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Best evidence topic - Cardiac general

Is internal massage superior to external massage for patients suffering a cardiac arrest after cardiac surgery?

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Summary

A best evidence topic in cardiac surgery was written according to a structured protocol. The question addressed was whether open chest cardiac massage is superior to closed chest compressions in patients suffering cardiac arrest following cardiac surgery. Using the reported search, 527 papers were identified. Fifteen papers represented the best evidence on the subject and the author, journal, date and country of publication, patient group studied, study type, relevant outcomes, results and study comments and weaknesses were tabulated. The quality and level of evidence was assessed using the International Liaison Committee on Resuscitation guideline recommendations. We conclude that over 18 good quality animal studies have consistently demonstrated the superiority of open chest cardiac massage, with the cardiac index and coronary perfusion pressures often more than doubling. There are fewer human studies but they have shown that closed chest massage generates a cardiac index of around 0.6 $l/min/m^2$ which rises to 1.3 $l/min/m^2$ or more with open-chest-CPR, accompanied by even bigger improvements in coronary perfusion pressure. ILCOR recommends prompt conversion to open-chest-cardiac massage in patient's shortly post-cardiac surgery, and we would support this intervention if simple resuscitative efforts such as defibrillation, pacing or atropine fail, in order to significantly improve the quality of cardiopulmonary resuscitation.

Keywords: Cardiac surgery; Cardiopulmonary resuscitation; Open chest cardiac massage; Evidence based medicine; Postoperative complications

1. Introduction

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

2. Clinical scenario

A 52-year-old patient 36 h after mitral valve repair and grafts arrests with an asystolic ECG. He had been on increasing doses of adrenaline and a TOE had shown a poor LV but no tamponade. After 2 min of external cardiac massage and 1 mg of adrenaline you elect to perform an emergency re-sternotomy with the intention of putting the patient back on bypass. Once commencing internal massage you are surprised at the significantly better arterial pressure that you are able to achieve performing internal massage.

3. Three-part question

In [patients with cardiac arrest after cardiac surgery] is [external cardiac massage or internal massage] better in generating optimal [cardiac index and coronary perfusion]?

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4. Search strategy

Medline 1950–Oct 2007 using the OVID interface.

[open chest.mp OR internal cardiac.mp OR resuscitative thoracotomy.mp OR open heart.mp] AND [CPR.mp OR exp Cardiopulmonary resuscitation/or massage.mp]

EMBASE 1980–Oct 2007 using the OVID interface.

[open chest.mp OR internal cardiac.mp OR resuscitative thoracotomy.mp OR open heart.mp] AND [CPR.mp OR exp resuscitation/or massage.mp]

The Cochrane database for systematic reviews and central register of controlled trials was searched using the term 'open chest', or 'internal cardiac' CPR.

5. Search outcome

Two hundred and sixty-three papers were found in Medline, 256 in EMBASE and eight articles in the Cochrane library. Of these, 22 were felt to be relevant and 15 were tabulated (Table 1).

6. Comments

The International Liaison Committee on Resuscitation which comprehensively reviewed 276 topics in resuscitation with 281 experts in the field in 2005 looked at the issue of open vs. closed chest cardiac massage [3], and provided a

