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Research Article

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Managing Cardiac Arrest after Cardiac Surgery: The Impact of a Five Year Evolving Re-Sternotomy Policy and a Review of the Literature

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Abstract

Objectives: This study was conducted to review current practice in the resuscitation of cardiac arrest after cardiac surgery, and to determine the impact of an evolving strategy in a new unit.

Methods: We performed an extensive search of the MEDLINE database and reviewed publications relating to current practice of cardiac arrest after cardiac surgery. We then retrieved the clinical data for 94 patients who suffered a cardiac arrest after cardiac surgery between January 2008 and December 2012. The data was analyzed to determine the survival-to-hospital discharge and the re-sternotomy rates, and the trend in these endpoints over time. The nursing and medical staff of our Center underwent specialized training and simulation in resuscitation of cardiac patients in 2009.

Results: Current guidelines acknowledge the unique circumstances for post cardiac surgery patients. A modified cardiopulmonary resuscitation strategy is recommended. A total of 94 patients had cardiac arrest after cardiac surgery from 2008 to 2012. The mean age was 69.5 ± 10.6 years, and 31 (33%) were female. Emergency re-sternotomy was performed in 52 (55%) and survival to hospital discharge was 50% (n=47). Whereas the rates of re-sternotomy declined from 66.7% in the first 2-year period (2008-2009) to 47.3% (p=0.06) in the later 3 years (2010-2012), the survival-to-hospital discharge improved from 36.3% to 63.8% (p=0.08) in the same period.

Conclusion: Although emergency re-sternotomy is a very important element of resuscitation for cardiac surgery patients, our study shows that with appropriate training of the medical and nursing staff the rate of emergency resuscitative re-sternotomy can be reduced and the survival-to-hospital discharge improved.

Introduction

Although advances in knowledge and improvements in managing cardiac arrest resulting from research, training and implementation of guidelines has led to vast improvements in survival, the outcomes are still generally poor. Cardiac arrest in patients who have undergone cardiac surgery present different management challenges and is associated with a better prospect of successful outcome. In acknowledgement of this fact, the European Resuscitation Council published a specific section on resuscitation of patients with cardiac arrest after cardiac surgery in 2005 [1].

A successful outcome for resuscitation of cardiac arrest following cardiac surgery is highly favored by close monitoring which is common in these patients who are managed in the Intensive Care Unit (ICU) for the first 24 hours after surgery and subsequently on the wards. Cardiac arrest in these settings is frequently witnessed, and this allows early diagnosis of the mechanism and prompt institution of resuscitative intervention. Furthermore, the causes of cardiac arrest post cardiac surgery are more often reversible. Often cardiac arrest is preceded by a period of progressive deterioration, so pre-emptive or at the least preparatory measures can be put in place to facilitate resuscitation [2,3]. Importantly, emergency re-sternotomy performed timely is key to successful resuscitation as it allows correctable causes to be dealt with, effective re-establishment of circulation with internal cardiac massage and use of mechanical supportive devices.

In Europe almost 250,000 patients undergo cardiac surgery annually [4-6]. The incidence of postoperative cardiac arrest in adult cardiac surgery patients is 0.7% - 2.9% [3,5-12].

We, like others, [2,5,7-9,13,14] have previously shown that there is a clear temporal pattern for the risk of post-operative cardio-respiratory arrest with a steady decline in the frequency after the first postoperative day, as depicted in Figure 1. The outcome is usually better when cardiac arrest occurs in the intensive care compared to the surgical ward [2,8,15-18].

The principal causes of cardiac arrest post cardiac surgery may be due to electrophysiological disturbances like arrhythmia or it could also be related to reversible mechanical causes such as graft malfunction, cardiac tamponade, major surgical bleeding or tension pneumothorax. In order to derive maximal benefit in treating such reversible causes, timely emergency re-sternotomy performed is crucial [3,5].

