causes of the arrest, prevention of arrest recurrence,
236 optimization of cardiac output and oxygen delivery during the arrest, and implementation of
237 neuroprotective strategies after the return of spontaneous circulation. Thus, the need to raise the
238 awareness and training of the junior surgical doctors and intensive care staff with current guidance
239 and emergency sternotomy protocols is paramount.

240
241 The core message for our trainees and fellows; external chest compressions is ineffective in
242 tamponade, tension pneumothorax and extreme hypovolemia. Brain damage will occur in 5 minutes,
243 the only way to save those patients is to perform a rapid smooth emergency resternotomy.

244

245 **Limitations**

246 Our study has several limitations. Dissemination through social media is dependent on personal
247 efforts to reach our target audience, which explains the small number of respondents and the
248 reason 60% of the responses are from one centre. However, this was the best available alternative
249 as there is no structured method in Egypt for data collection from multiple centres.

Data regarding the number of procedures, closed chest compressions, resternotomy, and going back on bypass rates are mere speculations of the respondents and may not represent the actual figures and numbers as 77% of the respondents are middle-grade doctors and might not always be oriented with the numbers, also it is not feasible to access these institutional numbers easily. Moreover, COVID 19 pandemic has significantly impacted the number of procedures performed and could be a valid reason for the heterogeneity of data from respondents from the same centre.

Conclusion

Resuscitation after cardiac surgery has a high survival rate due to the high incidence of reversible causes. A structured protocol and a well-trained staff are advocated by the current resuscitation guidelines. An action plan is required to improve the awareness of the junior surgeons with the Cardiac Advanced Life Support Protocol. Proper training of the intensive care staff to implement the protocol in a timely organised manner is needed. Emergency resternotomy under 5 minutes is the only effective way to save patients with tamponade and extreme hypovolemia.

Conflict of interest Statement

No competing financial interests exist.

Funding statement

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

Author contribution statement

Author 1 contributed to conception, design, analysis, interpretation and writing of the work.

Author 2, 3 and 4 contributed to data acquisition and revising the manuscript.

272 **Supplementary tables**

273 **Table 3**

274

	Responses	percentages
(6) Precordial thump (total)	95	
(a) Witnessed	36	37.9%
(b) Heard of success	15	15.8%
(c) Have a go	14	14.7%
(d) Of little use	18	18.9%
(e) Potentially harmful	12	12.6%
(7) Defibrillation or ECM for VF	95	
(a) Immediate ECM	72	75.8%
(b) Immediate defibrillation	23	24.2%
(8) Sequence of shocks for VF	95	
(a) Three attempts, 2 min ECM then single shocks	34	35.8%
(b) Single attempts with 1 min ECM	12	12.6%
(c) Single attempts with 2 min ECM	35	36.8%
(d) Three attempts, ECM till resternotomy	14	14.7%
(9) When is adrenaline warranted	95	
(a) As soon as possible	54	56.8%
(b) After 2 min of ECM	26	27.4%
(c) After 3—5 min after ECM	8	8.4%
(d) Only after emergency resternotomy	1	1.1%
(e) Only in exceptional circumstances	6	6.3%
(15) Emergency resternotomy	95	
(a) A surgeon should always do this	56	58.9%
(b) A trained non-surgeon could do this	35	36.8%
(c) Any non-surgeons could do this	4	4.2%
(17) Do you train for emergency resternotomy	95	
(a) We never practise, not necessary	14	14.7%
(b) We never practise might be good idea	33	34.7%
(c) Informal talks and experience	11	11.6%
(d) We have occasionally practised	28	29.5%
(e) We regularly practise	9	9.5%
(18) Current guidelines for the ICU	95	
(a) I advocate the ERC/AHA 2005 guidelines	67	70.5%
(b) I do not agree with these, we have our own protocol	1	1.1%
(c) I do not agree with these, we have no protocol	4	4.2%
(d) I have not read the ERC/AHA guidelines	23	24.2%
(19) Current training	95	
(a) It is adequate currently but not tailored	17	17.9%
(b) We give additional training	7	7.4%
(c) Tailored training might be useful	18	18.9%
(d) Tailored training is important and should be given	53	55.8%

