WORKSHEET for Evidence-Based Review of Science for Veterinary CPCR

1. Basic Demographics

Worksheet author(s)

Kate Hopper	**Date Submitted for review:**
[redacted]	[redacted]

2. Clinical question:

In small dogs and cats with cardiac arrest (P), do circumferential chest compressions (I), compared to lateral chest compressions (C), improve outcome (eg. ROSC, survival)(O)?

3. Conflict of interest specific to this question:

The authors listed above have no conflict of interest disclosures relevant to this worksheet.
None

4. Search strategy (including electronic databases searched):

4a. Databases

Pubmed (NLM) (no date restriction) (performed on April 28, 2011); all searches were textword searches

1. CPR
2. Chest compressions
3. Circumferential
4. Vest
5. Positioning
6. Technique
7. Dogs
8. Cats
9. Infants

1 and 3: 3 relevant hits out of 14 total hits
1 and 4: 7 relevant hits out of 53 total hits
2 and 3: No additional relevant hits
2 and 4: No additional relevant hits
2 and 5: No additional relevant hits
2 and 6: No additional relevant hits
2 and 7: No additional relevant hits
2 and 8: No additional relevant hits
1 and 8: 1 relevant hit out of 36 total hits
1 and 9: 2 relevant hit out of 136 total hits

CAB Abstracts (1910 to Feb 2011) performed on April 28, 2011)

1. CPR
2. Chest compressions

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3. Circumferential
4. Vest
5. Positioning
6. Technique
7. Dogs
8. Cats

1 and 3: No relevant hits
1 and 4: No relevant hits
2 and 3: No relevant hits
2 and 4: No relevant hits
2 and 5: No relevant hits
2 and 6: No relevant hits
2 and 7: No relevant hits
2 and 8: No relevant hits

4b. Other sources

Google Scholar – Performed on April 7, 2011

1. Chest compressions
2. Circumferential
3. Vest
4. Positioning
5. Technique
6. Dogs
7. Cats
8. Infants

1 and 2: No additional relevant hits
1 and 3: No additional relevant hits
1 and 4: No additional relevant hits
1 and 5: No additional relevant hits
1 and 6: No additional relevant hits
1 and 7: No additional relevant hits
1 and 8: No additional relevant hits

In addition all references of identified articles as well as the following review article were checked:
Smith 2002
This yielded 2 additional relevant papers.

4c. State inclusion and exclusion criteria for choosing studies and list number of studies excluded per criterion

Inclusion criteria

Human and animal studies comparing circumferential chest compressions with conventional external chest compressions with a measurable outcome

Exclusion criteria

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Articles without a comparison group, articles evaluating load distributing band CPR, non English language articles, review articles or abstracts only.

4d. Number of articles/sources meeting criteria for further review: 11

- Two relevant human studies were identified (Halperin et al. 1993) and (Swenson 1988)
- Two relevant manikin studies were identified (Udassi 2009; Dorfsman 2000).
- Seven relevant animal experimental studies were identified (Halperin 1986a), (Halperin 1986b), (Newton 1988), (Niemann 1985), (Shafner 1994) (Kern 1987) (Krep 2003)

5. Summary of evidence

Evidence Supporting Clinical Question

Good						
Fair						***Udassi 2009***; *E=compression depth & pressure* ***Dorfsman 2000***; *E=arterial blood pressure*
Poor			**Halperin 1986**a; B, E=CPP **Niemann 1985**; B, E=CPP			
	1	**2**	**3**	**4**	**5**	**6**
Level of evidence (P)						

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

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Evidence Neutral to Clinical question

Good						
Fair			**Halperin 1986b**; E = cerebral & myocardial blood flow & 24hr survival **Kern 1987;** A,B, E = CPP, 24 hour survival & neurologic deficits			***Halperin 1993****;A, E=CPP*
Poor			**Krep 2003;** E = no cpr endpoint			***Shaffner 1994****; E = cerebral & myocardial blood flow* ***Swenson 1988****; E=aortic and CPP*
	1	**2**	**3**	**4**	**5**	**6**
Level of evidence (P)						

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

Evidence Opposing Clinical Question

Good						
Fair						
Poor			**Newton1988**; E=brachiocephalic blood flow, cardiac output & CPP			
	1	**2**	**3**	**4**	**5**	**6**
Level of evidence (P)						

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

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

Circumferential chest compressions can be achieved by manual techniques in small patients, or alternatively automated systems can be used. Two studies were found that evaluated manual chest compression techniques in the form of a 'two thumb' technique for human infants. In this technique the rescuer places both hands around the chest with their thumbs meeting at the sternum. There is some similarity between this approach and the hand position that can be used in cats and small dogs. These two studies used human infant manikins and reported higher compression pressures, greater compression depth and higher arterial pressures with the two thumb technique compared to the more usual two finger technique for chest compressions (Udassi 2009; Dorfsman 2000).