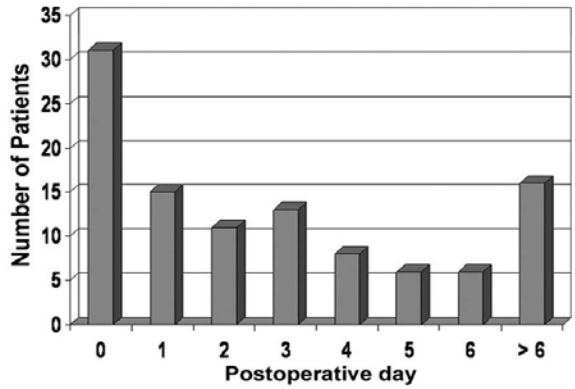


Figure 1: Relationship between the number of patients who experienced cardiorespiratory arrest and the postoperative day of arrest after coronary artery bypass or aortic valve replacement.

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Institution background and practice

Essex Cardiothoracic Centre is a new, modern, tertiary referral centre in the UK performing elective and emergency adult cardiac surgery. The Centre, housed in a four-storey building, has its cardiac intensive care unit immediately adjacent to the operating theatres on the third floor. The postoperative surgical step-down wards are located on the second and fourth floors, neither of which have high dependency facilities. The maximum distance to the operating theatre from ICU is 150 m; 160 m from the fourth floor and 200 m from the second floor (plus one floor lift journey). Out-of-hours cover is provided by resident surgical, anaesthetic and cardiology training grade Doctors, while other on-call staff are available within 30 minutes.

It was realised through simulation, to 'scoop and run' a patient from the ward to cardiac intensive care took a minimum of 9.5 minutes. In reality it was much longer as delays resulting from indecision, geographical location of the patient, difficulties with resources and equipment. We contacted 19 cardiothoracic centres in the UK; 17 performed emergency re-sternotomy on the surgical step-down wards. The 'scoop and run' policy was therefore abandoned. In June 2008 we conducted a one-day course on Cardiac Advanced Life Support (CALS) for senior nursing staff, training grade doctors and, consultant surgeons and anaesthetists. The training was then cascaded and subsequently adopted as part of routine practice. All ward staff have completed the training and are involved in on-going simulation training. There are well rehearsed ward based procedures for performing emergency re-sternotomies which include collecting additional equipment, retrieving flying squad as well as contacting theatre team. Both surgical step-down wards now have 'chest opening' trolley which include a five piece, basic chest opening set (Figure 2).

Study objective

The primary study objective was to review the current practice of cardiopulmonary resuscitation for cardiac arrest following cardiac surgery, and to report the survival-to-hospital discharge for our patients in light of our institution's application of the guidelines and, evolving re-sternotomy policy.

The secondary objective was to examine the trend in survival and re-sternotomy over time.



Figure 2: The layout of the basic emergency resuscitation set kept on the step-down wards.

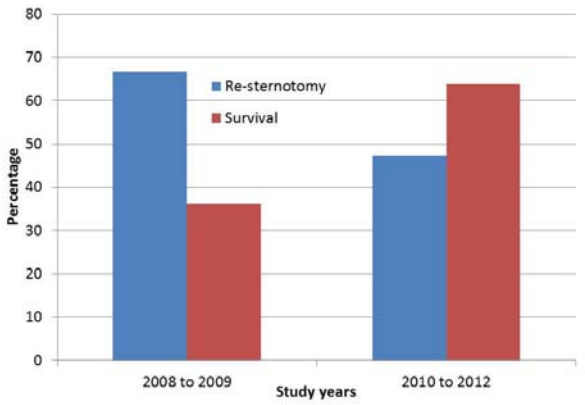


Figure 3: Trends in the survival-to-hospital discharge and emergency re-sternotomy rates over the study period.

Methods

Literature search strategy

We performed an extensive research of MEDLINE database (public domain database) using PubMed (web-based search engine) to identify the relevant papers.

