doi:10.1510/icvts.2008.182980

INTERACTIVE CARDIOVASCULAR AND THORACIC SURGERY

Interactive CardioVascular and Thoracic Surgery 7 (2008) 878–887

www.icvts.org

Best evidence topic - Cardiac general

If a patient arrests after cardiac surgery is it acceptable to delay cardiopulmonary resuscitation until you have attempted either defibrillation or pacing?

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Received 15 May 2008; accepted 19 May 2008

Summary

A best evidence topic in cardiac surgery was written according to a structured protocol. The question addressed was whether it is acceptable to delay cardiopulmonary resuscitation if a patient arrests after cardiac surgery in order to attempt defibrillation or pacing, prior to performing external cardiac massage. Altogether 550 papers were found in Medline and 990 in Embase using the reported search, of which 22 represented the best evidence to answer the clinical question. The authors, journal, date and country of publication, patient group studied, study type, relevant outcomes and results of these papers are tabulated. We conclude that current resuscitation guidelines state that there is no evidence to support or refute external cardiac massage prior to defibrillation in-hospital, although a benefit has been shown for patients out-of-hospital if the response time is over 4–5 min. In addition, four large studies including the AHA National Registry of Cardiopulmonary Resuscitation, who reported the findings of 6789 in-hospital arrests, emphasise the importance of early defibrillation within 1–2 min. More concerning in patients post-cardiac surgery are four case reports after cardiothoracic surgery and five in the non-surgical literature where significant harm has been caused from external cardiac massage, although equally we found cohort studies of cardiac surgical patients who had external cardiac massage followed by re-sternotomy and found no trauma due to external cardiac massage. We recommend that guidelines for immediate external massage should be adhered to currently as the evidence that these guidelines may do harm is not yet strong enough to recommend a change in practice. However, we acknowledge that there are no in-hospital data to support very short periods of external massage prior to defibrillation and there have been examples of damage to the myocardium due to external massage. This should be borne in mind when external massage is being performed on a patient after cardiac surgery.

Keywords: Cardiopulmonary resuscitation; Ventricular fibrillation; Electrical countershock; Cardiac surgical procedures

1. Introduction

A best evidence topic was constructed according to a structured protocol. This is fully described in the ICVTS [1]. The quality of each study was assessed using the International Liaison Committee on Resuscitation 2005 protocol [2].

2. Three-part question

In [patients after cardiac surgery who suffer an arrest] is [Immediate cardiopulmonary resuscitation (CPR)] vs. [Immediate defibrillation or pacing] the most effective strategy to optimise [survival to discharge].

3. Clinical scenario

You have just performed CABGx2 on a 67-year-old gentleman with triple-vessel disease. His obtuse marginal artery was too small to graft. Unfortunately, 2 h postoperatively he suddenly goes into ventricular fibrillation. The staff perform external cardiac massage for 30 s until the anaesthetist gives a single biphasic 150J DC shock which converts him back into sinus rhythm and his blood pressure quickly recovers. With amiodarone loading he remains stable and is discharged from the ICU two days later, however, on day 4 you have to take him back to theatre for sternal rewiring. You feel the CPR should have been avoided but the nurses tell you that immediate CPR is a key part of current guidelines.

4. Search strategy

Medline 1950 and Embase 1980 to April 2008 using OVID-SP Interface.

[ventricular fibrillation.mp OR exp Ventricular Fibrillation/] AND [exp Electric Countershock/OR Defibrillation.mp OR exp Defibrillators/OR Defibrillators.mp] AND [exp Cardiopulmonary Resuscitation/OR cardiopulmonary resuscita-

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tion.mp OR CPR.mp OR Cardiac Massage.mp]LIMIT to Human studies.

5. Search outcome

Five hundred and fifty papers were found in Medline and 990 in Embase using the reported search. From these 22 papers were identified. These are presented in Table 1.

6. Results

There are two main issues to consider in this topic. Firstly, whether a period of CPR will benefit the patient prior to defibrillation. The second issue is whether a period of external massage on the sternotomy could cause excessive harm.

In 2005, the International Liaison Committee on Resuscitation (ILCOR) task force [4] recommended that for out-of-hospital arrests where the response time is more than 4–5 min, a 1.5–3 min period of external cardiac massage may be of benefit. They also state that there is no evidence to support or refute the use of CPR before defibrillation for in-hospital cardiac arrest. This is based on the worksheet by Gazmuri et al. [3]. This reviewed 14 papers, including 2 randomized trials, 2 cohort studies, and 10 experimental studies in coming to its conclusions. The 10 experimental studies showed that attempting defibrillation upon initiation of resuscitation is more efficacious than CPR first if the duration of untreated ventricular fibrillation is 5 min or less.