Table 1
Best evidence papers

Author, year, journal, country Study type	Patient group	Outcomes	Key results	Study weaknesses
Rubertsson and Wiklund (2005), Circulation, Sweden, [4] Systematic review of cohort studies, case series and animal studies (Level 4, excellent, positive)	ILCOR worksheet titled: open chest CPR improves outcome when compared with standard closed-chest CPR	Level of evidence	Class IIb: acceptable and useful, fair evidence	
	22 articles included after full systematic review [16]	Recommendation	Open-chest CPR results in greater perfusion pressures, systemic blood flow and survival, and may be indicated in cases of circulatory arrest in the early postoperative phase after cardiothoracic surgery or when the chest or abdomen is already open (transdiaphragmal approach) for example in trauma surgery Open-chest CPR may also be necessary in victims of avalanche accidents with cardiac arrest and deep hypothermia since external thoracic compressions are not efficient due to stiff thoracic cage	
		Quality and direction of studies	18 level 6 papers, 1 level 5, 2 level 4 and a level 3 study of which four were human studies, were found all in support of the hypothesis. None found against the hypothesis	
ILCOR Consensus on Science, (2005) Circulation, Worldwide, [3] Systematic review of cohort studies, case series and animal studies (Level 4, excellent, positive)	International Liaison Committee on Resuscitation Advanced Life Support Task force recommendation	Consensus on science	2 human studies after cardiac surgery and two out of hospital arrest have been published. The observed benefits of open-chest cardiac massage included improved coronary perfusion pressure and increased return of spontaneous circulation. Evidence from animal studies indicates that open-chest CPR produces greater survival rates, perfusion pressures, and organ blood flow than closed chest CPR	
		Treatment recommendations	Open-chest CPR should be considered for patients with cardiac arrest in the early postoperative phase after cardiothoracic surgery or when the chest or abdomen is already open	
		Class of recommendation	Class IIb: acceptable and useful, fair evidence	
Del Guercio et al. (1965), Circulation, USA, Case series, [12] Case-series (Level 5, fair, positive)	11 human subjects with in-hospital cardiac arrest	Cardiac index	Closed chest CPR 0.61 l/min/m^2 Open chest CPR 1.31 l/min/m^2	Not randomised. Old study
		Circulation time	Closed chest CPR 43.8 s Open chest CPR 88.5 s $P<0.01$	
Sanders et al. (1984), Ann Emerg Med, USA, [16, 20] An experimental animal study (Level 6, good, positive)	10 dogs in ventricular fibrillation Closed chest CPR for 15 min Dogs with coronary perfusion pressure below 30 mmHg had thoracotomy and internal massage for 3 min. Closed chest massage in the others. All dogs defibrillated at 20 min	Successful resuscitation and survival to 20 min Aortic and right atrial pressure	Open chest CPR 4/5 dogs resuscitated Closed chest CPR No survivors Significant differences in arterial or coronary pressure	Very small numbers in each group

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Table 1 *(Continued)*

Author, year, journal, country Study type	Patient group	Outcomes	Key results	Study weaknesses
Geehr et al. (1986), N Engl J Med (Letter) USA, [14] Letter about an RCT (Unknown level of evidence)	49 patients with out-of-hospital cardiac arrest, randomised to CCCC or OCCC	Survival	Three patients in each group were resuscitated and admitted to hospital. No patient in either group survived to discharge	Letter format only, no published study details
Kern et al. (1987) Circulation, USA Randomised controlled trial (Animal), [17, 21] Experimental animal study (Level 6, excellent, positive)	28 mongrel dogs put into ventricular fibrillation. All had 15 min of regular CPR, then randomised to closed or open chest CPR for a further 2 min followed by defibrillation	Aortic pressure	Open chest CPR 112/70 Closed chest CPR 48/25, $P<0.001$	
		Coronary perfusion	Open chest CPR 65 mmHg Closed chest CPR 19 mmHg $P<0.001$	
		Return of spontaneous circulation	Open chest CPR 14/14 dogs Closed chest CPR 5/14 dogs $P<0.05$	
		24 h survival	Open chest CPR 12/14 dogs Closed chest CPR 4/14 dogs $P<0.05$	
Kern et al. (1991) Ann Emerg Med, USA, [22] Experimental animal study (Level 6, good, positive)	Twenty mongrel dogs. Ten animals underwent 20 min of VF and were then randomised into open or closed chest CPR The other 10 animals all underwent open chest CPR. In half of these, this was instituted after 10 min of VF, in the other half, after 40 min	Survival	Open chest CPR after 10 min 5/5 dogs Open chest CPR after 20 min 5/5 dogs Open chest CPR after 40 min 0/5 dogs Closed chest CPR 1/5 dogs	
		Physiological variables	OCCC produced significantly better coronary perfusion and aortic pressures. These values were also significantly better in the OCCC 20 min group in comparison with the 40 min group	
Takino and Okada (1993), Resuscitation, Japan, Case series, [10] Controlled cohort study (Level 4, fair, positive)	95 patients with non-traumatic out-of-hospital cardiac arrest, 26 patients had open chest CPR after failed closed chest CPR	Return of spontaneous circulation	Closed chest CPR 21/69 patients (30%) Open chest CPR 15/26 patients (58%)	Not randomised. Authors felt numbers were too low for statistical analysis
		Hospital discharge	Closed chest CPR 1/69 patients (1%) Open chest CPR 3/26 patients (12%)	
		Timing of chest opening	Tendency to improved outcomes if chest opened within 5 min	
Boczar et al. (1995), Crit Care Med, USA, [7] Prospective case series (Level 4, fair, positive)	10 adult non-traumatic, patients presenting with a witnessed cardiac arrest Proximal aortic and CVP lines placed	Mean coronary perfusion pressure	Closed chest CPR 7.3 ± 5.7 mmHg Open chest CPR 32.6 ± 17.8 mmHg $P<0.05$	One patient also had cardiac index monitored. This