The keywords used were resuscitation, European Resuscitation Council guidelines, cardiac arrest, and cardiac arrest post cardiac surgery. We identified 15 main articles relating to cardiac arrest post-cardiac surgery published in recent years. We further searched the references of selected papers, reviews and editorials. Studies and guidelines that report cardiac arrest and outcomes including survival-to-hospital discharge for in-hospital cardiac arrest were also considered.

Clinical study patients

From 2009, clinical data for all patients undergoing cardiac surgery at our institution are prospectively collected and stored in an electronic cardiothoracic surgery database. The data for patients had surgery prior to 2009 were retrospectively imputed into the database which is managed by dedicated and trained staff. We identified 94 patients who suffered a cardiac arrest following cardiac surgery out of 4,660 (2%), from January 2008 through December 2012 and retrieved the relevant clinical data from the cardiothoracic surgery database. Approval for the study and a waiver for individual patient consent were obtained from the research and ethics committee of our institution.

Statistical analysis

The primary outcome measure was the survival-to-hospital discharge. The secondary outcome was the trend in emergency resuscitative re-sternotomy.

The frequency of categorical variables are reported as counts and percentages, and compared between survivors and non-survivors using Pearson's Chi-square test with Beferroni correction. Continuous variables are reported as mean ± standard deviation and compared between the groups with *t*-test. A two-sided p value of <0.05 was considered significant. Statistical analysis was performed using SPSS version 21.0 statistical software package for windows (SPSS, Inc, Chicago, IL, USA) (Figure 3).

Results

Of the 94 patients who suffered a cardiac arrest post cardiac surgery, 31 (33%) were female. The mean age of the cohort was 69.5 ± 10.6 year. The predominant primary surgical procedures were coronary artery bypass grafting (29.8%), valvular heart surgery (23.4%) and the combined operation (20.2%). Table 1 displays the baseline characteristics of the study cohort. Emergency resuscitative re-sternotomy was performed in 52 (55%) and 47 (50%) survived to hospital discharge. Most of the re-sternotomies (92.3%, n=48) were performed in the first week of surgery. Majority of re-sternotomies were performed in the operating theatre (n=28); 22 in cardiac intensive care unit and 2 on the ward (1 was successfully resuscitated and discharged home). The details of the cardiac arrest are depicted on Table 2. The most common location of cardiac arrest was the cardiac intensive cardiac unit, the most frequent arresting rhythm was ventricular fibrillation, and most patients were scooped to the operating theatre or cardiac intensive care for emergency re-sternotomy. Over 50% of patients who had cardiac arrest in the cardiac intensive care or had ventricular tachyarrhythmia had a successful resuscitation and were discharged home.

There is a trend towards an increase in survival-to-hospital discharge from the first 2 years (2008 and 2009) to the last 3 years (2010 – 2012); 36.3% versus 63.8% (p=0.08) while the re-sternotomy rate dropped from 66.7% to 47.3% (p=0.06) in the same time frame.

Table 3 compares clinical characteristics between survivors and

Table 1: Baseline characteristics of the study population.

Variable	Frequency (n=94)	Percentage (%)
Female	31	33
Mean age in years	69.5 ± 10.6	
Surgical procedure		
Coronary artery bypass grafting	28	29.8
Heart Valve replacement/repair	22	23.4
Coronary artery bypass and heart valve surgery	19	20.2
Coronary artery bypass and Other	4	4.3
Heart valve replacement/repair and other	6	6.4
Other	15	16.0
Left ventricular ejection fraction		
>0.50	34	36.2
0.3 – 0.50	36	38.3
<0.30	13	13.8
Unknown	11	11.7
Previous cardiac surgery	8	8.5
Diabetes	20	21.3
Hypertension	64	68.1
Previous stroke	11	11.7
Chronic obstructive pulmonary disease	17	18.1
Surgical priority		
Elective	55	58.5
Urgent	22	23.4
Emergency	17	18.1
Resternotomy	52	55
Postoperative renal replacement therapy	19	20.2
Postoperative neurological event	8	8.5
Infection	11	11.7
Survival to hospital discharge	47	50

Table 2: Characteristics of cardiac arrest following cardiac surgery.