Automated approaches to external chest compressions have been utilized in animal models and human clinical trials. Circumferential chest compressions are achieved by use of a pneumatic vest (vest CPR) that encircles the thorax and is rhythmically inflated to a specific pressure then deflated. This generates blood flow via the thoracic pump mechanism. All the studies comparing circumferential chest compressions with regular external compressions perform the regular compressions in the anterior posterior (sternal) direction.

Two experimental studies in dogs found vest CPR generated greater coronary perfusion pressures and was associated with greater 24 hour survival when compared to sternal compressions (Niemann 1985; Halperin 1986a). A difficulty in comparison of external compression techniques is variations in the force or pressure and compression rate used. In one of the aforementioned studies, vest CPR generated far greater cerebral blood flow than conventional CPR when a compression force of 300N was used for both techniques (Halperin 1986a). When conventional CPR was performed with a force of 430N, similar coronary and cerebral perfusion pressures to vest CPR could be generated. The higher compression force was associated with more severe rib and liver trauma and 24 hour survival was still greater in the vest CPR group. In the second study the vest device was pressurized to 200mmHg during inflation and this device also generated abdominal pressures of 100mmHg so it is difficult to directly compare these two studies (Niemann 1985).

The majority of identified studies evaluating circumferential CPR did not find it to be superior or inferior compared to conventional sternal chest compressions. In one experimental dog study, no significant difference in the coronary perfusion pressure was achieved between vest CPR and sternal compressions, with compressions maintained at equal force (400N) and rate in both techniques (Halperin 1986b). In a second experimental dog study, vest CPR pressurized to 200mmHg found no difference in coronary perfusion pressure, return of spontaneous circulation, 24 hour survival or neurological recovery (Kern 1987). An experimental study in pigs compared cerebral and myocardial blood flow achieved with vest CPR inflated to 150mmHg, to previously published studies of conventional CPR in the same model from the same laboratory and found no difference in efficacy (Shaffner 1994). One human clinical study comparing vest CPR (pressures of 180-250 mmHg), in a small number of patients (n=15) that had suffered prolonged (42±16 minutes) unsuccessful conventional CPR with sternal compressions at a force of 400N found vest CPR generated greater coronary perfusion pressures but there was no statistical improvement in occurrence of return of spontaneous circulation. This study also performed early vest CPR in 17 patients (13±4 minutes of unsuccessful conventional CPR). There was an insignificant trend towards increased return of spontaneous circulation in this group. A second human clinical study evaluated vest CPR in 9 patients at pressures of 200 – 300mmHg and found it generated similar coronary perfusion pressure to conventional CPR. (Swenson 1988) Only one study of vest CPR in cats could be identified, this study demonstrated vest CPR could successfully resuscitate cats with ventricular fibrillation in an experimental setting, but no control group was included so the relative efficacy of this approach compared to conventional CPR could not be determined (Krep 2003).

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One experimental dog study compared vest CPR with both manual and mechanical sternal compression techniques and found that vest CPR generated the lowest coronary perfusion pressures of all methods evaluated (Newton 1988). It is important to note that in this study the inflation pressure of the vest was only 100mmHg so this may not be a valid comparison to other vest CPR studies.

There is insufficient evidence to recommend circumferential chest compressions during CPR in dogs and cats at this time. The studies of the human infant two thumb technique raise the possibility that manual circumferential compressions in small animals could be superior to lateral compressions and warrants further investigation. The majority of investigations published on circumferential chest compressions utilize a pneumatic vest and compare its performance to manual or mechanical sternal compressions. As CPR in clinical canine and feline patients is most commonly performed in lateral recumbency, it is difficult to extrapolate the findings of these studies. The commercially available pneumatic vest for human patients is large and inconvenient which may further reduce its applicability to the veterinary clinical setting.

7. Conclusion

DISCLAIMER: Potential possible wording for a Consensus on Science Statement. Final wording will differ due to other input and discussion.

CONSENSUS ON SCIENCE: Two human infant manikin studies (LOE6) found a circumferential manual chest compression technique, the two thumb technique, generated greater arterial pressures, compression pressure and compression depth than the more traditional two finger technique (Udassi 2009; Dorsman 2000). This technique may have similarities to manual circumferential techniques that can be used in cats and small dogs. Two experimental dog studies (LOE3) reported superior coronary perfusion pressure and short-term survival with circumferential (vest) compressions compared to sternal compressions (Niemann 1985; Halperin 1986a). Two experimental dog studies (LOE3), one pig study and two human clinical studies (LOE6) found neither superiority nor inferiority of vest CPR compared to sternal compressions. (Halperin 1986b; Kern 1987; Shaffner 1994; Halperin 1993; Swenson 1988). One experimental dog study (LOE3) using vest CPR at lower pressures than other studies found it generated lower coronary perfusion pressures compared to other sternal compression techniques (Newton 1988). As the vest pressures and compression rates utilized in these studies varied substantially and all studies compared performance to sternal chest compressions, the relevance of this approach to canine and feline CPR remains to be defined. One study of vest CPR in cats (LOE3) demonstrated this approach can be effective in feline patients but the relative efficacy of this approach compared to conventional CPR is unknown (Krep 2003). No studies are identified that examine manual circumferential chest compressions in dogs and cats.

