WORKSHEET for Evidence-Based Review of Science for Emergency Cardiac Care

Worksheet author(s)

Sten Rubertsson

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Clinical question.

"In adult cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P) including traumatic arrest, does the use of open-chest CPR (I) compared with standard CPR (C), improve any outcomes (eg. ROSC, survival) (O)?

Is this question addressing an intervention/therapy, prognosis or diagnosis? Intervention/therapy
State if this is a proposed new topic or revision of existing worksheet: Revision

Conflict of interest specific to this question

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet? No

Search strategy (including electronic databases searched).

Pubmed "Open chest CPR" AND "Cardiopulmonary resuscitation" (MESH) OR "Heart Arrest" All fields, 67 references, ((open chest) OR (thoracotomy)) AND ("heart arrest" [Mesh Terms] or "cardiopulmonary resuscitation" [Mesh Terms]) 326 references
OVID using "Cardiopulmonary resuscitation" AND "Heart arrest" AND/OR "Open chest CPR" All fields, 180 references
EMBASE search using Open chest and resuscitation or cardiac arrest. All fields, 60 references
AHA EndNote Master Library and Cochrane database for systematic reviews

- State inclusion and exclusion criteria

Articles which included the use of open-chest CPR as part of resuscitation from cardiac arrest were included. The following studies were excluded: Not true cardiac arrest models, open chest CPR with devices, reviews single case reports and letters

- Number of articles/sources meeting criteria for further review:

31 studies met criteria for further review. Of these 2 was LOE 2 (non-random fashion), 10 were LOE 4 (case control study, ,case series without true control, retrospective audit, retrospective case series,) and 19 LOE 5 (animal studies)

Summary of evidence

Evidence Supporting Clinical Question

Good				Anthi 1998[A]	*Angelos 1992*[AE] *Bartlett 1984* [E] *DeBehnke 1991*[A,E] *Benson 2005* [D,E] *Bircher 1985*[A, D] *Fleisher 1985*[E] *Jackson 1984*[E] *Kern 1987*[A, D] *Kern 1991*[A, B] *Raessler 1988*[AE] *Weiser 1962*[AE] *Redding 1961*[E] *Rubertsson 1995a*[A, E] *Rubertsson 1995b*[A, E] *Sanders1985*[A, E] *Sanders 1984*[E]
Fair		Raman 1989 [A,C,D] Takino1993[AC]		Boczar 1995[E] Fialka 2004 [C,D] Hachimi-Idrissi 1997 [A,C, D] Mackay 2002 [C] Pottle 2002 [A,C] Powell 2004 [C, D] Seamon 2008 [C, D]	*Arai 1984*[E] *Barnett 1986*[E] *Emerman 1988*[E]
Poor				Calinas-Correia 2000 [A, B] Sheppard 2006 [C, D]	
	1	**2**	**3**	**4**	**5**
Level of evidence					

A = Return of spontaneous circulation
B = Survival of event
C = Survival to hospital discharge
D = Intact neurological survival
E = Other endpoint
Italics = *Animal studies*

Evidence Neutral to Clinical question

Good					
Fair					
Poor					
	1	**2**	**3**	**4**	**5**
Level of evidence					

A = Return of spontaneous circulation
B = Survival of event
C = Survival to hospital discharge
D = Intact neurological survival
E = Other endpoint
Italics = Animal studies

Evidence Opposing Clinical Question

Good					
Fair					
Poor					
	1	**2**	**3**	**4**	**5**
Level of evidence					

A = Return of spontaneous circulation
B = Survival of event
C = Survival to hospital discharge
D = Intact neurological survival
E = Other endpoint
Italics = Animal studies

REVIEWER'S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK:

DISCUSSION: Detailed literature review identified 31 studies of specific relevance. The highest Level of Evidence was LOE 2 (**2** study), there were **ten** other studies involving human patients (LOE 4). Nineteen animal studies (LOE 5) were identified.

