WORKSHEET for Evidence-Based Review of Science for Veterinary CPCR

1. Basic Demographics

Worksheet author(s)

Steven Epstein	**Date Submitted for review:**
[redacted]	

2. Clinical question:

In dogs and cats with cardiac arrest (P), does any specific compression depth (I) as opposed to a comparator (C), improve outcome (O) (eg. ROSC, survival)?

3. Conflict of interest specific to this question:

None

4. Search strategy (including electronic databases searched):

4a. Databases

Pubmed (NLM) (no date restriction) (performed on April 25, 2011)
Search 1: Chest compression depth (textwords)
13 relevant hits out of 187 total hits
Search 2: Cardiopulmonary resuscitation compression depth (textwords)
No additional relevant hits
Search 3: Cardiac arrest compression depth (textwords)
No additional relevant hits
Search 4: Cardiopulmonary compression amplitude (textwords)
No additional relevant hits

Cab Abstracts (1910 to Feb 2011) (performed on April 25, 2011)
(1) Chest compression
(2) Compression depth
(3) Cardiopulmonary resuscitation
(4) Compression
(5) Depth
(1) No relevant hits
(2) No relevant hits
(1) and (3) no relevant hits
(2) and (3) no relevant hits
(3) and (4) no relevant hits

(3) and (5) no relevant hits

4b. Other sources

-In addition all references of identified articles and in particular the references of the following relevant review articles were checked:
European Resuscitation Council Guidelines for Resuscitation 2010 Section 2. Adult basic life support and use of automated external defibrillators
Part 5: Adult Basic Life Support
2010 American Heart Association Guidelines for Cardiopulmonary
Resuscitation and Emergency Cardiovascular Care
These yielded 2 additional relevant papers.

The references from the original 15 papers were reviewed and 3 additional relevant papers were identified.

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

Inclusion criteria

Human, animal and mathematical model studies looking at different compression depths with an outcome variable.

Exclusion criteria

Articles that did not address chest compression depth, C:V ratio studies, alternative method for CPR (abdominal compression, solely active compression-decompression (ACD), impedance threshold valve (ITV), etc.), mechanical models that did not test different depths of chest compression, not English language, or review articles.

4d. Number of articles/sources meeting criteria for further review: 18

-Two randomized trials were identified: (Rawles and Kenmure 1976) and (Wilson and Channer 1997)

-Five relevant human (mechanistic) studies were identified: (Thomas, Malmcrona et al. 1965), (Kenmure, Murdoch et al. 1968), (Foster, Casten et al. 1969), (Horvat, Yoshida et al. 1972) and (Madias, Madias et al. 1976).

-Six relevant animal studies were identified: (Maroko, Radvany et al. 1975), (Malm, Arborelius et al. 1977),(Ribeiro, Louie et al. 1979) (Weisse, Moore et al. 1982),(Ishikawa, Kanamasa et al. 1986) and (Kelly, Hursey et al. 1995)

- Five articles were no longer included as upon full review, they were not pertinent to the clinical question: (Wu, Li, Liu et al. 2009), (Sutton, Niles, Nysaether, et al. 2009), (Ornato, Levine, Young, et al. 1989), Kao, Chiang, Yang, et al. 2009), (Pickard, Darby, Soar 2006)

5. Summary of evidence

Evidence Supporting Clinical Question

Good			**Babbs 1983** E=Cardiac output			***Ristagno 2007*** A,B,D ***Li 2007*** A,B,D,E=coronary perfusion pressure, $EtCO_2$
Fair						***Bellamy 1984*** *E=coronary perfusion pressure, cardiac output, Mean Ao pressure* ***Bohn 2011*** A ***Edelson 2006*** *E=successful defibrillation* ***Kramer-Johansen 2006*** A, C
Poor						***Babbs 2008*** A ***Maher 2009*** *E=blood pressure* ***Braga 2009*** *E=CT assessment* ***Meyer 2010*** *E=CT assessment*
	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 Neutral to Clinical question

Good						
Fair						***Edelson 2006*** A, C ***Hostler 2011*** A, B, C
Poor						
	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						***Wik 1996*** *E=coronary perfusion pressure, EtCO2, MAP*
Poor						
	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

The Veterinary School 7/6/11 9:55 PM
Comment [1]: Please note my comment on this classification in the abstract part below.