275

276

277

278

279

280

281

282

283

284

285

286

287

288

289

290

291

292

293

References

1. Unger F. European Survey on Cardiac Interventions: open-heart surgery, percutaneous transluminal coronary angioplasty and cardiac catheterization in 1993. *Cardiovasc Surg* 1993;3(6):569–71.
2. Jacobs JP, Edwards FH, Shahian DM, et al. Successful linking of The Society of Thoracic Surgeons Adult Cardiac Surgery Database to Centers for Medicare and Medicaid Services Medicare data. *Ann Thorac Surg* 2010;90:1150–7.
3. Roger VL, Go AS, Lloyd-Jones DM, et al. Heart disease and stroke statistics—2012 update: a report from the American Heart Association. *Circulation* 2012;125:e2–220.
4. Girotra S, Lu X, Popescu I, Vaughan-Sarrazin M, Horwitz PA, Cram P. The impact of hospital cardiac specialization on outcomes after coronary artery bypass graft surgery: analysis of Medicare claims data. *Circ Cardiovasc Qual Outcomes* 2010;3:607–14.
5. Soar J, Perkins GD, Abbas G, Alfonso A, Barelli A, Bierens JJ, et al. European Resuscitation Council Guidelines for Resuscitation 2010 Section 8. Cardiac arrest in special circumstances: electrolyte abnormalities, poisoning, drowning, accidental hypothermia, hyperthermia, asthma, anaphylaxis, cardiac surgery, trauma, pregnancy, electrocution. *Resuscitation*. 2010;81:1400–33.
6. Vanden Hoek TL, Morrison LJ, Shuster M, Donnino M, Sinz E, Lavonas EJ, et al. Part 12: cardiac arrest in special situations: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2010;122:S829–61.
7. Pottle A, Bullock I, Thomas J, Scott L. Survival to discharge following open chest cardiac compression (OCCC). A 4-year retrospective audit in a cardiothoracic specialist centre—Royal Brompton and Harefield NHS Trust, United Kingdom. *Resuscitation* 2002;52(3):269–72.
8. Adam Z, Adam S, Everngam RL, et al. Resuscitation after cardiac surgery: results of an international survey. *Eur J Cardio-thoracic Surg*. 2009;36(1):29–34.
9. Mackay JH, Powell SJ, Osgathorp J, Rozario CJ. Six-year prospective audit of chest reopening after cardiac arrest. *Eur J Cardiothorac Surg* 2002;22(3):421–5.
10. Birdi I, Chaudhuri N, Lenthall K, Reddy S, Nashef SA. Emergency reinstitution of cardiopulmonary bypass following cardiac surgery: outcome justifies the cost. *Eur J Cardiothorac Surg* 2000;17(6):743–6.
11. El-Banayosy A, Brehm C, Kizner L, Hartmann D, Kortke H, Korner MM, Minami K, Reichelt W, Korfer R. Cardiopulmonary resuscitation after cardiac surgery: a two-year study. *J Cardiothorac Vasc Anesth* 1998;12(4):390–2.
12. Anthi A, Tzelepis GE, Alivizatos P, Michalis A, Palatianos GM, Geroulanos S. Unexpected cardiac arrest after cardiac surgery: incidence, predisposing causes, and outcome of open chest cardiopulmonary resuscitation. *Chest* 1998;113(1):15–9.
13. Charalambous CP, Zipitis CS, Keenan DJ. Chest reexploration in the intensive care unit after cardiac surgery: a safe alternative to returning to the operating theater. *Ann Thorac Surg* 2006;81(1):191–4.
14. Wahba A, Gotz W, Birnbaum DE. Outcome of cardiopulmonary resuscitation following open-heart surgery. *Scand Cardiovasc J* 1997;31(3): 147–9.
15. Kaiser GC, Naunheim KS, Fiore AC, Harris HH, McBride LR, Pennington DG, Barner HB, Willman VL. Reoperation in the intensive care unit. *Ann Thorac Surg* 1990;49(6):903–7.
16. McKowen RL, Magovern GJ, Liebler GA, Park SB, Burkholder JA, Maher TD. Infectious complications and cost-effectiveness of open resuscitation in the surgical intensive care unit after cardiac surgery. *Ann Thorac Surg* 1985;40(4):388–92.
17. Maccaroni MF, Watson ND, Gaage DL. Managing cardiac arrest after cardiac surgery: the impact of a five year evolving re sternotomy policy and a review of the literature. *Anal Resusc Curr Res* 2013;S1:1–7.
18. Dunning J, Nandi J, Ariffin S, Jerstice J, Danitsch D, Levine A. The cardiac surgery advanced life support course (CALS): delivering significant improvements in emergency cardiothoracic care. *Ann Thorac Surg* 2006;81:1767–72.
19. Danitsch D, Levine A, Choudrey S, Dunning J, Ariffin S, Jerstice J. Evaluation of a cardiac surgery advanced life support course. *Nurs Times* 2006;102:30–2.
20. Wilson CT, Fisher ES, Welch HG, Siewers AE, Lucas FL. U.S. trends in CABG hospital volume: the effect of adding cardiac surgery programs. *Health Aff (Millwood)* 2007;26:162–8.
21. Horwitz JR, Nichols A, Nallamothu BK, Sasson C, Iwashyna TJ. Expansion of invasive cardiac services in the United States. *Circulation* 2013;128:803–10.
22. Reddy HG, Shih T, Englesbe MJ, et al. Analyzing “failure to rescue”: is this an opportunity for outcome improvement in cardiac surgery? *Ann Thorac Surg* 2013;95:1976–81.
23. Dunning J, Levine A, Ley J, et al. The society of thoracic surgeons expert consensus for the resuscitation of patients who arrest after cardiac surgery. *Ann Thorac Surg* 2017; 103: 1005e20
24. Richardson L, Dissanayake A, Dunning J. What cardioversion protocol for ventricular fibrillation should be followed for patients who arrest shortly post-cardiac surgery? *Interact Cardiovasc Thorac Surg* 2007; 6: 799e805.
25. Webb ST. Caution in the administration of adrenaline in cardiac arrest following cardiac surgery. *Resuscitation* 2008; 78: 101.