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Six-year prospective audit of chest reopening after cardiac arrest☆

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Abstract

Objective: To identify which patients benefit from chest reopening after cardiac arrest. **Setting**: Cardio-thoracic hospital undertaking full range of adult cardio-thoracic surgery. **Methods**: In-hospital arrests were prospectively audited over a 6-year period. Information was collected for every patient whose chest was reopened following cardiac arrest: location of arrest, type of arrest, specialty, time since surgery, time to chest reopening, location of chest opening, surgical findings on reopening, time to cardiopulmonary bypass (if used) and patient outcomes. *Exclusions*: Arrests in theatre and chest openings for reasons other than cardiac arrest. **Results**: There were 818 confirmed in-hospital arrests following 'cardiac arrest calls'. Chest reopening was undertaken in 79 surgical patients. Overall survival to discharge was 20/79 (25%). Favourable determinants of outcome were: arrest on intensive care unit (ICU), arrest within 24 h of surgery and reopening within 10 min of arrest. Nineteen of 58 (33%) chest openings following arrests on the ICU survived to discharge compared to one of 21 (5%) patients whose initial arrest was outside the ICU ($P = 0.017$). One of nine ward arrests scooped to ICU for chest reopening survived whereas all 12 patients reopened on the ward died. Fifteen of 40 patients (38%) reopened within 24 h surgery survived compared to five of 39 patients where reopening was undertaken more than 24 h after surgery ($P = 0.02$). Fourteen of 29 (48%) patients opened within 10 min of arrest survived to discharge compared to six of 50 (12%) patients where time to reopening was more than 10 min ($P = <0.001$). Seven of 22 patients (32%) patients where emergency bypass was utilised survived to discharge. **Conclusion**: This study strongly confirms the benefit of chest reopening after cardiac arrest in the cardiac surgical ICU. Patients who arrest within 24 h of surgery and in whom reopening is instituted within 10 min are particularly likely to benefit. The value of chest reopening in arrests outside the ICU remains unresolved. All patients reopened on the ward died, suggesting that this practice should be discontinued. Early 'scoop and run' resulted in one solitary survivor though it should probably be restricted to patients who arrest within 72 h of surgery as surgically remediable problems are unlikely after this time. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Cardiac surgery; Cardiopulmonary resuscitation (CPR); Open-chest CPR; Resuscitation; Cardiopulmonary bypass

1. Introduction

Open-chest cardiopulmonary resuscitation is physiologically superior to closed-chest cardiac massage producing higher coronary and cerebral perfusions [1–3]. Chest reopening is potentially lifesaving in the treatment of the early postoperative complications of open heart surgery such as tamponade or bleeding [4]. The procedure is often performed in the intensive care unit (ICU) rather than in the operating room [5]. The success of chest opening in ICU has led to a culture among cardiac surgeons that all cardiac surgical patients should have their chests reopened following cardiac arrest if initial resuscitation is unsuccessful. The efficacy of chest opening in post-surgical patients who arrest more than 48–72 h post surgery in the ward setting is less well established.

The International Liaison Committee on Resuscitation (ILCOR) Guidelines 2000 called for more outcome studies to assess the use of open chest cardiopulmonary resuscitation following cardiac arrest [6]. There is also interest in the development of devices to permit direct massage of the heart for use outside cardiac surgical units [7].

We prospectively studied our experience of emergency chest opening following a cardiac arrest call in a large cardio-thoracic hospital over a 6 year period. Patients most likely to benefit from chest opening are identified and optimum location and timing of chest reopening are discussed.

☆ Interim findings were presented to the European Resuscitation Council, June 2000, Antwerp.

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2. Methods

Papworth Hospital is a specialist Cardiothoracic Hospital undertaking a full range of adult cardiothoracic surgery including transplantation.

All arrests where a call was put out through the hospital telephone switchboard were prospectively audited over a 6-year period (01/04/1995–31/03/2001). Audit forms are completed by the cardiac arrest team after every arrest call.

The audit form is a single side A4 'tick-box' form which asked the arrest team ten specific questions and left space for further comments. Question 10 specifically referred to chest opening or reopening at the scene of the arrest.

Switchboard recorded the date, location and time of all arrest calls. One hour after each arrest call, switchboard rang back the clinical area to obtain the following additional information:

1. patient's name;
2. Doctor and Nurse in charge of arrest;
3. whether an audit form had been completed.

Switchboard logged all this information on a spreadsheet which was e-mailed weekly to the Resuscitation Training Officer (RTO), cardiopulmonary resuscitation (CPR) consultant and Clinical Audit department.