Very few and non-conclusive human studies, evidence generally weak though the available human data does, however, support the experimental findings. In patients after non traumatic out-of-hospital cardiac arrest there are 4 studies:
8. Boczar 1995**, 498** (LOE 4, fair, positive) was a human clinical study involving 10 out-of hospital arrests who failed ACLS. The coronary perfusion pressure (CPP) was 7.3±5.7 and 32.6±17.8 mm Hg, in the CC-CPR and OC-CPR groups, respectively, thus confirming what repeatedly has been found in animal studies. Furthermore all patients had a CPP exceeding 15 mm Hg during OC-CPR.
30. Takino 1993**, 69** (LOE 2, fair, supportive) was a non-randomized uncontrolled study although a control group is involved. Totally 95 adult non-traumatic out-of-hospital patients were included out of which 26 consecutive patients had OC-CPR. Patient characteristics were similar in the two groups. On the basis of time statistics and experience the authors recommend OC-CPR to be undertaken within 5 min of arrival to hospital and unsuccessful preceding CC-CPR.
9. Calinas-Correia J 2000**, 201** (LOE 4, poor, positive) was a case series with 7 patients. Positive in physiological endpoints but no survivors. No control group
14. Hachimi-Idrissi S 1997**, 151** (LOE 4, fair, positive) was a case series of 33 patients with primarily unsuccessful resuscitation from out-of-hospital CA using closed-chest CPR. Open-chest was then tried with ROSC achieved in 13 patients. Two patients survived to discharge, one with no neurologic deficit and one patient with mild brain damage.

In cardiac arrest post cardiac surgery there are 4 studies:

2. Anthi 1998**, 113** (LOE 4, good, positive) was a study involving 29 consecutive cardiac patients (out of 3982 during a 30 months period) that arrested during the first 24h after cardiac surgery, given BLS or open-chest CPR. 45% resuscitated with CC-CPR, 48% with OC-CPR and 7% non-ROSC. Hospital discharge rate 79% with intact neurologic function. Internal control since closed-chest CPR was delivered before open-chest CPR.
18. Mackay 2002**, 421** (LOE 4, fair, positive) was a Prospective audit of a case series of 79 patients with CA after cardiac thoracic surgery, Better outcome in patients with reopening of chest within 10 mins from CA and also better outcome in patients where this was performed in the ICU and within 24 hrs from surgery.
19. Pottle 2002**, 269** (LOE **4**, fair, supportive) was a non-randomized clinical trial from the Royal Bromptom and Harefield hospitals extracted from a 4-year retrospective audit were reviewed in order to assess use of OC-CPR. Out of approx. totally 2500 cardiac operations (adults and children out of which approx 75% were adults) 72 arrested patients received OC-CPR. In this group ROSC was achieved in 46 % and survival to discharge in or 7%. No comparison is made to a control series or even historical controls but judged from their experience the authors obviously judged the results as good. On the basis of just personal experience and previous experimental work elsewhere the authors recommend that resternotomy and OC-CPR is performed already after 5 min of unsuccessful CC-CPR. Their findings of cardiac tamponade in 13% and surgical bleeding in 10% of the resternotomies further strengthens this recommendation.
22. Raman 1989**, 129** (LOE **2**, fair, positive) was a retrospective study of patients with cardiac arrest after cardiac surgery. Survival with NYHA Functional Class I and II status was noted in 75% of patients in treated with OC-CPR, compared with 20% in patients treated with CC-CPR only (P less than 0.002). According to autopsy results several of the patients only treated with CC-CPR would have required sternotomy which makes this study weak.

Finally, there are 4 studies of patient treated with thoracotomy and open chest CPR after trauma

12. Fialka 2004**, 809** (LOE 4, fair, positive) was a retrospective analysis of a case series of 38 patients with cardiac arrest after blunt chest or abdominal trauma. Supportive of open-chest CPR but not with any control group.
20. Powell **2004, 211** (LOE 4, fair, positive) was a register review of a case series of 26 patients with initial prehospital CPR followed by thoracotomy and open-chest CPR in emergency department. Positive outcome even if aystole at arrival at EMD if penetrating trauma and prehospital CPR of less than 15 minutes. No control group.
28. Seamon 2008**, 604** (LOE 4, fair, positive) was a retrospective review of 180 patients with penetrating injury and cardiac arrest that underwent emergency department thoracotomy. 23 patients survived to hospital discharge neurologically intact even if not evaluated as salvageable when presented at the field.
29. Sheppard 2006**, 574** (LOE 4, poor, positive) was a Case series of 27 patients with cardiac arrest after hemorrhagic shock after nontorso injury treated in EMD with open-chest CPR and aortic cross clamping. Three of 27 patients survived to hospital discharge with one patient having mild neurologic deficit.

Overwhelming homogenous animal evidence in favor of open-chest CPR as regards greater survival, perfusion pressures and organ blood flow. The available human data do, however, support the experimental findings but there is a lack of well performed

prospective randomized controlled studies in humans. Only hospital use of open-chest CPR is possible and appropriate and should be limited to physicians trained to perform open-chest CPR techniques. Open-chest CPR 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 indicated in cardiac arrest after blunt or penetrating trauma.