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

The majority of research on depth of compression and how this affects outcome is with compressions being performed in an anterior posterior direction. One study performed in pigs using a lateral compression technique (Bellamy 1984) showed that as depth of compression increased, cardiac output and mean aortic pressure increased. No statistics were performed at the time of publication, however after performing a t-test using the mean, standard deviation, and number of subjects: there was a statistically significant increase in cardiac output, mean aortic pressure and circumflex coronary blood flow ($p<0.03$) when comparing a 1.5 to 2.5 inch (38-64mm). The only canine study using dogs weighing 6 to 12 kg (Babbs 1983) showed that cardiac output increased linearly from 25 to 60 mm compression depth. Mean arterial pressure increased linearly with increased depth of compression. Using a linear regression technique cardiac output and mean arterial pressure would be zero with a compression depth of 23 and 18 mm respectively. The human literature shows increased depth of compression is associated with increased success in defibrillation (Babbs, 2008 and Edelson 2006), and increased success in ROSC (Babbs 2008, Bohn 2011, Kramer-Johansen 2006). Increased likelihood of successful defibrillation and ROSC with increased depth of compression in swine was shown in two studies from the same laboratory (Li 2008 and Ristagno 2007). It should be noted that two human studies showed similar rates of ROSC and rates of hospital discharge with increasing depth of compressions (Edelson 2006 and Hostler 2011). Only one swine study (Wik 1996) failed to demonstrate beneficial cardiac effects (CPP) of increasing compression depth from 40-50 mm (20 -25% compression), although carotid blood flow was increased.

From this one can conclude that depth of compression is a very important issue with potential beneficial effects at the ideal compression depth. This ideal depth has not been determined, but is in excess of 38 mm in adult humans, a number that approximates 16% the external diameter of the thorax, and likely less than 50% external diameter. Two computed tomography based studies (Braga 2009 and Meyer 2010) in pediatrics demonstrated that over-compression, defined as less than 10 mm residual internal diameter of the thorax, would occur with greater frequency when a compression depth of 1/2 was used compared to 1/3rd or 1/4th.

It is reasonable to perform lateral chest compressions on dogs and cats at a depth of 1/4th to 1/3rd the external diameter of the chest. Further lateral compression studies are needed to evaluate the effect of various depths of chest compressions for a definitive recommendation to be made.

The Veterinary School 7/6/11 9:57 PM
Deleted: is

The Veterinary School 7/6/11 9:58 PM
Deleted: as well

The Veterinary School 7/6/11 9:59 PM
Deleted: some

The Veterinary School 7/6/11 10:09 PM
Comment [2]: The only thing that could be worthwile evaluating is whether there is any documented limit to the depth of compression that we know of; any citation that describes that injury actually occurs when compressing e.g. 50% compared to 33%? Probably not in peds, but in any animal studies? It seems that the goal would be to increase compression depth until the negative impact of injury overrides the benefit of more compression depth.

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: One experimental dog study (LOE 3) and 7 swine or human studies (LOE 6) document improvement in physiologic parameters (cardiac output, coronary perfusion pressure, end-tidal CO_2 or mean arterial pressure), ROSC, or success in defibrillation when increased depth of compression is performed. Three studies (LOE 6) are neutral to the question. The optimal compression depth in dogs and cats has not been examined.

8. Acknowledgement

none

9. Citation list

1. Babbs CF, Kemeny AE, Quan W, Freeman G. A new paradigm for human resuscitation research using intelligent devices. Resuscitation. 2008 Jun;77(3):306-15.
OBJECTIVES: To develop new methods for studying correlations between the

The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline

performance and outcome of resuscitation efforts in real-world clinical settings using data recorded by automatic devices, such as automatic external defibrillators (AEDs), and to explore effects of shock timing and chest compression depth in the field.
METHODS: In 695 records of AED use in the pre-hospital setting, continuous compression data were recorded using AEDs capable of measuring sternal motion during compressions, together with timing of delivered shocks and the electrocardiogram. In patients who received at least one shock, putative return of spontaneous circulation (P-ROSC) was defined as a regular, narrow complex electrical rhythm > 40 beats/min with no evidence of chest compressions at the end of the recorded data stream. Transient return of spontaneous circulation (t-ROSC) was defined as the presence of a post-shock organized rhythm > 40 beats/min within 60s, and sustained > or = 30 s. 2x2 contingency tables were constructed to examine the association between these outcomes and dichotomized time of shock delivery or chest compression depth, using the Mood median test for statistical significance.
RESULTS: The probability of P-ROSC for first shocks delivered < 50 s (the median time) after the start of resuscitation was 23%, versus 11% for first shocks > 50 s (p=0.028, one tailed). Similarly, the probability of t-ROSC for shorter times to shock was 29%, compared to the 15% for delayed first shocks (p=0.016). For shocks occurring > 3 min after initiation of rescue attempts, the probability of t-ROSC with pre-shock average compression depth > 5 cm was more than double that with compression depth < 5 cm (17.7% vs. 8.3%, p=0.028). For shocks > 5 min, the effect of deeper compressions increased (23.4% versus 8.2%, p=0.008).
CONCLUSIONS: Much can be learned from analysis of performance data automatically recorded by modern resuscitation devices. Use of the Mood median test of association proved to be sensitive, valid, distribution independent, noise-resistant and also resistant to biases introduced by the inclusion of hopeless cases. Efforts to shorten the time to delivery of the first shock and to encourage deeper chest compressions after the first shock are likely to improve resuscitation success. Such refinements can be effective even after an unknown period of preceding downtime
LOE 6 Poor (Supporting)
For shocks occurring > 3 min after initiation of rescue attempts, the probability of t-ROSC with pre-shock average compression depth > 5 cm was more than double that with compression depth < 5 cm (17.7% vs. 8.3%, p=0.028). For shocks > 5 min, the effect of deeper compressions increased (23.4% versus 8.2%, p=0.008).
No statement about funding