Of the 2 randomized studies, Wik et al. [5] reported the results of a study in 200 patients who suffered an out-of-hospital VF arrest randomized to immediate defibrillation then CPR or 3 min of CPR then defibrillation. There was no difference between groups if the response time was <5 min. However, in the remaining patients, the return of spontaneous circulation was 58% in the CPR group compared to 38% in the defibrillation group.

In the second RCT by Jacobs et al. [6], 256 patients who suffered a VF arrest were randomized to immediate defibrillation, or 90 s of CPR, followed by defibrillation. The mean response time was 9 min but no differences in either group were shown in resuscitation or survival.

Of the cohort studies, Cobb et al. [7] in Seattle looked at the implementation of AEDs for non-paramedic Emergency Medical Teams in over 1000 arrests. In the first period of the study, there was no improvement in survival, which led to a change in practice with the recommendation of 90 s of CPR before defibrillation resulting in an increase in survival to discharge of 24–30%.

Stotz et al. [8] retrospectively examined the implementation of AEDs in Basel. They found that conversely the survival to discharge dropped from 24–14% after implementation of early defibrillation instead of CPR.

Considering studies of in-hospital arrests, the largest was by the AHA national registry of cardiopulmonary resuscitation [9] in 2008 who reported data on 6789 patients who suffered an in-hospital VF arrest across 369 hospitals. Of note, 61% of arrests were in intensive care units and 10% were in patients after cardiac surgery. The best survival was in patients defibrillated in under 1–2 min (39%). There was a significant reduction in survival if defibrillation was over 2 min (22%) and prognosis worsened the longer defibrillation was delayed.

Spearpoint et al. [10] reported that in 2 years of VF arrests in 124 patients at the Hammersmith hospital, survival to discharge was 48% with defibrillation in <2 min compared to 14% if defibrillation was delayed. Of note 15 patients had defibrillation with no CPR and 80% survived to discharge. Fredriksson [11, 12] reported that in 910 consecutive arrests, the survival to hospital discharge was 34%. This was thought to be in part due to fast defibrillation times (median 2 min). Hajbaghery et al. [13] reported 206 patients who arrested in an Iranian hospital. Survival to discharge was 33% if defibrillation was under 4 min, but only 5% if over this. Zafari et al. [14] reported 569 in-hospital arrests. Of defibrillated patients only 2.2% survived, but after initiation of an early defibrillation programme this increased to 16%. Skrifars et al. [15] analysed risk factors for survival at 12 months among 441 patients who suffered an in-house arrest. Although arrests in a cardiac surgical unit had a better outcome, delay to defibrillation did not come out as a predictor. Of note, apart from 15 patients, none of these in-hospital studies contained patients who had CPR deferred until after defibrillation.

Considering possible harm from external cardiac massage, the most concerning report was from Bohrer and Böttiger [16]. They reported 3 patients who after cardiac surgery suffered a VF-arrest. They all had brief periods of external CPR and died from massive haemorrhage resulting from mechanically induced rupture of vascular sutures. They specifically describe a patient who had only 5 compressions before 1500 ml of blood suddenly came down the drains in 30 s. In addition, Kempen and Allgood [20] reported a right ventricular tear secondary to external CPR in a patient who arrested shortly after a right pneumonectomy. We also identified 5 case reports of cardiac damage due to external cardiac massage in the non-surgical literature [17–19, 21, 22].

Several cohort studies report the results of cardiac arrest after cardiac surgery but none mention significant complications due to the external CPR. El-Banayosy and colleagues [24] reported 113 patients who underwent at least 20–30 min of external CPR, with a survival of 70% without any complications due to external CPR. Raman reported 39 patients who suffered a cardiac arrest after cardiac surgery. Twenty-four had emergency resternotomy and the authors specifically stated that 'no significant damage to the myocardium was considered to have occurred as a result of direct cardiac compression'.

We found no studies reporting cohorts of patients resuscitated by external pacing or temporary wire pacing. Thus we considered this intervention to be equivalent to defibrillation in patients with asystole or bradycardic pulseless electrical activity in arrests after cardiac surgery as there may be a short delay in obtaining the required specialist equipment during which CPR would normally be considered.