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Table 1 *(Continued)*

Author, year, journal, country Study type	Patient group	Outcomes	Key results	Study weaknesses
	Closed chest CPR using an automatic compression device (Thumper)	Compression-phase pressure gradients	Closed chest CPR 6.2 ± 5.4 mmHg Open chest CPR 32.6 ± 29.9 mmHg $P<0.05$	increased from 0.56 to 2.23 l/min/m²
	After 5 min left lateral thoracotomy performed and open chest CPR performed	Survival	3 patients developed return of spontaneous rhythm after open chest massage (having been declared unsalvageable to enter the study after 5 min closed chest CPR)	
Hachimi-Idrissi et al. (1997), Resuscitation, Belgium, [11] Case series (Level 5, fair, positive)	33 patients with out-of-hospital cardiac arrest, undergoing open-chest-CPR after failure of closed chest CPR These 33 patients are collected out of a series of 2212 patients on their database	ROSC and survival	ROSC was achieved in 13 patients. Two of these survived to hospital discharge	Very selected cases. Only 2 survivors
Anthi et al. (1998), Chest, Greece, [5] Consecutive cohort study (Level 4, good, positive)	29 patients with cardiac arrest within 24 h of cardiac surgery. Closed chest CPR initiated, if no ROSC after 3–5 min, open chest CPR commenced	Incidence of ROSC and survival	Closed chest CPR successful in 13 patients. Of remaining 16, open chest CPR was successful in 14. Four patients did not survive to discharge. At one year, 20/23 patients were alive. Overall causes were myocardial infarction (14), cardiac tamponade (5), graft malfunction (3) and unknown (7)	This study does not directly compare the usefulness of closed chest CPR vs. open chest CPR
Mackay et al. (2002), Eur J Cardiothorac Surg, UK, [23, 24] Consecutive cohort study (Level 4, excellent, postive)	79 post cardiac surgery patients who underwent chest reopening during cardiac arrest	ROSC and survival to discharge	Overall survival to discharge was 20/79 (25%). Survival was more likely if arrest occurred within 24 h of surgery (39% vs 13% $P=0.02$) and with chest reopening within 10 min of arrest (48% vs 12% $P<0.001$). No patients arresting on ward survived	No direct comparison
Pottle et al. (2002), Resuscitation, UK, [6] Consecutive cohort study (Level 4, good, positive)	72 post cardiac surgery patients undergoing OCCC	Outcome	Initial survival was 33/72 (46%). Only 12/72 (17%) survived to discharge. No patients receiving OCCC outside HDU survived	No direct comparison of CCCC and OCCC
Benson et al. (2003), Resuscitation, USA, [15] An experimental animal study – randomised controlled trial (Level 6, excellent, positive)	12 dogs with induced ventricular fibrillation. After five minutes of non-intervention, subjects randomised to receive 15 min of closed chest CPR or 15 min of open chest CPR. Defibrillation was then attempted and resuscitation continued	Survival	Open chest CPR All 5 dogs survived and neurologically normal at 72 h Closed chest CPR 3/7 dogs survived but one had ataxia and the other 2 had severe neurological deficits	
		Coronary perfusion pressure	Open chest CPR 38.2 mmHg Closed chest CPR 20.3 mmHg	