Forms were returned to the RTO in the first instance for initial follow up. They were then forwarded to the Consultant Intensivist responsible for CPR and the Clinical Audit Department. The CPR Consultant reviewed the clinical notes of all patients where the audit form indicated that chest opening or reopening was part of the arrest management.

The following information was obtained for all arrest calls: location, date and time of arrest. Only confirmed cardiac or respiratory arrests were included. False alarms and requests for urgent medical assistance were excluded. Time since surgery was the time between arrival on the ICU and time of arrest call. For those patients who underwent chest reopening, the time and stage in the arrest process and location of chest reopening if different to the scene of arrest were recorded. For the subgroup of patients in whom cardiopulmonary bypass was used during resuscitation the time from arrest call to time on bypass was obtained from the perfusion records. Our outcome measure was survival to discharge from hospital.

Fishers Exact Test was used for the comparison of frequencies of outcomes between the following sub-groups: reopening of ICU versus ward arrests, reopening more than versus less than 24 h after surgery, and reopening more than versus less than 10 min after arrest call.

3. Results

Number of 'arrest calls': Papworth Hospital undertook 9600 open heart surgery cases and 1500 major thoracic procedures between 1995 and 2001. There were 818 confirmed in-hospital arrests during this 6-year audit period. Of these 419 were in cardiac surgical patients, 84 in cardiothoracic transplant patients and 44 in thoracic surgical patients. These 547 audited surgical arrests were from a population of almost 12 000 major surgical cases. The remaining 271 arrest calls were in cardiology and thoracic medical patients.

3.1. Compliance

Compliance for return of audit forms was 84%. The RTO followed up the locations putting out the remaining 16% of calls and established that many of the calls where no form was returned were either requests for 'urgent medical assistance' or 'false alarms'. She also confirmed that all chest openings in the ward were reported and followed up. At the end of this, data collection was 100% complete.

Chest openings: There were 80 chest openings following arrest calls in 80 patients. Seventy-nine of the 80 were reopening of sternotomies following cardiac surgery. One Cardiology patient underwent mini thoracotomy following a complication in the Catheter Laboratory and was excluded from further analysis. Characteristics of the 79 surgical patients are summarised in Table 1.

Survival rates were significantly higher for those patients whose chest reopening was within 24 h of surgery compared to those patients whose chest reopening was more than 24 h after surgery (39 versus 13%, $P = 0.02$). Similarly, patients who had their chests opened within 10 min of arrest had significantly higher survival rates compared to those patients whose chests were reopened more than 10 min after arrest (48 versus 12%, $P < 0.001$). Thirty-nine of 40 (98%) patients who were reopened within 24 h of surgery and 27 of 29 (93%) patients reopened within 10 min were on the ICU at the time of arrest.

Surgical findings at reopening are summarised in Table 2.

Surgically remediable problems such as bleeding, tamponade and graft problems were present in 15 of the 20 (75%) survivors compared to 15 of 59 (25%) of those patients who died. In almost half of the patients who died (27 of 59), the main finding on reopening was very poor cardiac function. All 27 of these patients were requiring inotropic support ± intra aortic balloon pump prior to cardiac arrest. Perioperative myocardial infarction was subsequently diagnosed at post-mortem in 13 of these 27 patients.

It was not possible to give a precise cause of arrest for all 59 deceased patients at the time of reopening. The following additional diagnoses were made at post-mortem: bowel infarction (three patients), pulmonary embolus (two patients), and pancreatitis (one patient).

Table 3 provides additional information on the 20 survivors including type of operation, signs heralding the cardiac arrest, findings on reopening and the procedures performed thereafter. Predictive factors were present in 13 of the 20 survivors.

Table 1
Characteristics of 79 chest reopenings

Chest opening characteristics		Survival to discharge
Location of arrest call	Patients	Survivors (%)
Critical care	58	19 (33)
Ward	21	1 (5)
Location of chest opening		
Critical care/theatre	58	19 (33)
Ward	12	0
Scooped from ward	9	1 (11)
Type of arrest		
VF/VT[a]	22	4 (18)
EMD[b]	36	13 (36)
Asystole	12	2 (17)
Other	9	1 (11)
Time since surgery to chest opening (h)		
<24	40	15 (39)
24–72	16	4 (25)
>72	23	1 (4)
Time from arrest to chest opening (min)		
<10	29	14 (48)
10–20	21	3 (14)
>20	29	3 (10)
Bypass utilised during resuscitation		
No	57	13 (23)
Yes	22	7 (32)

[a] VF/VT, ventricular fibrillation or pulseless ventricular tachycardia.
[b] EMD, electro-mechanical dissociation.