Acknowledgements:

Citation List

1. Angelos, M. G et al. : Arterial pH and carbon dioxide tension as indicators of tissue perfusion during cardiac arrest in a canine model. Crit Care Med 1992; 20:1302-1308.

Level 5. Good. Positive.
Twenty-four anaesthetized dogs studied to compare indicators of the chance of survival after VF after OC-CPR , CC-CPR and CPB. Left anterior descending coronary artery occluded before induction of VF. Four min downtime after which 8 min BLS was given. Then ACLS, CPB or OC-CPR was initiated. OC-CPR increased the CPP from 18 ±10 to 75± 41 mm Hg while the corresponding pressures for ACLS was 14±8 to105±40 and 16±16 to 22±53 mm Hg for CC-CPR. Survival was greater in the OC-CPR compared to BCLS, 75% survival after OC-CPR compared to 25% survival after BCLS. Survivors showed a significant greater metabolic acidosis compared to non-survivors during CPR. Coronary perfusion pressure was sign correlated to pH and $PaCO_2$. It was concluded that continuous central arterial pH as well as PaCO2 correlates with tissue perfusion during experimental cardiac arrest and CPR and may be a useful predictor of perfusion adequacy and eventual resuscitation.

2. Anthi, A et al: Unexpected cardiac arrest after cardiac surgery: Incidence, predisposing causes, and outcome of open chest cardiopulmonary resuscitation. Chest 1998;113:15-19.

Level 4. Good. Positive.
29 consecutive cardiac patients (out of 3982 during a 30 months period) that arrested during the first 24h after cardiac surgery, given BLS or open-chest CPR. 45% resuscitated with CC-CPR, 48% with OC-CPR and 7% non-ROSC. Hospital discharge rate 79% with intact neurologic function. Internal control since closed-chest CPR was delivered before open-chest CPR.

3. Arai, T et al : Cerebral blood flow during conventional, new and open-chest cardio-pulmonary resuscitation in dogs. Resuscitation 1984;12:147-154.

Level 5. Fair. Positive.
On the basis of 15 dogs studied they concluded that OC-CPR was far superior to CC-CPR as regards cerebral perfusion. Correctly estimated cerebral perfusion pressures for the two groups were 22 and 60 mm Hg, respectively. ICP was elevated to 30 and 36 MM Hg, respectively. The perfusion pressures resulted in a sinus blood flow of 18 and 42% of control prearrest values, respectively.

4. Barnett, W. et al: Comparison of open-chest cardiac massage techniques in dogs. Ann Emerg Med 1986;15:408-411.

Level 5. Fair. Positive.
Different positions of the hand and fingers were tested to assess the kind of open chest-CPR that gave most blood pressure and common carotid blood flow and ICP. The reference not quite adequate for our purposes.

5. Bartlett, R. L et al: Comparative study of three methods of resuscitation: closed-chest, open-chest manual, and direct mechanical ventricular assistance. Ann Emerg Med 1984;13: 773-777.

Level 5. Good. Positive.
Fifteen mongrel anaesthetized dogs of approx. 25 kg were studied. All received CC-CPR before OC-CPR. CC-CPR resulted in a cardiac output of 19% while OC-CPR gave 52% of control prearrest values, simultaneously mean arterial blood pressure was 19 and 45%, respectively, of prearrest control values.

6. Benson D. M et al: Open-chest CPR improves survival and neurologic outcome following cardiac arrest. Resuscitation 2005;64:209-217.

Level 5. Good. Positive.
Twelve mongrel dogs studied and were randomized to either CC-CPR or OC-CPR after 5 mins of untreated cardiac arrest. Animals were followed for 72 hrs and neurologic outcome evaluated as well as study of brain histology after animals were sacrified. Even if small number of animals significant better neurologic outcome after OC-CPR.

7. Bircher, N. and Safar P: Cerebral preservation during cardiopulmonary resuscitation. Crit Care Med 1985;13:185-190.

Level 5. Excellent. Positive.
Thirty-two dogs in 4 groups studied to compare OC-CPR with immediate defibrillation, standard CC-CPR and simultaneous ventilation-compression. OC-CPR yielded higher mean arterial and lower central venous pressures than external method. Six out of 8 dogs in the OC-CPR group were resuscitated while 7 out of 8 dogs in OC-CPR survived with a neurologic outcome not significantly different from the controls (immediate defib). All but one of the dogs in the simultaneous ventilation-compression group died, either as non-ROSCs (2) or as severe brain damage that did not survive 24h.