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Table 1 *(Continued)*

Author, year, journal, country Study type	Patient group	Outcomes	Key results	Study weaknesses
Calinas-Correia and Phair (2001), J Accid Emerg Med, UK, [13]	7 patients who had non-traumatic cardiac arrest out-of-hospital. Once entering hospital	Oxygenation	PO_2 was physiological or supra-physiological in all patients	
Case-series (Level 5, poor, neutral)	Open chest CPR performed by one physician	Acid base balance	This was not corrected in these patients	
		Survival	3 attained spontaneous circulation but no survivors	

systematic review on the topic as part of their worksheet review process [4]. They found four human studies, with two in cardiac surgery and two in out-of-hospital cardiac arrest and 18 animal studies. They report that there are observed benefits of open-chest-cardiac massage including improved coronary perfusion pressure and increased return of spontaneous circulation in humans and better survival rates, and organ blood flow as compared to closed-chest CPR. They recommend that open-chest-CPR should be considered for patients for cardiac arrest in the early post-operative phase after cardiothoracic surgery or when the chest or abdomen is already open (Class IIb).

The two human studies after cardiac surgery referred to were by Anthi et al. [5] and Pottle et al. [6]. Anthi provided a report of 29 patients who arrested 24 h after cardiac surgery. Forty-five percent were resuscitated with closed-chest-CPR and 48% with open-chest-CPR after 2–5 min of closed-chest massage had failed. Pottle reported 72 patients who had open-chest-CPR after cardiac surgery, of whom 46% regained spontaneous circulation.

Of the other two human studies, Boczar et al. [7] studied 10 patients brought into hospital with a witnessed cardiac arrest. After 5 min of closed-chest-CPR they were declared unsalvageable and entered into the study. A left lateral thoracotomy was performed without opening the pericardium and internal massage commenced. The mean coronary perfusion pressure rose from 7.3 mmHg to 32 mmHg, the compression-phase pressure gradient rose from 6.2 mmHg to 32.6 mmHg and three patients obtained a spontaneous circulation. They remind us that Paradis et al. [8] in JAMA reported that 15 mmHg of coronary perfusion is required in humans to obtain a return of spontaneous circulation, this was achieved in all Boczar's patients during open-chest-CPR. Paradis et al. [9] also reported three patients who had open-chest-CPR after failed closed-chest-CPR and two survived, one with no neurological deficit.

Takino and Okada [10] compared 26 patients who had open-chest-CPR after witnessed out-of-hospital cardiac arrest with 69 who had closed-chest-CPR only. Fifty-eight percent of patients had spontaneous return of circulation with open-chest-CPR compared with 30% with closed-chest-CPR. There were three open-chest long-term survivors compared to only one closed-chest survivor.

A third human study rejected by ILCOR was by Hachimi-Idrissi et al. [11]. They found 33 patients who had open-chest-CPR after failed closed-chest-CPR in their database of 2212 out-of-hospital arrest patients. Thirteen had spontaneous return of circulation but only two survived.