4. Discussion

One quarter of patients whose chest was reopened following cardiac arrest throughout the hospital survived to discharge during the 6-year audit period. Many more patients survived the initial resuscitation but died in hospital. The overall survival-to-discharge figure hides the fact that there were major differences between the ICU and Ward subgroups.

This study reconfirms the value of chest reopening following cardiac arrest in the cardiac surgical ICU where one third of patients survived to discharge [8]. A major determinant of good outcome was the finding of a surgically treatable problem on reopening [9]. Given the pathology encountered on reopening, it is clear that the vast majority of our survivors would have succumbed without surgical intervention. Patients most likely to benefit were those within 24 h surgery and those in whom chest opening was achieved within 10 min of the time of arrest [10,11]. A total of 50% of patients opened within 24 h of surgery and within 10 min from time of arrest survived to discharge, compared to 3% of patients where chest reopening took place more than 10 min after arrest and more than 24 h after surgery.

Outcome in patients who underwent chest reopening following arrests on the wards was much poorer with only one of 21 patients surviving to discharge. Analysis of the role of chest reopening following ward arrests is complicated by the fact that some patients were reopened at the scene of arrest whereas others were scooped to Theatre or ICU for reopening. None of the twelve patients who were reopened on the wards survived to discharge, which has led many to question the value of this intervention outside the ICU. Chest reopening can never be undertaken as quickly in the ward setting and the procedure is often fraught with problems. Inadequate lighting, surgical instruments and suction result in sub-optimal operating conditions. Lack of venous access and minimal monitoring ensure that the anaesthetist is also hampered. Further, the chances of encountering a surgically treatable cause for cardiac arrest become less likely as the time out from cardiac surgery increases. Consequently, the almost invariably poor outcome of chest opening in the ward environment is often perceived as 'an exercise in futility'. Potential psychological damage may also be inflicted on other patients, visitors and indeed some members of the ward staff [12].

One alternative strategy to opening at the scene of the ward arrest is to scoop the patient to ICU or Theatre for reopening. Our solitary survivor who was one of nine patients scooped from the wards merits further discussion; spontaneous circulation was restored using closed-chest massage, atropine and adrenaline prior to transfer to the ICU. Chest opening was performed after the patient re-arrested on arrival to the ICU. Given the fact that this patient arrested twice – albeit within a 30-min period – it could be argued that this patient could be reclassified into the ICU reopening group. Such reclassification would have further increased the difference between the ICU and Ward outcomes and resulted in 20 consecutive deaths in ward arrests irrespective of whether 'scoop & run' or 'stay & stabilise' groups was utilised. Given such appalling outcomes, the question has to be asked (and indeed has been in our institution) whether a third option should be considered when surgical patients arrest more than 48–72

Table 2
Surgical findings on reopening for survivors and deaths

Diagnosis	Survivors		Deaths	
	n	%	*n*	%
Bleeding/tamponade	9	45	7	12
Graft occlusion/avulsion	6	30	8	14
Arrhythmias	3	15	6	10
Poor cardiac function	2	10	27	46
Aortic dissection	–	–	2	3
Pulmonary embolus	–	–	2	3
Gut pathology	–	–	4	7
Others/unexplained	–	–	3	5
Total	20		59	

Table 3
Surgical findings, operative procedures and predictive factors of survivors[a]

Operation	Findings on reopening	Procedure	Graft Problem	Predictive factors
CABG	Bleeding	Liga clip to side branch of vein graft	Y	Hypertension bleeding
CABG	Tamponade	Repair of avulsed side branch of vein graft	Y	Hypotension
CABG	Graft occlusion (LIMA)	Emergency bypass vein graft to LAD	Y	Bleeding, hypotension
CABG	Graft occlusion, recent anterior MI	Pacing wires, IABP	Y	Spiral dissection LAD in Catheter Lab prior to CABG
CABG	Intractable VF, grafts patent	Emergency bypass, IABP, pacing	N	None
CABG	Graft avulsion (LIMA)	LIMA reanastomosed to 1st diagonal, new vein graft to LAD, IABP	Y	None
CABG	Graft occlusion	Grafts to PDA and 2nd diagonal	Y	Chest pain, hypotension, bradycardia
CABG	Graft occlusion (LIMA)	Vein graft to LAD, IABP	Y	None
Redo CABG	Asystolic distended heart	Massage, atrial wires	N	Poor LV function, acidosis, hypotension,
Redo CABG	Graft occlusion	Redo RCA vein graft	Y	3 VF arrests
CABG and valve surgery	Bleeding	Repair aortic suture line	N	Bleeding, hypotension
CABG and valve surgery	Bleeding	Repair top end vein graft to RCA, IABP	Y	Hypotension, acidosis, oliguria
CABG and valve surgery	Bleeding	Repair LIMA bottom end	Y	Bleeding, hypotension
CABG and plication of LV aneurysm	Bleeding	Repair of plication site	N	None
Aortic root replacement and CABG	Poor LV function	Improved with observation	N	Hypotension, arrhythmias
Aortic Interposition graft for type A dissection	No bleeding	Internal DC shock	N/A	Runs of VT, acidosis
Aortic surgery	Tamponade, bleeding	Repair of distal anastosmosis to proximal descending arch	N/A	None
AVR and ascending aorta interposition graft	Intractable VF	3 grafts undertaken	N/A	None
Heart transplant redo sternotomy	Large clot behind aortic root	Removal of clot	N/A	Renal failure, pulmonary oedema
Lung transplant	Bleeding	Repair of anastosmosis from LA to right pulmonary vein	N/A	None