7. Clinical bottom line

We recommend that guidelines for immediate external massage should be adhered to currently as the evidence

Table 1
Best evidence papers

Author, date and Study type	Patient group	Outcomes	Key results	Comments
Gazmuri et al., (2005), Circulation, USA, [3] Systematic review of RCT, cohort studies and experimental studies (level 3 excellent)	ILCOR worksheet titled: In adult victims of ventricular fibrillation with long response times, a period of CPR before attempting defibrillation may improve ROSC and survival to hospital discharge 14 papers selected for inclusion after systematic review up to December 2003	Level of evidence Recommendation	Class IIb Immediate defibrillation is the treatment of choice for ventricular fibrillation/ventricular tachycardia cardiac arrest where the duration of the ventricular fibrillation/ventricular tachycardia is likely to be shorter than 5 min In adult out-of-hospital cardiac arrest victims of ventricular fibrillation with long response time intervals, a period of CPR before attempting defibrillation may improve ROSC and survival to hospital discharge Animal research has shown that attempting defibrillation upon initiation of resuscitation is more efficacious than CPR first if the duration of untreated ventricular fibrillation is 5 min or less. Human studies have reported high survival rates if defibrillation is administered soon after collapse, generally within 3–5 min	
ILCOR Consensus on Science, Resuscitation, Worldwide, [4] Review of RCT, cohort studies and experimental studies (level 3 excellent)	International Liaison Committee on Resuscitation Task Force Recommendation	Consensus on science Treatment recommendation	In a before and after study and an RCT 1.5–3 min of CPR by paramedics before defibrillation improved return of spontaneous circulation and survival rates for adults with out-of-hospital VF or VT when the response interval was 4–5 min. Animal studies of VF lasting >5 min, CPR before defibrillation improved haemodynamics and survival rates A 1.5–3 min period of CPR before attempting defibrillation may be considered in adults with out-of-hospital VF or pulseless VT and EMS response intervals 4–5 min. There is no evidence to support or refute the use of CPR before defibrillation for in-hospital cardiac arrest	
Wik et al., (2003), J Am Med Assoc, Norway, [5] Randomized controlled trial (level 2, good)	200 patients with out-of-hospital cardiac arrest with ventricular fibrillation and a response time over 5 min Oslo, 1999–2001 Randomized by sealed envelope: 1. Standard care: (96 patients) Immediate defibrillation, then CPR and defibrillation every 1 min 2. CPR first: (104 patients) 3 min of basic CPR prior to defibrillation, then further shocks every 3 min	Survival to discharge Survival to discharge in patients with response time >5 min Return of spontaneous circulation (ROSC) ROSC in patients with response time >5 min	Standard group 14/96 (15%) CPR first 23/104 (22%) $P=0.17$ Standard group 2/41 (4%) CPR Group 14/40 (22%) $P=0.06$ Standard group 44/96 (46%) CPR first 58/104 (56%) $P=0.2$ Standard group 21/41 (38%) CPR first 37/40 (58%) $P=0.04$	Final enrolment was half of that intended 60% of patients received bystander CPR
Jacobs et al., (2005), Emerg Med Australas, Australia, [6] Randomized controlled trial (level 2, good)	256 patients with a witnessed out-of-hospital VF arrest June 2000–June 2002 On arrival paramedics commenced resuscitation. On identification of VF Randomized on call to arrest by ambulance control to:	Return of spontaneous circulation Survival to hospital discharge	CPR first 11/119 (9.2%) Defibrillation first 11/137 (8.0%) CI 0.42–2.8 CPR first 5/119 (4.2%) 7/137 (5.1%) CI 0.25–2.64	In this study the overall resuscitation and survival rates were substantially lower that those reported previously in similar clinical settings and lower than their own historical experience. It is worth noting that vasopressor agents were not given. Moreover, endotracheal intubation was progressively introduced starting 10 months into the study

(Continued on next page)