2. Babbs CF, Voorhees WD, Fitzgerald KR, Holmes HR, Geddes LA. Relationship of blood pressure and flow during CPR to chest compression amplitude: evidence for an effective compression threshold. Ann Emerg Med. 1983 Sep;12(9):527-32.
This study was conducted to investigate the importance of the depth of chest compression in producing effective cardiopulmonary resuscitation (CPR) in animals, as indicated by cardiac output and mean arterial blood pressure. Cardiac output was measured by a modified indicator dilution technique in 8 anesthetized dogs, 6 to 12 kg body weight, during repeated 2-minute episodes of electrically induced ventricular fibrillation and CPR provided by a mechanical chest compressor and ventilator (Thumper). Chest compression exceeding

The Veterinary School 7/6/11 9:10 PM
Formatted: Font:Not Bold

The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline

a threshold value (xo) between 1.5 and 3.0 cm was required in each animal to produce measurable cardiac output. In particular, cardiac output (CO) was linearly related to chest compression depth (x) by an expression of the form CO = a(x-xo) for x greater than xo. The mean value of xo was 2.3 cm. A similar threshold for measurable blood pressure was observed in 7 of the 8 dogs, with a mean value of 1.8 cm. For chest compression of 2.5 cm or greater, relatively modest increases in chest compression depth caused relatively large changes in cardiac output.

LOE 3 Good (Supporting)
In anesthetized dogs (6-12 kg), cardiac output (CO) was linearly related to chest compression depth applied ventro-dorsally. For chest compression of 2.5 cm or greater, relatively modest increases in chest compression depth caused relatively large changes in cardiac output
This work was supported by a grant-in-aid from the American Heart Association and with funds contributed in part by the Indiana Affiliate Heart Association.

3. Bellamy RF, DeGuzman LR, Pedersen DC. Coronary blood flow during cardiopulmonary resuscitation in swine. Circulation. 1984 Jan;69(1):174-80.
Recent papers have raised doubt as to the magnitude of coronary blood flow during closed-chest cardiopulmonary resuscitation. We will describe experiments that concern the methods of coronary flow measurement during cardiopulmonary resuscitation. Nine anesthetized swine were instrumented to allow simultaneous measurements of coronary blood flow by both electromagnetic cuff flow probes and by the radiomicrosphere technique. Cardiac arrest was caused by electrical fibrillation and closed-chest massage was performed by a Thumper (Dixie Medical Inc., Houston). The chest was compressed transversely at a rate of 66 strokes/min. Compression occupied one-half of the massage cycle. Three different Thumper piston strokes were studied: 1.5, 2, and 2.5 inches. Mean aortic pressure and total systemic blood flow measured by the radiomicrosphere technique increased as Thumper piston stroke was lengthened (mean +/- SD): 1.5 inch stroke, 23 +/- 4 mm Hg, 525 +/- 195 ml/min; 2 inch stroke, 33 +/- 5 mm Hg, 692 +/- 202 ml/min; 2.5 inch stroke, 40 +/- 6 mm Hg, 817 +/- 321 ml/min. Both methods of coronary flow measurement (electromagnetic [EMF] and radiomicrosphere [RMS]) gave similar results in technically successful preparations (data expressed as percent prearrest flow mean +/- 1 SD): 1.5 inch stroke, EMF 12 +/- 5%, RMS 16 +/- 5%; 2 inch stroke, EMF 30 +/- 6%, RMS 26 +/- 11%; 2.5 inch stroke, EMF 50 +/- 12%, RMS 40 +/- 20%. The phasic coronary flow signal during closed-chest compression indicated that all perfusion occurred during the relaxation phase of the massage cycle. We concluded that coronary blood flow is demonstrable during closed-chest massage, but that the magnitude is unlikely to be more than a fraction of normal.