8. Acknowledgement

None

9. Citation list

Two-thumb vs. two-finger chest compression in an infant model of prolonged cardiopulmonary resuscitation.
Dorfsman ML, Menegazzi JJ, Wadas RJ, Auble TE.
Acad Emerg Med. 2000;7(10):1077-82.

OBJECTIVE:

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Comment [1]: 1. Resuscitation. 2010 Jun;81(6):712-7. Epub 2010 Mar 12.

Two-thumb technique is superior to two-finger technique during lone rescuer
infant manikin CPR.

Udassi S, Udassi JP, Lamb MA, Theriaque DW, Shuster JJ, Zaritsky AL, Haque IU.

Division of Pediatric Critical Care Medicine, Department of Pediatrics,
University of Florida College of Medicine, Gainesville, FL 32610, USA.

OBJECTIVE: Infant CPR guidelines recommend two-finger chest compression with a
lone rescuer and two-thumb with two rescuers. Two-thumb provides better chest
compression but is perceived to be associated with increased ventilation
hands-off time. We hypothesized that lone rescuer two-thumb CPR is associated
with increased ventilation cycle time, decreased ventilation quality and fewer
chest compressions compared to two-finger CPR in an infant manikin model.
DESIGN: Crossover observational study randomizing 34 healthcare providers to ... [1]

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Comment [2]: Was just wondering whether you want to look quickly through some neonatal peds CPR, where the two-thumb technique is pretty close to what we are doing in cats, maybe? What do you think. Cer ... [2]

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Previous experiments in the authors' swine lab have shown that cardiopulmonary resuscitation (CPR) using two-thumb chest compression with a thoracic squeeze (TT) produces higher blood and perfusion pressures when compared with the American Heart Association (AHA)-recommended two-finger (TF) technique. Previous studies were of short duration (1-2 minutes). The hypothesis was that TT would be superior to TF during prolonged CPR in an infant model.

METHODS:

This was a prospective, randomized crossover experiment in a laboratory setting. Twenty-**one** AHA-certified rescuers performed basic CPR for two 10-minute periods, one with TT and the other with TF. Trials were separated by 2-14 days, and the order was randomly assigned. The experimental circuit consisted of a modified manikin with a fixed-volume arterial system attached to a neonatal monitor via an arterial pressure transducer. The arterial circuit was composed of a 50-mL bag of normal saline solution (air removed) attached to the manikin chest plate and connected to the transducer with a 20-gauge intravenous catheter and tubing. Rescuers were blinded to the arterial pressure tracing. Systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) were recorded in mm Hg, and pulse pressures (PPs) were calculated. Data were analyzed with two-way repeated-measures analysis of variance. Sphericity assumed modeling, with Greenhouse-Geisser and Huynh-Feldt adjustments, was applied.

RESULTS:

Marginal means for TT SBP (68.9), DBP (17.6), MAP (35.3), and PP (51.4) were higher than for TF SBP (44.8), DBP (12.5), MAP (23.3), and PP (32.2). All four pressures were significantly different between the two techniques (p< or =0.001).

CONCLUSION:

In this infant **CPR** model, TT chest compression produced higher MAP, SBP, DBP, and PP when compared with TF chest compression during a clinically relevant duration of prolonged CPR.

Key point: LOE 6, **supportive**, fair. A human infant manikin study that found the two thumb chest compression technique generated higher arterial pressures than the traditional two finger technique.

Effect of alternative chest compression techniques in infant and child on rescuer performance.

Udassi JP, Udassi S, Theriaque DW, Shuster JJ, Zaritsky AL, Haque IU.
Pediatr Crit Care Med. 2009;10(3):328-33.

OBJECTIVE:

Current chest compression (CC) guidelines for an infant recommend a two-finger (TF) technique with lone rescuer and a two- thumb (TT) technique with two rescuers, and for a child either an one hand (OH) or a two hand (TH) technique with one or two rescuers. The effect of a 30:2 compression:ventilation ratio using these techniques on CC quality and rescuer fatigue is unknown. We hypothesized that during lone rescuer CC, TT technique, in infant and TH in child achieve better compression depth (CD) without additional rescuer fatigue compared with TF and OH, respectively.