Variable	Number of patients n=94 (%)	Number surviving to hospital discharge
Location of cardiac arrest		
Cardiac Intensive care unit	68 (72.3)	40
Cardiac ward	26 (27.7)	7
Cardiac arrest rhythm		
Ventricular tachyarrhythmia	42 (44.7)	27
Asystole	10 (10.6)	6
Pulseless electrical activity	12 (12.8)	6
Undertemined	30 (31.9)	8
Emergency resternotomy		
Operating theatre	28 (29.8)	22
Cardiac intensive care	22 (23.4)	
Cardiac Ward	2 (2.1)	

Table 3: Comparison between survivors and non-survivors of cardiac arrest following cardiac surgery.

Variable	Survivors (n=47)	Non-survivors (n-47)	P value
Female	14 (29.8)	17 (36.2)	.51
Mean age in years	67.0 ± 11.0	73.0 ± 9.2	.02
Surgical procedure Coronary artery bypass grafting Heart Valve replacement/repair Coronary artery bypass and heart valve surgery Coronary artery bypass and Other Heart valve replacement/repair and other Other	 14 (31.1) 9 (20.0) 11 (24.4) 2 (4.4) 3 (6.7) 6 (13.3)	 14 (30.4) 13 (28.3) 8 (17.4) 2 (4.3) 3 (6.5) 6 (13.0)	.95
Left ventricular ejection fraction >0.50 0.3 – 0.50 <0.30 Unknown	 18 (38.3) 18 (38.3) 7 (14.9) 4 (8.5)	 16 (34.0) 18 (38.3) 6 (12.8) 7 (14.9)	.80
Diabetes	10 (21.7)	10 (21.7)	.91
Hypertension	34 (75.6)	30 (69.8)	.54
Previous stroke	6 (13.0)	5 (11.4)	.81
Chronic obstructive pulmonary disease	10 (21.7)	7 (15.9)	.48
Surgical priority Elective Urgent Emergency	 33 (71.7) 9 (18.6) 4 (8.7)	 22 (46.8) 13 (29.5) 9 (20.5)	.09
Resternotomy	20 (42.6)	32 (68.1)	.01
Postoperative renal replacement therapy	3 (7.7)	16 (35.6)	.001
Postoperative neurological event	4	4	.46

non-survivors of cardiac arrest. Survivors were significantly younger than non-survivors.

Discussion

This study shows that as our resuscitation strategy, including re-sternotomy has evolved, there has been a steady improvement in the outcome of cardiac arrest following cardiac surgery. The observed survival-to-discharge rate of 50% compares favorably with published results, and demonstrates that adaptation of practice to suit local circumstances, but in line with guidelines, can be a very effective strategy. The training of members of staff, particularly the cardiac intensive care and ward staff, increases the awareness and empowers them to manage both arrest and pre-arrest situations better. This may partly explain why we observed the decline in the rate of re-sternotomy with improvement in the survival of cardiac arrest. The implication is that cardiac arrests, pre-arrests and deteriorating patients are probably managed better hence re-sternotomy is no longer required as frequently as previously and when it is performed, more often leads to a better outcome. Overall, the survival-to-discharge after re-sternotomy is inferior to the group that was managed without re-sternotomy. This suggests that the "scoop and run" practice might have delayed the timing of re-sternotomy because of the layout of our unit and hence its benefit was not realized. A limitation of this study is that the interval between the onset of cardiac arrest and the timing of re-sternotmy could not be accurately determined and hence, has not been reported.

The cardiac arrest following cardiac surgery is sometimes preceded by a period of progressive deterioration in which the patient deviates from the expected postoperative course, potentially providing a "window of opportunity" to act preemptively. Most institutions have now adopted 'track and trigger systems' to identify the acutely deteriorating patient for escalation of treatment.