Table 1 *(Continued)*

Author, date and Study type	Patient group	Outcomes	Key results	Comments
	CPR first 90 s of CPR with 18 cycles of 5:1 compressions. Or immediate defibrillation	1-year survival	CPR first 5/119 (4.2%) 7/137 (5.1%) CI 0.25−2.62	Mean response time was 9 min
Cobb et al., (1999), J Am Med Assoc, USA, [7] Comparative cohort study (level 3, good)	639 patients treated for out-of-hospital VF arrest, using emergency medical technician teams with automated external defibrillators using the protocol of immediate defibrillation (1990−1993) 478 patients then treated by the same teams but with 90 s of CPR prior to defibrillation. 1994−1996	Return of spontaneous circulation and survival to hospital	Defibrillation first 340/639 (53%) CPR first 281/478 (59%) $P=0.06$	The study was prompted by a lack of improvement in survival on the initiation of AEDs for emergency medical teams, thus other training factors may also have played a part
		Survival to hospital discharge	Defibrillation first 155/639 (24%) CPR first 142/478 (30%) $P=0.04$	All significant results were generated by the subgroup where response time was more than 4 min
		Survival to discharge in patients with response time >4 min	Defibrillation first 56/321 (17%) CPR first 60/220 (27%) $P=0.01$	
		Intact neurological survival	Defibrillation first 106/639 (17%) CPR first 109/478 (23%) $P=0.01$	
Stotz et al., (2003), Resuscitation, Switzerland, [8] Retrospective cohort study (level 4, good)	Retrospective review of 168 patients who had suffered a VF arrest out-of-hospital before and after the change of AED protocol. 1993−1997 Period 1 Before AED implementation. Personnel would arrive and start EMS CPR until a paramedic arrived with a defibrillator. $n=76$ patients, mean time to defib 15 min mean time of CPR 10 min) Period 2 After AED Implementation, immediate defibrillation. ($n=92$ patients mean time to defibrillation 5.7 min	Initial resuscitation	Period 1 48.7% [37/76] Period 2 37.0% [34/92]	
		Hospital survival	Period 1 23.7% [18/76] Period 2 14.1% [13/92], $P=0.112$	
		1-year survival	Period 1 17.1% [13/76] Period 2 9.8% [9/34] $P=0.161$	
		Neurologically intact survival	Period 1 14.5% [11/76] Period 2 8.7% [8/34] $P=0.239$	
Chan et al., (2008), N Engl J Med, USA, [9] Multicentre registry data (level 4, excellent)	Data collected on 6789 patients who had cardiac arrest in-hospital due to ventricular fibrillation or pulseless ventricular tachycardia at 369 hospitals participating in the National Registry of Cardiopulmonary Resuscitation. 2000−2005 Median time to defibrillation was 1 min Delayed defibrillation definied as more than 2 min occurred in 2045 patients (30.1%)	Survival to discharge	Defibrillation <2 min 39.3% Defibrillation >2 min 22.2%, $P<0.001$	There was a graded association seen between increasing time to defibrillation and lower rates of survival to hospital discharge for each minute of delay (P for trend <0.001) 1565 patients excluded if the arrest was in a patient receiving i.v. adrenaline, amiodarone or lignocaine and 766 patients with inaccurate data
		Survival with delay to defibrillation	<1 min 1577/3994 (39%) 2 min 286/750 (38%) 3 min 160/472 (34%) 4 min 67/291 (23%) 5 min 98/394 (25%) 6 min	

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Table 1 *(Continued)*

Author, date and Study type	Patient group	Outcomes	Key results	Comments
	61% of patients were in intensive care and another 30% were in monitored beds 10% were cardiac surgical patients		27/145 (19%) >6 min 103/743 (14%)	
Spearpoint et al., (2000), Resuscitation, UK, [10] Prospective cohort study (level 4, excellent)	124 patients who suffered an in-hospital VF arrest from 1997–1999 at the Hammersmith hospital 81 patients had rapid defibrillation 21 patients had delayed defibrillation of 2 min or more. 15 had rapid defibrillation and no CPR	Return of spontaneous circulation	Overall 87/124 Defibrillation <2 min 68/81 (84%) Defibrillation >2 min 11/21 (52%) *P* <0.05	
		Hospital discharge	Overall 43/124 Defibrillation <2 min 39/81 (48%) Defibrillation >2 min 3/21 (14%) *P* <0.05	
Fredriksson et al., (2006), Resuscitation, Sweden, [11, 12] Cohort study (level 4, good)	910 consecutive patients who suffered an in-hospital cardiac arrest in Sahlgrenska hospital from 1994–2001 80% of arrests had CPR within a minute. 442 had VF arrest 3.6% were post CABG	Survival to discharge Time to defibrillation 0–18 min	310/910 (34%) Median 2 min Mean time 4.28 min S.D. 7 min, range	No breakdown of survival with length of time to defibrillation Second paper by Herlitz [13] gives a further breakdown by monitored or non-monitored wards
Hajbaghery et al., (2005), Resuscitation, Iran, [13] Prospective cohort study (level 4, good)	206 patients who suffered an in-hospital cardiac arrest in a single hospital in Iran in a 6-month period in 2002	Short-term survival Survival to discharge	41/206 (20%) Defibrillation 1–4 min 33% Defibrillation 5–7 min 5.4% Defibrillation 0.8 min 1%	
Zafari et al., (2004), J Am Coll Cardiol, USA, [14] Prospective cohort study, (level 3, good)	569 consecutive patients who suffered an in-hospital cardiac arrest from 1995 to 2002 141 events occurred after an early defibrillation programme was initiated, and momphasic defibrillators replaced with biphasic 40% of arrests were on the intensive care unit	Survival to discharge Survival to discharge of patients who had defibrillation	Control period 21/428 (4.9%) Early defibrillation 18/141 (13%) *P*=0.001 Control period 4/176 (2.2%) Early defibrillation 10/64 (16%)	Only 20% had VF as initial rhythm and only 50% were defibrillated No documentation of time to defibrillation
Skrifvars et al., (2007), J Intern Med, Finland, [15] Cohort study (level 4, good)	441 patients suffering an in-hospital cardiac arrest in six Scandinavian hospitals	Survival at 12 months	age [OR 0.95, 95% CI 0.93–0.98], renal disease (OR 0.3, CI 0.1–0.9), emergency ward (OR 4.7, CI 1.4–15.3), cardiac care unit (OR 2.8, CI 1.2–6.4), intensive care unit (OR 2.4, CI 1.1–5.7), Thoracic surgery ward (OR 10.2, CI 2.6–40.1), Interventional radiology (OR 13.3, CI 3.4–52.0). There was no difference in: - Initial rhythm, - Delay to defibrillation - Delay to return of spontaneous circulation	
Bohrer and Böttiger (1996), J Cardiothorac Vasc Surg Germany, [16] Case series (level 5, poor)	In a 10-year period, three patients have died from exanguination after CPR due to VF arrest CPR initiated before external defibrillation	Cause of death Cause of arrest	Rupture of vascular sutures after CPR Patient 1 2 h post CABG, uneventful. After five external compressions	