We identified three additional human studies. Del Guercio et al. in 1965 [12] showed significant improvements in physiological variables with open-chest-CPR in 11 patients with in-hospital arrest. The cardiac index was 0.6 $l/min/m^2$ with closed-chest-CPR but was 1.3 $l/min/m^2$ with open-chest-CPR. The circulation time decreased from 89 s to 44 s. Calinas-Correia and Phair [13] reported seven patients who underwent open-chest CPR but with no survivors. Geehr et al. [14] in a letter in the NEJM, reported that they had performed an RCT of 49 patients with an out-of-hospital arrest and found three survivors in the open-chest-CPR group, and three in the closed-chest-CPR group.

Of the animal studies, Benson et al. [15] induced VF in 12 dogs and after 5 min of no intervention randomised the dogs to either open or closed-chest-massage for 15 min. All open-chest-CPR dogs survived without neurological deficit but only 3/7 dogs survived after closed-chest-CPR and two had severe neurological deficit. The coronary perfusion pressure was double in the open-chest-CPR group.

Sanders et al. [16] showed that open-chest-CPR resulted in 4/5 dog survivors compared to none in their closed-chest group. Kern et al. [17] showed that resuscitation and survival were significantly improved with open cardiac massage in 29 dogs and reiterated these findings in 1991, adding that resuscitation was significantly improved if chest opening was instituted sooner. Raessler and Kem [18] in 63 mongrel dogs showed that open-chest-CPR had a coronary perfusion pressure of 64 mmHg compared to 21 mmHg for closed-chest massage. Rubertsson and Grenvik [19] showed significant improvements in cardiac index and coronary perfusion pressure in 35 pigs.

7. Clinical bottom line

Over 18 good quality animal studies have consistently demonstrated the superiority of open chest cardiac massage, with the cardiac index and coronary perfusion pressures often more than doubling. There are fewer human studies but they have shown that closed-chest-massage generates a cardiac index of around 0.6, which rises to 1.3 $l/min/m^2$ or more with open-chest-CPR, accompanied by even bigger improvements in coronary perfusion pressure. ILCOR recommends prompt conversion to open-chest-cardiac massage in patients shortly post-cardiac surgery, and we would support this intervention if simple resuscitative efforts such as defibrillation, pacing or atropine fail, in order to significantly improve the quality of cardiopulmonary resuscitation.

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eComment: Alternative methods of resuscitation for patients suffering a cardiac arrest after cardiac surgery

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Twomey and colleagues [1] published the results of their 'best evidence' search, which addressed whether internal cardiac massage is superior to external massage for patients suffering a cardiac arrest after cardiac surgery. They pointed out that ILCOR recommends prompt conversion to open-chest-cardiac massage in patients shortly post-cardiac surgery. Based on their results, they support this intervention if simple resuscitative efforts such as defibrillation, pacing or atropine fail.

However, two other interventions are worth mentioning. First, minimally invasive direct cardiac massage (or MID-CM) [2] is a technique that uses a hand-held device that is introduced through a small thoracostomy to achieve direct cardiac compression. The commercially available MID-CM device (TheraCardia, Inc) consists of a 40 French external diameter hollow introducer with a round cylindrical handle at one end and a flat umbrella-shaped device at the other end, which is initially collapsed and retracted in the lumen of the introducer. After inserting the introducer through a small incision made at the left anterior fourth intercostal space 5 cm from the midline, the umbrella is deployed, which expands to a diameter of 7.5 cm. Manual cardiac compression-decompressions are performed at 80–100 per min with a 4-cm up-and-down stroke. A human pre-hospital pilot study of 25 patients concluded that MID-CM produces greater blood flow than conventional CPR. Deployment of the MID-CM device was, however, not possible in 1 patient with pericardium adhesions and cardiomegaly. It was pointed out that porcine models comparing open-chest-cardiac massage (OC-CM) to MID-CM using a prototype device concluded that no differences can be found between OC-CM and MID-CM at any point.