[a] CABG, coronary artery bypass grafting; LIMA, left internal mammary artery; LAD, left anterior descending; IABP, intra-aortic balloon pump; PDA, posterior descending artery; RCA, right coronary artery.

h post surgery in the ward setting and conventional advanced life support (ALS) with closed-chest massage fails to restore spontaneous circulation. Should the team then withdraw resuscitation and accept that these patients are not going to survive?

The compliance with returning audit forms was 84%. Although the majority of the remaining 16% non-audited arrest calls were requests for urgent medical assistance or 'false alarms', there will have been some confirmed arrests among the 166 calls for which no audit form was returned. Secondly, many resuscitation interventions were undertaken in ICU without putting out a call if appropriate medical staff were readily available. Patients with impending arrest such as those reopened for bleeding on the ICU were specifically excluded from this study. More than ten patients a year are therefore reopened on our ICU. Our 58 patients represent those reopenings following confirmed in-hospital arrests for which a call was put out through switchboard over a 6-year period.

In contrast, cardiac arrest calls are put out after all arrests in ward areas irrespective of who is present at the time of arrest. Given that the RTO followed up all cardiac arrest calls we are confident that our data on chest openings following ward arrests is complete.

Although the decision to utilise bypass was uncontrolled & non-randomised, the impact of cardiopulmonary bypass (CPB) raises some interesting questions.

1. How many of the patients put onto CPB who subsequently survived would have survived without this intervention? The majority would not. Given that patients who were put onto bypass were those that failed to respond to simple reopening, it can be assumed that the population of patients who survived following CPB were sicker than those whose hearts were not given the chance to recover following a period of CPB.
2. Should CPB have been used in more arrests? Similar overall survival rates in the CPB and non-CPB groups despite the survivors in the former group being sicker could be interpreted in two ways. It is possible that the overall number of survivors could have been increased if CPB had been utilised in more arrests. However, it is

more likely the institution or reinstitution of bypass would have been futile in the vast majority of these cases.

Patients with bleeding, tamponade and graft problems accounted for 15 of the 20 (75%) survivors. A major determinant of survival was the finding of a surgically remediable lesion. Most of the 16 patients who required further surgical procedures after chest reopening would certainly have died without these further interventions. Three patients improved with simple interventions of pacing, internal cardioversion and insertion of an intra-aortic balloon. Only one survivor responded to observation and pharmacological support after chest opening.

Twenty-seven of the 29 patients where poor cardiac function was the sole finding on reopening died. Given that these patients were all requiring inotropic support ± intra aortic balloon pump prior to cardiac arrest and that typically reopening was undertaken as a last resort, these results are not surprising. Post mortem attributed half of these deaths to perioperative myocardial infarction.

5. Conclusion

How does this study help the cardiac arrest team to practice evidence-based medicine when faced with a cardiac surgical patient who fails to respond to conventional resuscitation? Reopening is of proven benefit in the ICU. Patients who arrest within 24 h of surgery and those reopened early are particularly likely to benefit. Further, our results support the utilisation of bypass in this setting.

In contrast, the optimum management of ward patients who fail to get return of spontaneous circulation with initial closed chest cardiac massage and Advanced Life Support management remains unresolved. The team have three choices:

1. reopen the chest on the ward;
2. 'scoop & run' to theatre for reopening;
3. abandon resuscitation.

The team must recognise that the chances of a neurologically intact survivor are small whichever of the first two approaches is followed particularly if there is any delay instituting the procedure. The decision must take into account the patient's condition prior to the call. If the history suggests the possibility of a surgically treatable problem, we encourage 'scoop and run' maintaining good quality closed chest cardiac massage and stressing that time is of the essence. However for the majority of patients in this scenario, the most sensible management decision is to accept that the patient is not going to survive and withdraw active resuscitation. We endorse ILCOR's statement that chest reopening should not be used as a last effort at the end of a lengthy resuscitation sequence.

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