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Table 1 *(Continued)*

Author, date and Study type	Patient group	Outcomes	Key results	Comments
			1500 ml of blood drained into the chest drains in 30 s – right atrial sutures ruptured	
		Recommendation	The first shock to be administered prior to any CPR if VF/VT as paddles should be no more than 20 s away	
Klintschar et al., (1998), Int J Legal Med, Austria, [17] Case report (level 5, fair)	An 84-year-old woman was unsuccessfully resuscitated for 3 min using standard cardiopulmonary resuscitation (CPR), followed by 15 min of active compression-decompression (ACD)	Post-mortem	Death was due to myocardial infarction complicated by rupture of the infracted area	
Fosse and Lindberg, (1996), Acta Anaesthesiol Scand, Norway, [18] Case report (level 5, fair)	A case of a 62-year-old woman suffering an acute cardiac arrest during a court dispute is presented. Cardiopulmonary resuscitation was immediately started by bystanders. In hospital there were signs of intrathoracic bleeding. A left thoracotomy revealed a cardiac rupture of the left ventricle and a large pericardial tear	Emergency thoracotomy	Left ventricular rupture and pericardial tear. This was sutured and the patient survived to discharge	
Sokolove et al., (2002), J Emerg Med, USA, [19] Case report (level 5, fair)	61-year-old woman in whom cardiopulmonary resuscitation (CPR) was unsuccessful. While the patient was initially resuscitated from the primary cardiac arrest, with evidence of neurologic recovery, she ultimately succumbed to injuries resulting directly from closed-chest CPR	Post-mortem	Multiple rib fractures, a sternal fracture, pulmonary laceration, and cardiac rupture	
Kempen and Allgood, (1999), Crit Care Med, USA, [20] Case report (level 5, fair)	The collapse of a patient immediately after right pneumonectomy with right pericardiotomy with cyanosis resulted in closed-chest, subsequent thoracotomy, and demise secondary to right ventricular rupture	Emergency re-thoracotomy	A 2-cm long rent in the right ventricle was noted along the apical interventricular septum	
Noffsinger et al., (1991), J Forensic Sci, USA, [21] Case report (level 5, fair)	69-year-old woman who underwent surgery for a perforated duodenal ulcer. Eighteen hours postoperatively she sustained a cardiac arrest; vigorous resuscitation efforts, using advanced cardiac life-support procedures, failed	Post-mortem	She had 350 ml of fresh blood in her pericardial sac, which had caused cardiac tamponade. Three ribs were fractured at the left sternal border. Directly underneath the fractured ribs were a 0.4-cm laceration of the pericardium and an accompanying 0.7-cm laceration of the left ventricle. There was an acute thrombus in the left anterior descending artery. Microscopic examination of the heart showed acute infarction of the left ventricle in the vicinity of the laceration	
Bitkover et al., (1996), Ann Thorac Surg, Sweden, [22] Case report (level 5, fair)	83-year-old man was found unconscious and was successfully resuscitated. Progressive failure developed	Thoracotomy	Exploration showed a laceration of the left atrium at the junction of the left pulmonary veins, which was closed with a direct suture on cardiopulmonary bypass. The postoperative course was uneventful	
Raman et al., (1989), Anaesth Intensive Care, Australia, [23]	39 patients who arrested within 72 h of a cardiac surgical operation between 1984 and 1988.	Cause of arrest	Group A (after resternotomy) Tamponade 5 (21%)	Of note no damage to the heart was noted from any external cardiac compression