The rate of 'survival-to-hospital discharge' after cardiac arrest has been considered a potential performance indicator. However concerns have been raised that hospitals that perform well in this outcome measure may not be doing well in preventing cardiac arrests. This theory was tested in a recently published study [19] and the authors found a significant negative correlation between hospital's incidence and case-survival rates for in-hospital cardiac arrest thereby refuting the above assumption. Hospitals that excelled in preventing cardiac arrest also had higher survival rates after cardiac arrest.

Literature review

Some aspects of resuscitation of cardiac arrest following cardiac surgery are significantly different from any other routine cardiac arrest. We have highlighted and discussed the salient and sometime controversial issues.

Managing cardiac arrest: The European Association of Cardiothoracic Surgery guidelines recommend a key team of six people who are all well practiced in their roles [5]. The six key roles described with specific management contributions are: external cardiac massage, airways and ventilation, defibrillation, drugs, team leader, and intensive care coordinator.

Early re-sternotomy is strongly recommended in patients with cardiac arrest if a stable cardiac output is not achieved within 5 minutes of the onset of the cardiac arrest [5,20-25]. Emergency re-sternotomy is required in 20-50% of cardiac arrest after cardiac surgery. In a six year prospective audit of chest reopening at the Papworth Hospital it was found that if the chest was reopened within

10 minutes, 48% of patients survived to hospital discharge compared with only 12% if the reopening took longer [5,8,13].

Re-sternotomy enables internal massage at a rate of 100 beats/ min; with an aim to achieve systolic arterial pressure of at least 60 mm of Hg. Re-sternotomy should be considered until 10 days post-operatively, beyond which it should be risk assessed by the operating surgeon and a decision taken.

Institution of cardiopulmonary bypass is sometimes necessary and a 56% survival in 16 patients with refractory VF despite internal cardiac massage has been reported with this strategy. The incidence of emergency reinstitution of cardiopulmonary bypass after cardiac arrest in cardiac surgery is 0.2% [3,5,9,18,26].

Defibrillation: A significant deviation in the most recent European Resuscitation Council guideline (2010) is to provide three consecutive shocks followed by early sternotomy instead of having 2 minutes of cardiopulmonary resuscitation between each shock [1,3,5]. Data from the American Heart Association registry of cardiopulmonary resuscitation documented that 39% patients survived when defibrillation was performed within 2 minutes and only 22% when it was performed beyond 2 minutes [27].

The Hammersmith Hospital, London, reported a survival-to-hospital discharge of 48% if defibrillation was performed within 2 min, compared to 14% if it was delayed [28].

There are studies showing that the likelihood of restoring a cardiac output declines dramatically from the first to the second shock and declines further from the second to the third and so on [29].

Considering the importance of minimizing the delay to re-sternotomy not more than three shocks should be delivered prior to performing a chest reopening in patient with VF/VT cardiac arrest after cardiac surgery. This is because the chances of successful outcome after each passing attempt to defibrillate decrease dramatically [3,5,29,30].

External-internal cardiac massage: If the rhythm is a VF or pulseless VT the external cardiac massage may be delayed until three shocks have been delivered but a defibrillator needs to be available in less than one minute. If the rhythm is a severe bradycardia or asystole and the epicardial wires are in place immediate institution of epicardial pacing should take place.

If the cardiac output is not restored within one minute the external cardiac massage needs to be started. If the rhythm is pulseless electrical activity (PEA) and the patient is paced, the pacing needs to be turned off to exclude underlying VF. Basic life support with external massage needs to be started immediately [3,5].

Animal and human studies have quite successfully demonstrated that open cardiac message is superior to external cardiac compression with regards to generating cardiac output. One such study performed on humans showed that cardiac index improved from 0.6 l/ min/ m^2 to 1.3 l/min/m^2 and the circulation time decreases from 89 seconds to 44 seconds with open cardiac message [31]. Patients who had undergone cardiac surgery with a partial or non-sternotomy incision pose a major difficulty for emergency chest opening.