DESIGN:

Randomized observational study.

SETTING:

University-affiliated pediatric hospital.

SUBJECTS:

Adult healthcare providers certified in basic life support or pediatric advanced life support.

INTERVENTIONS:

Laerdal baby advanced life support trainer and Resusci junior manikin were modified to digitally record CD, compression pressure (CP) and compression rate. Sixteen subjects were randomized to each of the four techniques to perform 5 minutes of lone rescuer 30:2 compression:ventilation cardiopulmonary resuscitation. Rescuer heart rate (HR) and respiratory rate were recorded continuously and the recovery time interval for HR/respiratory rate to return to baseline was determined. Subjects were blinded to data recording. Groups were compared using two-sample, two-sided Student's t tests.

MEASUREMENTS AND MAIN RESULTS:

Two-thumb technique generated significantly higher CD and peak CP compared with TF ($p < 0.001$); there was no significant difference between OH **vs**. TH. TF showed decay of CD and CP over time compared with TT. Compression rate (per minute) and actual compressions delivered were not significantly different between groups. No significant differences in fatigue and recovery time were observed, except the TT group had greater increase in the rescuer's HR (bpm) from baseline compared with TF group ($p = 0.04$).

CONCLUSIONS:

Two-thumb compression provides higher CD and CP compared with TF without any evidence of decay in quality and additional rescuer fatigue over 5 minutes. There was no significant difference in child CC quality or rescuer fatigue between OH and TH. Two-thumb technique is preferred for infant CC and our data support the current guidelines for child CC.

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Key point: LOE 6, **supportive**, fair. A human infant manikin study that found the two finger technique of chest compression generated higher compression pressure and greater compression depth than two finger compressions.

Vest inflation without simultaneous ventilation during cardiac arrest in dogs: improved survival from prolonged cardiopulmonary resuscitation.

Halperin HR, Guerci AD, Chandra N, Herskowitz A, Tsitlik JE, Niskanen RA, Wurmb E, Weisfeldt ML. Circulation. 1986 Dec;74(6):1407-15.

Abstract

Myocardial and cerebral blood flow can be generated during cardiac arrest by techniques that manipulate intrathoracic pressure. Augmentation of intrathoracic pressure by high-pressure ventilation simultaneous with compression of the chest in dogs has been shown to produce higher flows to the heart and brain, but has limited usefulness because of the requirement for endotracheal intubation and complex devices. A system was developed that can produce high intrathoracic pressure without simultaneous ventilation by use of a pneumatically cycled vest placed around the thorax (vest cardiopulmonary resuscitation [CPR]). The system was first tested in a short-term study of the maximum achievable flows during arrest. Peak vest pressures up to 380 mm Hg were used on eight 21 to 30 kg dogs after induction of ventricular fibrillation and administration of epinephrine. Microsphere-determined myocardial blood flow was 108 +/- 17 ml/min/100 g (100 +/- 16% of prearrest flow) and cerebral flow was 51 +/- 12 ml/min/100 g (165 +/- 39% of prearrest). Severe lung or liver trauma was noted in three of eight dogs. If peak vest pressure was limited to 280 mm Hg, however, severe trauma was no longer observed. A study of the hemodynamics during and survival from prolonged resuscitation was then performed on three groups of seven dogs. Vest CPR was compared with manual CPR with either conventional (300 newtons) or high (430 newtons) sternal force. After induction of ventricular fibrillation, each technique was performed for 26 min. Defibrillation was then performed. After 20 min of resuscitation, vest CPR produced a myocardial flow of 54 ± 13 ml/min/100g (40 ± 9% of prearrest flow) and a cerebral flow 37 ± 4 ml/min/100g (99 ± 11% of prearrest). With conventional sternal force, manual CPR produced lower myocardial and cerebral flows than did the vest method ($p<.04$), and resulted in fewer next-day surivors (7/7 for vest vs 1/7 for manual, $p<.003$). With high sternal force, flows were similar to those obtained with the vest, but more dogs had severe rib or liver trauma (0/7 for vest vs 4/7 for manual, $p<.04$), and there were still fewer survivors than with the vest method (3/7, $p<.04$ vs vest). Thus, at very high pressures, vest CPR can generate essentially normal myocardial and cerebral flow, but can also produce severe trauma. At lower pressures, vest CPR can improve survival after cardiac arrest, while producing less trauma than manual CPR performed with sufficient compression to generate comparable flows. Vest CPR warrants study in many as a potential means for augmenting flow during cardiac arrest without the need for endotracheal intubation and simultaneous ventilation.

Key point: LOE 3, Supportive, Poor. Experimental study in a small number of dogs found vest cpr was associated with greater myocardial and cerebral blood flow and greater survival than manual sternal compressions. Manual sternal compressions sufficient to produce similar hemodynamic performance as vest cpr caused greater thoracic trauma.