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Table 1 *(Continued)*

Author, date and Study type	Patient group	Outcomes	Key results	Comments
Retrospective cohort study (level 4 good)	25 CABG, 2 transplants, 12 valves, 1 aneurysmectomy Divided into 2 groups retrospectively Group A (24 patients): open cardiac massage and resternotomy Group B (15 patients): external cardiac massage only Mean time to reopening 5.6±2 min After successful chest reopening patient always taken to theatre for closure after povodine-iodine washout. Peri-resuscitative antibiotics were 'recommended' for 48 h		Bleeding 8 (33%) Dissection 1 Graft thrombosis 1 Ruptured ventricle 1 RV failure 1 Arrhythmia 1 Group B (autopsy) Group A Evacuation of clot 4 Regraft or repair 7 (29%) CPB 7 (29%) IABP 4 RVAD 1 Pacing 5	No sternal wound infections They provided a protocol indicating emergency re-sternotomy after 5 min of unsuccessful resuscitation. Reopening by a cardiac surgeon, return to theatre for closure, iv antibiotics, povodine-iodine washout
		Interventions during arrest, or cause of arrest		
		Arrest survival	Group A 21/24 (87%) Group B 5/15 (33%)	
		Out-of-hospital survival	Group A 18/24 (75%) Group B 3/15 (20%)	
		Resuscitation not in ICU	Not applicable	
		Incidence requiring CPR	Not given	
			Not given	
el-Banayosy et al., (1998), J Cardiothorac Vasc Anaesth, Germany, [24] Retrospective cohort study (level 4, Good)	2-year retrospective audit of 113 patients Dates: Jan 1993–Dec 1994 Patient groups: All patients with circulatory collapse requiring CPR within 7 days of surgery Adults but transplants and paediatric patients excluded Single centre: North Rhine Heart Centre, Bad Oeynhausen, Germany Protocol: After 20–30 min of CPR IABP performed. If unsuccessful and operation <48 h – chest reopening Unsuccessful and operation 48 h – Fem Fem Bypass	Cause of arrest	58/113 (51%) VF 22/113 (19.5%) EMD 6/113 (5.3%) Asystole	Duration of CPR 2–230 min (mean 30 min) Significant predictors of adverse survival: CPR time, CK-MB rise, time from surgery It was stated that there were no complications found due to external CPR in the 113 patients
		Interventions during arrest, or cause of arrest	47 MI 9 bleeding 4 Heart failure 5 patients had Fem Fem bypass – all died 49/113 had IABP (24–49% survived) 24/113 had resternotomy (13 or 54% survived) 6 patients had a VAD (7 or 47% survived)	
		Arrest survival	Not reported	
		Out-of-hospital survival	79/113 (70%) survived to discharge	
		Resuscitation not in ICU	15 arrests outside ICU but 7 survived (47%)	
		Incidence requiring CPR	113/4988 (2.3%) required CPR	
		Longest time to reopening resulting in survival to discharge	18 arrests more than 18 h post-surgery (10 survived)	

that these guidelines may do harm is not yet strong enough to recommend a change in practice. However, we acknowledge that there are no in-hospital data to support very short periods of external massage prior to defibrillation and there have been examples of damage to the myocardium due to external massage. This should be borne in mind when external massage is being performed on a patient after cardiac surgery.

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eComment: Avoiding the adverse consequences of external cardiac massage during in-hospital resuscitation after cardiac surgery

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doi:10.1510/icvts.2008.182980A

Lockowandt and colleagues [1] published results from their 'best evidence' search, which addressed whether it is acceptable to delay cardiopulmonary resuscitation (CPR) if a patient arrests after cardiac surgery in order to attempt defibrillation or pacing prior to performing external cardiac massage (ECM). They recommended that guidelines for immediate ECM prior to defibrillation in-hospital should be followed as the evidence that significant trauma to the myocardium due to ECM has been reported in cardiac surgery patients is not yet strong enough to recommend a change in practice. The adverse consequences caused by ECM, however, can be avoided by using alternative CPR methods.

The likelihood of achieving return of spontaneous circulation (ROSC) and surviving a cardiac arrest has been linked to the ability to achieve and maintain coronary perfusion pressure (CPP) adequately above a threshold level of 15 mmHg prior to defibrillation [2]. One can argue that failure to achieve ROSC despite prompt defibrillation is possible in many post-cardiac-surgery patients due to some level of impaired left ventricular diastolic filling, which likely more rapidly decreases CPP to below threshold levels. Therefore, to avoid unnecessary defibrillation, which can increase the already existing myocardial dysfunction, and to avoid the potential adverse consequences of ECM and the subsequent need for sternal rewiring, two alternative methods of CPR [3] can be utilized to maintain adequate CPP before defibrillation.