8. Boczar, M. E et al: A technique revisited: hemodynamic comparison of closed- and open-chest cardiac massage during human cardiopulmonary resuscitation. Crit Care Med 1995;23:498-503.

Level 4. Fair. Positive.
Human clinical study on 10 out-of hospital arrests who failed ACLS. The coronary perfusion pressure (CPP) was 7.3±5.7 and 32.6±17.8 mm Hg, in the CC-CPR and OC-CPR groups, respectively, thus confirming what repeatedly has been found in animal studies. Furthermore all patients had a CPP exceeding 15 mm Hg during OC-CPR.

9. Calinas-Correia J and Phair, I: Physiological variables during open chest cardiopulmonary resuscitation: results from a small series. J Accid Emerg Med 2000;17:201-204

Level 4. Poor. Positive
Case series with 7 patients. Positive in physiological endpoints but no survivors. No control group

10. DeBehnke, D. J et al: Comparison of standard external CPR, open-chest CPR, and cardiopulmonary bypass in a canine myocardial infarct model. Ann Emerg Med 1991;20:754-760.

Level 5. Good. Positive.
Canine myocardial infarct VF model. Survival was 9/9 after CPB, 6/9 after OC-CPR, and 2/8 after CC-CPR after 4 min down-time and 8 min of CC-CPR. There was a ratio of necrotic/ischemic myocardium at 4h of 015±0,31, 0,39±0,25 and 1,16±0,31 in the CPB, OC-CPR and CC-CPR groups, respectively, that can be explained by differences in the CPP achieved during CPR.

11. Emerman, C. L et al: Effect of injection site on circulation times during cardiac arrest. Crit Care Med 1988;16:1138-1141.

Level 5. Fair. Positive.
Eight dogs were studied 115 times to determine the circulation time from injection of dye to the carotid artery. After approx 75 minutes CC-CPR, OC-CPR was performed for 35 min. This protocol tends to underestimate the differences between the two different sorts of CPR. Anyway, while the circulation time was 62.7±19.6 after central injection it was in the order of 85-95 sec after more peripheral injection during CC-CPR. During OC-CPR the circulation time was 21.3±5.7 after central injection and 30-35 sec after more peripheral injection, thus confirming the more rapid blood flow generated during OC-CPR in comparison to CC-CPR.

12. Fialka C et al:Open-chest cardiopulmonary resuscitation after cardiac arrest in cases of blunt chest abdominal trauma: A consecutive series of 38 cases. J Trauma 2004;57: 809-814.

Level 4 Fair. Positive
Retrospective analysis of a case series of 38 patients with cardiac arrest after blunt chest or abdominal trauma. Supportive of OC-CPR but not with any control group.

13. Fleisher, G et al:Open- versus closed-chest cardiac compressions in a canine model of pediatric cardiopulmonary resuscitation. Am J Emerg Med 1985;3:305-310.

Level 5. Good. Positive.
Two groups, 5 animals each. Pediatric CPR model with determination of CBF according to Kety-Schmidt. OC-CPR generated a CBF 3-4 times as high as CC-CPR.

14. Hachimi-Idrissi S et al: Open chest cardiopulmonary resuscitation in out of hospital cardiac arrest. Resuscitation 1997;35:151-156.

Level 4 Fair. Positive

Case series of 33 patients with primarily unsuccessful resuscitation from out-of-hospital CA using closed-chest CPR. Open-chest was then tried with ROSC achieved in 13 patients. Two patients survived to discharge, one with no neurologic deficit and one patient with mild brain damage

15. Jackson, R. E et al : Blood flow in the cerebral cortex during cardiac resuscitation in dogs. Ann Emerg Med 1984;13: 657-659.

Level 5. Good. Positive.
Regional cerebral blood flow was determined in 15 anaesthetized large dogs by double thermistor dilution technique during VF and treatment with CC-CPR (with and without epinephrine) and OC-CPR, 5 dogs in each group. CC-CPR gave only 9.8 ±3.4% that increased to 36.1±22.3% of the pre-

arrest value when epinephrine was added. OC-CPR was much more effective resulting in a regional cerebral cortical flow of 156.6±79.2%. Differences were statistically significant.

16. Kern, K. B et al: Long-term survival with open-chest cardiac massage after ineffective closed-chest compression in a canine preparation. Circulation 1987;75:498-503.