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Comment [3]: I guess this 1986a and not 1986b

Mechanical "cough" cardiopulmonary resuscitation during cardiac arrest in dogs.

Niemann JT, Rosborough JP, Niskanen RA, Alferness C, Criley JM. Am J Cardiol. 1985 Jan 1;55(1):199-204.

Abstract

Hemodynamic findings during ventricular fibrillation (VF) and closed-chest cardiopulmonary resuscitation (CPR) are similar to those described during VF and vigorous coughing. Interventions during CPR that mimic the physiologic events of coughing (high intrathoracic pressure and high intraabdominal pressure) improve perfusion during VF and CPR. An external circulatory assist apparatus was devised to emulate cough physiology, i.e., simultaneous pulsatile increases in intrathoracic pressure (pneumatic vest), intraabdominal pressure (abdominal binder) and airway pressure (high-pressure airway inflation). In this study, vest/binder CPR was compared with conventional CPR during 30 minutes of VF and artificial support in 18 randomized dogs. Defibrillation and long-term (more than 24 hours) survival were chosen as end points. During VF and artificial support, aortic and right atrial (RA) pressures, the instantaneous aortic-RA pressure difference (coronary perfusion pressure) and blood gas levels were measured. After 30 minutes of VF and administration of 1 mg of epinephrine, countershock was attempted. Systolic aortic and RA pressures, mean aortic-RA pressure difference and blood gas levels were not significantly different between dogs that were successfully resuscitated and those that were not. However, peak diastolic coronary perfusion pressure (peak diastolic aortic-RA pressure) for survivors averaged 23 +/- 6 mm Hg, but only 6 +/- 10 mm Hg for non-survivors (p less than 0.001). A peak diastolic coronary perfusion pressure 16 mm Hg or greater had a positive and negative predictive value for a successful outcome of 1.00. Only 1 of 9 conventional CPR dogs survived 24

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hours; 7 of 9 dogs supported with the vest/binder device were alive and neurologically normal at 24 hours (p = 0.007). Thus resuscitation techniques that exploit the CPR "thoracic pump" can sustain systemic perfusion during VF, and diastolic coronary perfusion pressure is a determinant of CPR/countershock outcome and is favorably manipulated by mechanical means.
Key point: **LOE 3, Supportive, Poor.** Experimental dog study found vest cpr associated with greater coronary perfusion pressures and 24 hour survival than conventional (sternal) cpr. The vest device used in this study also generated abdominal pressures.

Determinants of blood flow to vital organs during cardiopulmonary resuscitation in dogs.

Halperin HR, Tsitlik JE, Guerci AD, Mellits ED, Levin HR, Shi AY, Chandra N, Weisfeldt ML.
Circulation. 1986 Mar;73(3):539-50.

Abstract
Whether blood flow during cardiopulmonary resuscitation (CPR) results from intrathoracic pressure fluctuations or direct cardiac compression remains controversial. From modeling considerations, blood flow due to intrathoracic pressure fluctuations should be insensitive to compression rate over a wide range, but dependent on the applied force and compression duration. If direct compression of the heart plays a major role, however, flow should be dependent on compression rate and force, but above a threshold, insensitive to compression duration. These differences in hemodynamics produced by changes in rate and duration form a basis for determining whether blood flow during CPR results from intrathoracic pressure fluctuations or from direct cardiac compression. Manual CPR was studied in eight anesthetized, 21 to 32 kg dogs after induction of ventricular fibrillation. There was no surgical manipulation of the chest. Myocardial and cerebral blood flows were determined with radioactive microspheres. At nearly constant peak sternal force (378 to 426 newtons), flow was significantly increased when the duration of compression was increased from 14 +/- 1% to 46 +/- 3% of the cycle at a rate of 60/min. Flow was unchanged, however, after an increase in rate from 60 to 150/min at constant compression duration. The hemodynamics of manual CPR were next compared with those produced by vest inflation with simultaneous ventilation (vest CPR) in eight other dogs. Vest CPR changed intrathoracic pressure without direct cardiac compression, since sternal displacement was less than 0.8 cm. At a rate of 150/min, with similar duration and right atrial peak pressure, manual and vest CPR produced similar flow and perfusion pressures. Finally, the hemodynamics of manual CPR were compared with the hemodynamics of direct cardiac compression after thoracotomy. Cardiac deformation was measured and held nearly constant during changes in rate and duration. As opposed to changes accompanying manual CPR, there was no change in perfusion pressures when duration was increased from 15% to 45% of the cycle at a constant rate of 60/min. There was, however, a significant increase in perfusion pressures when rate was increased from 60 to 150/min at a constant duration of 45%. Thus, vital organ perfusion pressures and flow during manual external chest compression are dependent on the duration of compression, but not on rates of 60 or 150/min. These data are similar to those observed for vest CPR, where intrathoracic pressure is manipulated without sternal displacement, but opposite of those observed for direct cardiac compression. We conclude that intrathoracic pressure fluctuations generate blood flow during manual CPR.
Key point: **LOE 3, neutral, fair.** An experimental dog study in a small number of animals – vest CPR produced similar hemodynamic performance as manual sternal compressions. Provides evidence for thoracic pump mechanism.