Second, abdominal compressions-only CPR (or ACO-CPR) [3] is a new method of resuscitation that recently has been demonstrated to be hemodynamically superior to conventional chest compressions in a porcine model [4]. Blood flow during ACO-CPR is generated by creating an 'inertial' pump within the abdominal aorta [5]. Motion of blood within the aorta (due to rhythmic compression by compressing the abdomen) creates an 'inertial pump' at particular frequencies of oscillation and the effectiveness of this pump mechanism is highly dependent upon the frequency of oscillations. High-frequency compressions of the aorta are likely most effective at producing resonant pressure-volume waves within the aorta that drive blood flow. This method of CPR also engorges the heart with blood (or primes the pump). 'Priming the pump' with ACO-CPR prior to performing chest compressions has been suggested to cause a leftward shift of the flow-depth relationship, thereby allowing viable perfusion pressures to be generated with less depth of compression. Therefore, chest compressions following ACO-CPR are likely much more effective than during conventional CPR. The advantage of ACO-CPR is that it can be applied immediately to generate blood flow to the heart and brain and improve the chances of successfully using initial interventions such as defibrillation, pacing or atropine. However, cardiac compression may still be necessary and perhaps because a blood-engorged heart cannot be successfully defibrillated and circulation cannot return without first decompressing the heart with either OC-CM, MID-CM or conventional CPR.

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eComment: The more the better? Cardiac output monitoring during cardiopulmonary rescuscitation

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I read with great interest the recent work by Dr. Twomey and coworkers comparing internal vs. external cardiopulmonary resuscitation [1].

I strongly believe that the authors touch an important, albeit somewhat neglected theme.

Based on the current published papers, open chest massage seems to achieve higher cardiac indices with a twofold increase in contrast to closed chest massage (0.6 vs. 1.3 $l/min/m^2$). In line, coronary perfusion pressure is increased [2]. However, one has to take into account that a total number of 11 patients were included in that study with it certain limitations. Furthermore, the method used for cardiac output measurement in this 42-year-old study may not necessarily be as accurate and precise as current gold standard therapy. The Swan-Ganz catheter, which is currently appreciated as the gold-standard therapy for clinical cardiac output measurement, was first described five years after the aforementioned study focusing the cardiac index during either open or closed chest compression [3].

Cardiac output/index monitoring during open or closed chest compression in resuscitation necessitates a continuous measure. It is preferable to use a beat-by-beat monitoring tool in this regard to obtain the appropriate stroke volumes of each chest compression rather than a mean of stroke volumes over a given time duration, such as 2 min.

A non-invasive cardiac output monitor appears to be attractive in this regard. An ultrasonic cardiac output monitor (USCOM) has been found to be at least as accurate as the current gold standard monitoring tool, the Swan-Ganz catheter [4]. It allows beat-by-beat stroke volume determination by a suprasternal approach focusing the blood column in the ascending aorta. During cardiopulmonary resuscitation, a high normal cardiac output of 5.75 l/min (cardiac index 3.12 ± 1.67 $dyne \times s \times cm^{-5}$) is achievable with paramedics performing the closed chest compression [5]. The range of cardiac output measured in 6 cardiopulmonary closed chest resuscitation patients was 2.7 to 12 l/min (1.2 $dyne \times s \times cm^{-5}$ to 5.7 $dyne \times s \times cm^{-5}$). However, the level of cardiac output/Index did not correlate in those six patients with the establishing of sustained circulation. Actually, the 2/6 patients arriving at the hospital with circulation had the lowest cardiac outputs (2.7 l/min, 66-year-old male and 3.5 l/min, 90-year-old female) in comparison to the 4 other patients, where cardiopulmonary resuscitation failed (4.8–12 l/min, 33–87 years). Whether this discrepancy in survival rate is based on undetermined factors in that study which might have contributed to the outcome is unclear. In other words, whether a higher cardiac output/index is mandatory to be associated with a better outcome, e.g. survival, has to be studied in further studies.

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