Level 5. Good. Positive.
Dogs were assigned to 2 min of either CC-CPR, or OC-CPR after 15 min unsuccessful CC-CPR and defibrillation attempts. A follow-up revealed an immediate resuscitation success in all animals of the OC-CPR group vs. 4/14 in the CC-CPR group, and a follow-up after 7 days a survival of 11/14 vs 4/14, respectively. That means a significantly better 7 days survival after OC-CPR compared to CC-CPR after 15 min down-time.

17. Kern, K. B et al. Limitations of open-chest cardiac massage after prolonged, untreated cardiac arrest in dogs. Ann Emerg Med 1991;20:761-767.

Level 5. Good. Positive.
Although OC-CPR produced significantly better coronary perfusion pressure after 20 min down-time than CC-CPR, dogs did not survive 40 min down-time (all non-ROSCs). OC-CPR was equally effective after 10 and 20 min down-time, all had ROSC. Survival after CC-CPR was just 1 of 5 dogs after 20 min down-time.

18. Mackay JH et al: Six-year prospective audit of chest reopening after cardiac arrest. Eur J Cardiothorac Surg 2002;22:421-425.

Level 4. Fair. Positive

Prospective audit of a case series of 79 patients with CA after cardiac thoracic surgery, Better outcome in patients with reopening of chest within 10 mins from CA and also better outcome in patients where this was performed in the ICU and within 24 hrs from surgery.

19. Pottle, A et al: Survival to discharge following Open Chest Cardiac Compression (OCCC). A 4-year retrospective audit in a cardiothoracic specialist centre - Royal Brompton and Harefield NHS Trust, United Kingdom. Resuscitation 2002;52:269-272.

Level 4. Fair. Positive.
Non-randomized clinical trial from the Royal Bromptom and Harefield hospitals extracted from a 4-year retrospective audit were reviewed in order to assess use of OC-CPR. Out of approx. totally 2500 cardiac operations (adults and children out of which approx 75% were adults) 72 arrested patients received OC-CPR. In this group ROSC was achieved in 46 % and survival to discharge in or 7%. No comparison is made to a control series or even historical controls but judged from their experience the authors obviously judged the results as good. On the basis of just personal experience and previous experimental work elsewhere the authors recommend that resternotomy and OC-CPR is performed already after 5 min of unsuccessful CC-CPR. Their findings of cardiac tamponade in 13% and surgical bleeding in 10% of the resternotomies further strengthens this recommendation.

20. Powell DW et al: Is emergency department resuscitative thoracotomy futile care for the critically injured patient requiring prehospital cardiopulmonary resuscitation? J Am Coll Surg. 2004;199:211-215

Level 4 Fair. Positive
Register review of a case series of 26 patients with initial prehospital CPR followed by thoracotomy and open-chest CPR in emergency department. Positive outcome even if aystole at arrival at EMD if penetrating trauma and prehospital CPR of less than 15 minutes. No control group.

21. Raessler, K. L et al: Aortic and right atrial systolic pressures during cardiopulmonary resuscitation: a potential indicator of the mechanism of blood flow. Am Heart J 1988;115:1021-1029.

Level 5. Good. Positive.
Large series of dog studies, small and large anesthetized dogs. Three min down-time. Coronary perfusion pressure (CPP) determined in CC-CPR and OC-CPR (and vest-CPR) during VF. CPP was highest (64±4 mm Hg) in OC-CPR, somewhat smaller in small dogs in CC-CPR and still smaller in large dogs (21±2) in CC-CPR, and least in vest-CPR. This resulted in ROSC of all dogs in OC-CPR and small dogs in CC-CPR, but only 7/10 in groups given CC-CPR (and 8/10 in vest-CPR). Thus the CPP was 3 times higher in OC-CPR and 24h survival in CC-CPR approx 50% compared to approx 95% after OC-CPR.

22. Raman, J et al: Open cardiac compression in the postoperative cardiac intensive care unit. Anaesth Intens Care 1989;17:129-135.

Level **2**. Fair. Positive
Retrospective study of patients with cardiac arrest after cardiac surgery. Survival with NYHA Functional Class I and II status was noted in 75% of patients in treated with OC-CPR, compared with 20% in patients treated with CC-CPR only (P less than 0.002). According to autopsy results several of the patients only treated with CC-CPR would have required sternotomy which makes this study weak.