Comparison of mechanical techniques of cardiopulmonary resuscitation: survival and neurologic outcome in dogs.

Kern KB, Carter AB, Showen RL, Voorhees WD 3rd, Babbs CF, Tacker WA, Ewy GA.
Am J Emerg Med. 1987 May;5(3):190-5.

Abstract
Three currently available mechanical devices for cardiopulmonary resuscitation (CPR) were compared using a canine cardiac arrest model. Twenty-four-hour survival without neurologic deficit was the goal. A group of 30 large mongrel dogs was divided equally among Thumper CPR, simultaneous compression and ventilation (SCV) CPR, and vest CPR. Ventricular fibrillation was induced electrically, and after 3 minutes of no intervention, one of the three types of mechanical CPR was performed for 17 minutes. SCV CPR and vest CPR produced significantly greater aortic and right atrial systolic pressures than Thumper CPR (P less than .03). The SCV CPR technique also produced significantly higher aortic diastolic pressure and right atrial diastolic pressure than either of the other methods (P less than .03). However, coronary perfusion pressure was not different among the three mechanical methods. No differences in immediate resuscitation, 24-hour survival, or neurologic deficit scores at 24 hours were found. Neither SCV nor the vest techniques of CPR appear better for survival or neurologic outcome than standard cardiopulmonary resuscitation performed with the Thumper.

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Key point: **LOE 3, neutral, fair.** An experimental dog study comparing vest CPR, mechanical sternal compressions and simultaneous compression/ventilation CPR and found no difference in coronary perfusion pressure or 24 hour survival between the techniques.

A preliminary study of cardiopulmonary resuscitation by circumferential compression of the chest with use of a pneumatic vest.

Halperin HR, Tsitlik JE, Gelfand M, Weisfeldt ML, Gruben KG, Levin HR, Rayburn BK, Chandra NC, Scott CJ, Kreps BJ, et al.
N Engl J Med. 1993 Sep 9;329(11):762-8.

Abstract
BACKGROUND:
More than 300,000 people die each year of cardiac arrest. Studies have shown that raising vascular pressures during cardiopulmonary resuscitation (CPR) can improve survival and that vascular pressures can be raised by increasing intrathoracic pressure.
METHODS:
To produce periodic increases in intrathoracic pressure, we developed a pneumatically cycled circumferential thoracic vest system and compared the results of the use of this system in CPR (vest CPR) with those of manual CPR. In phase 1 of the study, aortic and right-atrial pressures were measured during both vest CPR (60 inflations per minute) and manual CPR in 15 patients in whom a mean (+/- SD) of 42 +/- 16 minutes of initial manual CPR had been unsuccessful. Vest CPR was also carried out on 14 other patients in whom pressure measurements were not made. In phase 2 of the study, short-term survival was assessed in 34 additional patients randomly assigned to undergo vest CPR (17 patients) or continued manual CPR (17 patients) after initial manual CPR (duration, 11 +/- 4 minutes) had been unsuccessful.
RESULTS:
In phase 1 of the study, vest CPR increased the peak aortic pressure from 78 +/- 26 mm Hg to 138 +/- 28 mm Hg ($P < 0.001$) and the coronary perfusion pressure from 15 +/- 8 mm Hg to 23 +/- 11 mm Hg ($P < 0.003$). Despite prolonged unsuccessful manual CPR, spontaneous circulation returned with vest CPR in 4 of the 29 patients. In phase 2 of the study, spontaneous circulation returned in 8 of the 17 patients who underwent vest CPR as compared with only 3 of the 17 patients who received continued manual CPR ($P = 0.14$). More patients in the vest-CPR group than in the manual-CPR group were alive 6 hours after attempted resuscitation (6 of 17 vs. 1 of 17) and 24 hours after attempted resuscitation (3 of 17 vs. 1 of 17), but none survived to leave the hospital.
CONCLUSIONS:
In this preliminary study, vest CPR, despite its late application, successfully increased aortic pressure and coronary perfusion pressure, and there was an insignificant trend toward a greater likelihood of the return of spontaneous circulation with vest CPR than with continued manual CPR. The effect of vest CPR on survival, however, is currently unknown and will require further study.
Key point: **LOE 6, neutral, fair.** Human clinical study comparing vest CPR with manual CPR in patients following a period of unsuccessful manual CPR. Increased ROSC, but no difference in survival could be shown. Given the late application of the intervention the clinical relevance of this study is unknown.