External cardiac massage may be associated with potentially fatal complication such as disruption of vascular sutures and right ventricular rupture [5,32,33].

The use of automated chest compression devices in patients who have had cardiac surgery is not recommended.

Adrenaline: Adrenaline have been recommended in cardiac arrest situations to convert a non- shockable rhythm like asystole and PEA to a shockable rhythm and to increase the systemic vascular resistance to maintain more perfusion in the central circulation for the cardiac message to be effective [34].

During cardiac arrest after cardiac surgery the chance of restoring a cardiac output after a defibrillation or after an emergency re-sternotomy is very high.

The use of resuscitation doses of adrenaline in this situation may result in dangerous hypertension and can cause catastrophic destruction of surgical anastomoses and decreased myocardial perfusion [5,35].

The guidelines recommended that the administration of adrenaline should be delayed until reversible causes of arrest are excluded. Most of the time an early re-sternotomy is the effective method to treat the cause of the cardiac arrest. It is safer to use adrenaline cautiously in smaller doses such as 100-300 mcg bolus intravenously and titrate the dose to response [3,5].

Cardiac arrest in the non-intensive care unit setting: Emergency re-sternotomy outside the intensive care is associated with poor survival [18]. The guidelines recommended chest reopening as soon as possible. Early re-opening (within 10 minutes) leads to higher survival to hospital discharge [3,5]. In the cardiac intensive care, emergency re-sternotomy is recommended within 5 min of the onset of cardiac arrest: after three attempts at defibrillation for VF/VT or immediately if there is no output with external compressions in PEA or asystole [5].

Outside the cardiac intensive care unit, the current guidelines do not make any recommendation.

There are different options if the cardiac arrest is in the surgical ward:

- Open the chest immediately in the ward, decompression of the heart if the cause of the cardiac arrest is tamponade and start the internal cardiac massage. Once the chest is opened, the patient is transferred in operating room or intensive care unit with ongoing internal cardiac massage if necessary.

- 'Scoop and run' to operating room or intensive care unit for reopening the chest with on-going external cardiac massage.

"Scoop and run" policy: In 2002, three UK centers published that none of patients who had their chest opened on the ward survived to hospital discharge [7,8,18].

Papworth Hospital [18] published the results of six–year prospective audit of 'scoop and run' for chest re-opening in 2012; only 'witnessed' or 'very recent' arrest was considered appropriate for scoop and run. The average time for re-sternotomy was over 20 minutes and

the time of transfer to the operating room was 2-3 minutes. Ninety seven patients had cardiac arrest outside the intensive care unit after cardiac surgery. 'Scoop and run' to the operating theatre was done for 21.6 % of patients and 23.8% survived to hospital discharge. There was no survival for 'scoop and run' undertaken during the night.

Whereas 'scoop and run' has advantages like early institution of Cardio-pulmonary bypass or mechanical support such as intra-aortic balloon pump and extra corporeal membrane oxygenation, it denies the patient the benefit of achieving early decompression of the heart within 5 minutes of onset of the cardiac arrest and immediate internal cardiac massage to allow return of spontaneous circulation.

Since there is no consensus but the timing of the chest re-opening is crucial, individual units should consider their local circumstances and adapt the practice as it best suits them. Our experience supports this approach.

Therapeutic hypothermia: Unlike out-of-hospital cardiac arrest where it is an accepted practice to cool patients to 32 -33 °C for 12-24 hours in order to improve the neurological outcome [36], for cardiac arrest post cardiac surgery therapeutic hypothermia is not common.

Conclusion

The survival-to-discharge of patients who suffer a cardiac arrest following cardiac surgery continues to improve. Efficacious resuscitation must take into cognizance the nuances peculiar to this patient cohort. The cardinal role of emergency re-sternotomy has been stressed, but our study shows that with appropriate training of the medical and nursing staff, improvement in survival-to-hospital discharge can be maintained with decline in the rates of emergency resuscitative re-sternotomy.

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