23. Redding, J. S. and Cozine R.A: A comparison of open-chest and closed-chest cardiac massage in dogs. Anesthesiology 1961;22:280-285. No abstract available.

Level 5. Good. Positive.
Old canine study of 20 anaesthetized dogs, rather small ones, 6-12 kg. Carotid blood flow measure by bubble flowmeter. CC-CPR preceded OC-CPR in 10 dogs in the others OC-CPR was begun immediately. Downtime only a few seconds. The mean arterial blood pressure and carotid blood flow was greater in during OC-CPR.

24. Rubertsson, S et al: Blood flow and perfusion pressure during open-chest versus closed-chest cardiopulmonary resuscitation in pigs. Crit Care Med 1995;23:715-725.

Level 5. Good. Positive.
Greater perfusion pressure and systemic blood flow =cardiac output was generated during OC-CPR compared to CC-CPR. Cardiac output is somewhat smaller than has been determined previously with other methods depending upon perfect mixing of indicator or dye. During relaxation phase some retrograde blood flow occurred in the pulmonary artery and the aorta.

25. Rubertsson, S et al: Systemic perfusion pressure and blood flow before and after administration of epinephrine during experimental cardiopulmonary resuscitation. Crit Care Med 1995;23: 1984-1996.

Level 5. Good. Positive.
A rather large pig study determining perfusion pressures and blood flows measured by a more unexceptional and modern technique that does not depend upon perfect mixing of indicator or dye (transit-time ultrasound flowmetry). The cardiac output during OC-CPR is at least double that during CC-CPR, the systemic blood flow is, however, less than determined with older methods (CC-CPR results in a flow of 5-10% and OC-CPR in 20% of prearrest control values). Epinephrine increases perfusion pressures both in CC-CPR and OC-CPR but temporarily decreases cardiac output.

26. Sanders, A. B et al: Improved resuscitation from cardiac arrest with open-chest massage. Ann Emerg Med 1984;13:672-675.

Level 5. Good. Positive.
After 15 min of CC-CPR and CPP less than 30 mm Hg OC-CPR was compared with CC-CPR. None of the dogs receiving CC-CPR survived while 4/5 of those given OC-CPR.

27. Sanders, A. B et al: Importance of the duration of inadequate coronary perfusion pressure on resuscitation from cardiac arrest. J Am Coll Cardiol 1985;6: 113-118.

Level 5. Good: Positive.
Although all the dogs receiving OC-CPR all had a significant increase in CPP the outcome of CPR depended upon the time of inadequate CPP before OC-CPR was initiated. After 15 min, 20 min and 25 min the incidence of ROSC was 6/8, 3/8 and none of eight dogs, respectively.

28. Seamon MJ et al: Emergency department thoracotomy: survival of the least expected. World J Surg 2008;32:604-612.

Level 4. Fair. Positive

Retrospective review of 180 patients with penetrating injury and cardiac arrest that underwent emergency department thoracotomy. 23 patients survived to hospital discharge neurologically intact even if not evaluated as salvageable when presented at the field.

29. Sheppard FR et al: Emergency department resuscitative thoracotomy for nontorso injuries. Surgery 2006;139:574-576

Level 4 Poor. Positive

Case series of 27 patients with cardiac arrest after hemorrhagic shock after nontorso injury treated in EMD with open-chest CPR and aortic cross clamping. Three of 27 patients survived to hospital discharge with one patient having mild neurologic deficit.

30. Takino, M. and Y. Okada: The optimum timing of resuscitative thoracotomy for non-traumatic out-of-hospital cardiac arrest. Resuscitation 1993;26: 69-74.

Level 2. Fair. Positive.
A non-randomized uncontrolled study although a control group is involved. Totally 95 adult non-traumatic out-of-hospital patients were included out of which 26 consecutive patients had OC-CPR. Patient characteristics were similar in the two groups. On the basis of time statistics and experience

the authors recommend OC-CPR to be undertaken within 5 min of arrival to hospital and unsuccessful preceding CC-CPR.

31. Weiser, F et al: Hemodynamic Effects of closed and open chest cardiac resuscitation in normal dogs and those with acute myocardial infarction. Am J Cardiol 1962;10:555-561. No abstract availble.

Level 5. Good. Positive.
Old, but an excellent canine study. In the first study it was clearly proven that CCCPR gives a cardiac output of 22% as opposed to OC-CPR that gives 55% of control prearrest values. In six dogs OC-CPR was preceded by CC-CPR and in all these cases there were higher mean arterial blood pressure in four and equal in 2.