Effect of vest cardiopulmonary resuscitation on cerebral and coronary perfusion in an infant porcine model.

Shaffner DH, Schleien CL, Koehler RC, Eberle B, Traystman RJ.
Crit Care Med. 1994 Nov;22(11):1817-26.

Abstract
OBJECTIVES:
To determine cerebral and myocardial blood flow rates during vest cardiopulmonary resuscitation (CPR) without direct cardiac compression in an infant porcine model. Also, to determine if circumferential chest compression without the chest deformity ordinarily associated with precordial compression maintains cerebral and myocardial blood flow rates during prolonged CPR. Finally, to establish the effect of compression rate and duty cycle on cerebral and myocardial blood flow rates during vest CPR in this model.
DESIGN:
Prospective, randomized comparison of two compression rates and two duty cycles in four groups during prolonged CPR.
SETTING:
University cerebral resuscitation laboratory.
SUBJECTS:
Thirty-two infant domestic swine.

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INTERVENTIONS:
Microsphere-determined cerebral and myocardial blood flow rates, perfusion pressures, and chest dimensions, were measured before and during prolonged vest CPR. Immediately after ventricular fibrillation, epinephrine administration was started and thoracic vest CPR was performed using a single combination of compression rates of 100 or 150/min and duty cycles of 30% or 60%. Measurements were made before and at 5, 10, 20, 35, and 50 mins of CPR.
MEASUREMENTS AND MAIN RESULTS:
Five minutes into CPR, between-group comparisons showed that cerebral blood flow was 16 to 20 mL/min/100 g and myocardial blood flow was 34 to 45 mL/min/100 g (48% to 62% and 25% to 33% of prearrest values). When CPR was prolonged, cerebral blood flow deteriorated similarly in all groups. Myocardial blood flow decreased over time but was better maintained in the groups with a 30% duty cycle (24 vs. 4 mL/min/100 g; $p < .006$). There were no differences between the two compression rates. Chest deformity after cessation of 50 mins of compression was < 3%.
CONCLUSIONS:
Cerebral and myocardial blood flow rates produced by vest CPR are comparable with rates reported using other types of CPR in this model. Deterioration in blood flow during prolonged CPR occurs despite a lack of chest deformation. The deterioration in myocardial blood flow during prolonged CPR is greater when a long duty cycle is used in this model.
Key point: **LOE 6, neutral, poor.** An experimental pig study of hemodynamic effects of vest cpr, the results are compared to a previous studies of sternal cpr. No significant differences were found between any of the techniques.

Hemodynamics in humans during conventional and experimental methods of cardiopulmonary resuscitation.

Swenson RD, Weaver WD, Niskanen RA, Martin J, Dahlberg S.
Circulation. 1988 Sep;78(3):630-9.

Abstract
High-fidelity hemodynamic recordings of aortic and right atrial pressures and the coronary perfusion gradient (the difference between aortic and atrial pressure) were made in nine patients during cardiopulmonary resuscitation (CPR). Findings during conventional manual CPR were compared with those during high-impulse CPR (rate, 120 cycles/min with a shorter compression:relaxation ratio) as well as during pneumatic vest CPR with and without simultaneous ventilation and abdominal binding. Aortic peak pressure during conventional CPR averaged 61 +/- 29 mm Hg but varied widely (range, 39-126 mm Hg) among patients. Although the magnitude of improvement was modest, the high-impulse method was the only technique tested that significantly elevated both aortic peak pressure and the coronary perfusion gradient during cardiac arrest. During conventional CPR, aortic pressure rose from 61 +/- 29 to 80 +/- 39 mm Hg during high-impulse CPR, and the gradient rose from 9 +/- 11 to 14 +/- 15 mm Hg, respectively; p less than 0.01. The pneumatic vest method significantly improved peak aortic pressure but not the coronary perfusion gradient. Simultaneous ventilation and chest compression created high end-expiratory pressure and lowered the coronary perfusion gradient. Abdominal binding had no significant hemodynamic effects. This evaluation of experimental resuscitation methods in humans shows that the high-impulse chest compression method augments aortic pressure over levels achieved during conventional CPR methods; however, the improvement in pressure is modest and may not be clinically important. Simultaneous ventilation as well as abdominal binding during CPR were associated with no benefit; in fact, simultaneous ventilation appears to adversely affect cardiac perfusion and, therefore, should not be used during clinical resuscitation.
Key point: **LOE 6, neutral, poor.** Human clinical study of a small number of patients comparing vest cpr with other cpr techniques, all techniques were performed in all patients in a randomized fashion. The coronary perfusion pressure (end point) was not improved in vest cpr compared to conventional cpr.