First, minimally invasive direct cardiac massage (or MID-CM) is a technique that uses a commercially available hand-held device (TheraCardia, Inc) that is introduced through a small thoracostomy to manually achieve direct cardiac compression with a 4-cm up-and-down stroke at a rate of 80–100 compression-decompressions per min. It has been pointed out that a human pre-hospital pilot study of 25 patients concluded that MID-CM produces greater blood flow than conventional CPR.

Second, abdominal compressions-only CPR (or ACO-CPR) (with an open airway possibly maintained by head rotation during single-rescuer CPR [4] or by manual airway maneuvers during two-rescuer CPR) is a new resuscitation method that can be applied immediately to circulate oxygenated blood to the heart and brain, which may improve the chances of successful pacing or defibrillation on the first attempt, in patients suffering an arrest after cardiac surgery. High-frequency compressions of the abdominal aorta (due to rhythmic compression by compressing the mid-abdomen) produce resonant pressure-volume waves within the aorta that drive blood flow. Because there is no direct pressure over the heart to empty the left ventricle with each compression during ACO-CPR and because left ventricular volume will increase as a result of flow from the higher-pressure pulmonary arteries to the lower-pressure left atrium and left ventricle, the heart acts as a conduit, thereby allowing significant increases in ventricular volume during ACO-CPR [5], which would compensate for the impaired left ventricular diastolic filling found in many post-cardiac-surgery patients. However, cardiac compressions with MID-CM may still be necessary because ACO-CPR engorges the heart with blood; a blood-engorged heart cannot be successfully defibrillated and circulation cannot return without first decompressing the heart with cardiac compressions [4, 5].

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eComment: Early emergency resternotomy is crucial in cardiac arrest after cardiac surgery

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doi:10.1510/icvts.2008.182980B

The above best evidence topic [1] reminds me of a patient I have been involved with recently. This lady had a cardiac arrest five days following aortic valve surgery. She suffered a witnessed cardiac arrest for which she had one minute of cardiopulmonary resuscitation (CPR) which was successful in returning a spontaneous cardiac output with a good blood pressure. Post-resuscitation she was found to have a left pneumothorax with a small left pleural effusion. A chest drain was inserted and the pneumothorax resolved. The patient remained stable and was transferred to cardiothoracic intensive care unit (CICU). In CICU her haemoglobin was 5.5 g/dl therefore, she received a blood transfusion. She remained stable for 24 h. She had minimal drainage and was discharged from CICU back to high dependency unit (HDU). The following day on HDU she arrested again. She received prolonged CPR for 25 min during which 1.5 l suddenly drained down the pleural drain as a result of the CPR. This patient died of an aortic dissection confirmed on emergency resternotomy.

So what did we learn from this case? The first arrest was attributed to the pneumothorax but in retrospect the main cause for the cardiac arrest must have been the aortic dissection. However, when in the CICU, we did not fully investigate this possibility. Then evidently the second period of 25 min of external cardiac massage caused this dissection to rupture.

In conclusion, prolonged massage in our experience did cause a severe haemorrhagic complication and thus early resternotomy would both reduce this trauma and also allow full inspection of the mediastinal contents. If this had been performed on the first arrest, then the aortic dissection may have been discovered. Even if a patient is successfully resuscitated without the need for emergency resternotomy we believe that these patients should be thoroughly investigated for all causes of this arrest, including a CT angiogram to exclude dissection if no other apparent cause has been found to explain the arrest.

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eComment: External cardiac massage may be harmful as well as unnecessary

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doi:10.1510/icvts.2008.182980C

Lockowandt and coworkers ask a very important question about whether it is ever acceptable to delay cardiac massage [1]. Cardiac arrest after cardiac surgery is different from cardiac arrest in a general hospital ward.

When due to ventricular fibrillation, a defibrillator is usually immediately available and the treatment of choice should be immediate defibrillation.

When due to severe bradycardia or complete heart block or asystole, pacing wires are often in place and if so, pacing is the treatment of choice.

When due to tamponade or catastrophic haemorrhage, external massage may not help and reopening the chest is the treatment of choice.

When due to tension pneumothorax, external massage may also not help and drainage is the treatment of choice.