Time course of circulatory and metabolic recovery of cat brain after cardiac arrest assessed by perfusion- and diffusion-weighted imaging and MR-spectroscopy.

Krep H, Böttiger BW, Bock C, Kerskens CM, Radermacher B, Fischer M, Hoehn M, Hossmann KA.
Resuscitation. 2003 Sep;58(3):337-48.

Abstract
Brain recovery after cardiac arrest (CA) was assessed in cats using arterial spin tagging perfusion-weighted imaging (PWI), diffusion-weighted imaging (DWI), and 1H-spectroscopy (1H-MRS). Cerebral reperfusion and metabolic recovery was monitored in the cortex and in basal ganglia for 6 h after cardiopulmonary resuscitation (CPR). Furthermore, the effects of an hypertonic/hyperoncotic solution (7.5% NaCl/6% hydroxyl ethyl starch, HES) and a tissue-type plasminogen activator (TPA), applied during CPR, were assessed on brain recovery. CA and CPR were carried out in the MR scanner by remote control. CA for

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15-20 min was induced by electrical fibrillation of the heart, followed by CPR using a pneumatic vest. PWI after successful CPR revealed initial cerebral hyperperfusion followed by delayed hypoperfusion. Initial cerebral recirculation was improved after osmotic treatment. Osmotic and thrombolytic therapy were ineffective in ameliorating delayed hypoperfusion. Calculation of the apparent diffusion coefficient (ADC) from DWI demonstrated complete recovery of ion and water homeostasis in all animals. 1H-MRS measurements of lactate suggested an extended preservation of post-ischaemic anaerobic metabolism after TPA treatment. The combination of noninvasive MR techniques is a powerful tool for the evaluation of therapeutical strategies on circulatory and metabolic cerebral recovery after experimental cerebral ischaemia.

Key point: **LOE 3, neutral, poor.** A study of brain function in cats post cpr, the cats were resuscitated with vest cpr technique. This study has no comparison group, it purely demonstrates that vest cpr can be effective in cats.

A physiologic comparison of external cardiac massage techniques.

Newton JR Jr, Glower DD, Wolfe JA, Tyson GS Jr, Spratt JA, Fenely MP, Rankin JS, Olsen CO.
J Thorac Cardiovasc Surg. 1988 May;95(5):892-901.

Abstract

On the basis of recent investigation, controversy has arisen regarding which of several cardiopulmonary resuscitation methods optimizes hemodynamics. The present study was designed to compare five recently described chest compression techniques: high-impulse manual chest compression at 150/min, mechanical compression at 60/min with simultaneous ventilation, mechanical compression at 60/min with simultaneous ventilation and either systolic or diastolic abdominal compression, and pneumatic vest compression at 60/min. Eight dogs were chronically instrumented with electromagnetic flow probes in the ascending and descending aorta while matched micromanometers measured aortic, left ventricular, and pleural pressures. At study, each dog was anesthetized with morphine, intubated, and the heart was fibrillated by rapid ventricular pacing. The five cardiopulmonary resuscitation methods were performed randomly in each preparation within 7 to 10 minutes of arrest. In four dogs, brachiocephalic blood flow was computed as total cardiac output minus descending aortic blood flow, and in all dogs coronary perfusion pressure was calculated as mean diastolic aortic pressure minus mean diastolic left ventricular pressure. Average cardiac output for seven studies was 662 +/- 61 ml/min with high-impulse manual compression, 340 +/- 46 ml/min with mechanical compression and simultaneous ventilation, 336 +/- 45 ml/min with mechanical compression and simultaneous ventilation with systolic abdominal compression, 366 +/- 52 ml/min with mechanical compression and simultaneous ventilation with diastolic abdominal compression, and 196 +/- 29 ml/min with vest resuscitation (high-impulse manual compression significantly greater than other techniques by multivariate analysis, p less than 0.05). Brachiocephalic blood flow generally followed cardiac output and was statistically the greatest with high-impulse manual compression at 273 +/- 47 ml/min (p less than 0.05). Finally, high-impulse manual compression provided the highest coronary perfusion pressure of 31 +/- 4 mm Hg (p less than 0.05) compared to 23 +/- 2 mm Hg for mechanical compression and simultaneous ventilation, 23 +/- 2 mm Hg for mechanical compression and simultaneous ventilation with systolic abdominal compression, 23 +/- 3 mm Hg for mechanical compression and simultaneous ventilation with diastolic abdominal compression, and 11 +/- 2 mm Hg for vest resuscitation. These data demonstrate that high-impulse manual compression generated physiologically and statistically superior hemodynamics when compared with other methods in this model of cardiopulmonary resuscitation.

Key point: **LOE 3, opposing, poor.** This experimental dog study compared the hemodynamic effects of vest CPR with other CPR techniques and found vest CPR to be the least effective.

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