When all this is added to the risk of damage to sternum, heart and suture lines, it makes a compelling case for delaying external massage by a few seconds if that allows the immediate administration of the treatment of choice (such as defibrillation or pacing) as there is every chance that these interventions may correct the problem thus avoiding the need for potentially damaging massage in the first place.

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eComment: Also in cardiac arrest it is important to think first

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doi:10.1510/icvts.2008.182980D

The question raised in the manuscript of Lockowandt and coworkers is a very important question [1]. In most cases patients after cardiac surgery will be monitored for at least 24 h. Because of this monitoring, if a patient arrests, it will be known if the arrest is due to, for instance, a severe bradycardia or a ventricular fibrillation. These causes can be treated very quickly in an intensive care unit. If pacing in the case of bradycardia or a few attempts of defibrillation in case of ventricular fibrillation are not successful, it is of utmost importance to start resuscitation and reopening of the chest as soon as possible [2]. Also a tension pneumothorax should be recognized in a few seconds in the intensive care unit. Drainage in that case is more successful than external massage. If the patient arrests a few days after cardiac surgery he will be on the ward and probably there will be more delay until it is clear what the arrest is due to. In those cases the nursing staff should start resuscitation while waiting for the doctors on call to arrive.

The resuscitation technique itself needs a warning notice. In our hospital we have seen several patients after an out of hospital resuscitation where a mechanical device had been used for the external cardiac massage. Sternal fractures were not uncommon just as damage to the myocardium and we have even seen esophageal ruptures in patients where the mechanical device was not perfectly adjusted to the patient's body size. The use of these devices in patients with a recently divided sternum will, without any doubt, lead to a number of sternal fragments unsuitable for sternal rewiring and damage to the underlying structures.

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eComment: The sooner the beginning of cardiopulmonary resuscitation, the better the outcome for the arrested cardiac operated patient

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doi:10.1510/icvts.2008.182980E

The two questions posed by your article [1] are of great importance as they concern every surgeon.

Concerning the first question, the immediate cardiopulmonary resuscitation (CPR) is not only necessary but also mandatory. We strongly believe that CPR should start as soon as possible, independently of the availability for defibrillation or pacing. We consider maintaining of an adequate blood flow and pressure for vital organs (brain and myocardium), before every

effort to defibrillate or pacing, as the most important constituent of a good final outcome. Cerebral blood flow must be preserved within first 2–3 min following arrest, in order to avoid a potential irreversible damage.

Immediate CPR is also imposed in cases where arrest is associated with acute dilation of left or right ventricle (ballooning heart). In these cases (on electrocardiogram: bradycardia, asystole, or pulseless electrical activity), attempting to pace or defibrillate is usually not effective. Acute 'passive' myocardial dilatation leads to a further deterioration of the ventricular function because the curve of Frank-Starling is shifted to the right. Simultaneously, the myocardium presents an asynergy, regarding ventricular conduction contrary to the normal excitation–contraction coupling. Consequently, if we do not interrupt mechanically this 'vicious circle' by cardiac massage, neither pacing nor defibrillation will be rendered effective.

Concerning the possibility of myocardial damage caused by external cardiac massage [1], there are few sporadic reported cases in literature [2, 3]. However, such cases are relatively rare compared to the total amount of patients subjected in CPR. It is notable that Fredriksson et al. [4] do not refer to any myocardial damage during post-cardiopulmonary bypass grafting (CABG) arrest, among 32 postoperative patients, in the majority of whom (80%) a cardiac massage was performed. El-Banayosy et al. [2] reported no cases of myocardial injury during CPR among 113 cardiac operated patients. However, there are several reported cases of harm after CPR in patients without previous sternotomy. Consequently, previous sternotomy does not appear to be significantly responsible for a potential myocardial injury or dysfunction during CPR.

In our opinion, myocardial damage may be caused by physician's over-zealous massage, usually characterized by violent manoeuvres. According to the guidelines, during external massage the 'immersion' of the lower half sternum must not exceed 4–5 cm, in order to produce drastic mechanical output without the potential of myocardial damage [5].

Finally, we follow a more 'aggressive strategy' for the arrested patients shortly after cardiac surgery: we immediately perform CPR by external cardiac massage. If after the first 2–3 min 'closed CPR' has no impact, we convert it to 'open CPR' after in bed emergency re-sternotomy. This strategy has been performed in 26 arrests on ICU patients and was successful in 18 patients (69.23%). In only one case we have observed at the end of a converted 'open CPR' a hemorrhage from the site of left internal mammary artery (LIMA) to left anterior descending (LAD) anastomosis. The patient was urgently transported to the theater for successful suture. Two others of the surviving patients were re-operated after two and three months, respectively for complications of the incision and of the sternum (infection and diastasis).

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