LOE 6 Fair (Supporting)
Three different thumper piston strokes were studied: 1.5, 2, and 2.5 inches. Mean aortic pressure and total systemic blood flow increased as chest compression depth increased.
No statement about funding.

4. Bohn A, Weber TP, Wecker S, Harding U, Osada N, Van Aken H, et al. The addition of voice prompts to audiovisual feedback and debriefing does not modify CPR quality or outcomes in out of hospital cardiac arrest--a prospective, randomized trial. Resuscitation. 2011 Mar;82(3):257-62.
AIMS: Chest compression quality is a determinant of survival from out-of-hospital

The Veterinary School 7/6/11 9:10 PM
Formatted: Font:Not Bold
The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline
The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline
The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline
The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline, German
The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline
The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline, Swedish
The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline
The Veterinary School 7/6/11 9:12 PM
Formatted: Font:Not Bold
The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline
The Veterinary School 7/6/11 9:28 PM
Deleted:
The Veterinary School 7/6/11 9:28 PM
Deleted: T
The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline

cardiac arrest (OHCA). ERC 2005 guidelines recommend the use of technical devices to support rescuers giving compressions. This prospective randomized study reviewed influence of different feedback configurations on survival and compression quality.
MATERIALS AND METHODS: 312 patients suffering an OHCA were randomly allocated to two different feedback configurations. In the limited feedback group a metronome and visual feedback was used. In the extended feedback group voice prompts were added. A training program was completed prior to implementation, performance debriefing was conducted throughout the study.
RESULTS: Survival did not differ between the extended and limited feedback groups (47.8% vs 43.9%, p = 0.49). Average compression depth (mean ¬± SD: 4.74 ¬± 0.86 cm vs 4.84 ¬± 0.93 cm, p = 0.31) was similar in both groups. There were no differences in compression rate (103 ¬± 7 vs 102 ¬± 5 min(-1), p=0.74) or hands-off fraction (16.16% ¬± 0.07 to 17.04% ¬± 0.07, p = 0.38). Bystander CPR, public arrest location, presenting rhythm and chest compression depth were predictors of short term survival (ROSC to ED).
CONCLUSIONS: Even limited CPR-feedback combined with training and ongoing debriefing leads to high chest compression quality. Bystander CPR, location, rhythm and chest compression depth are determinants of survival from out of hospital cardiac arrest. Addition of voice prompts does neither modify CPR quality nor outcome in OHCA. CC depth significantly influences survival and therefore more focus should be put on correct delivery. Further studies are needed to examine the best configuration of feedback to improve CPR quality and survival.

LOE 6 Fair (supporting)
In this group of patients with out of hospital cardiac arrest increasing chest compression depth was associated with increased rates of ROSC on presentation to the emergency department.
No statement about funding.

5. Braga MS, Dominguez TE, Pollock AN, Niles D, Meyer A, Myklebust H, et al. Estimation of optimal CPR chest compression depth in children by using computer tomography. Pediatrics. 2009 Jul;124(1):e69-74.
OBJECTIVE: Pediatric consensus-driven cardiopulmonary resuscitation guidelines target chest compression (CC) depths of one third to one half anterior-posterior (AP) chest depth. Estimates for this target as assessed by computed tomography (CT) measurements of internal and external AP chest dimensions could direct future pediatric cardiopulmonary resuscitation guidelines.
METHODS: A total of 280 consecutive chest CT scans in permuted blocks of 20 for each of 14 age divisions between 0 and 8 years were reconstructed and analyzed. External and internal AP depths were measured at midsternum, and residual chest depth was calculated at simulated one-third and one-half AP compressions.
RESULTS: After a simulated compression calculation, one-half external AP depth CC would result in residual internal depth of <10 mm for 94% (263 of 280) of children 3 months to 8 years. For a one-third external AP CC, only 0.4% (1 of 280) of children 3 months to 8 years had a calculated residual internal chest depth <10 mm.
CONCLUSIONS: By using CT reconstruction estimates of chest dimensions across the developmental spectrum from 0 to 8 years of age, we demonstrated that a simulated

CC targeting approximately one-third external AP chest depth seems radiographically appropriate for children aged 3 months to 8 years, whereas simulated CC targeting approximately one-half external AP chest depth seems radiographically to be too deep, resulting in residual internal chest depth of <10 mm for most patients of this age
LOE 6 Poor (supporting)
By using CT reconstruction estimates of chest dimensions in pediatric scans we demonstrated that a simulated chest compressions targeting approximately one-third external AP chest depth seems radiographically appropriate for children aged 3 months to 8 years, whereas simulated CC targeting approximately one-half external AP chest depth seems radiographically to be too deep, resulting in residual internal chest depth of <10 mm for most patients of this age.
No statement about funding.

6. Edelson DP, Abella BS, Kramer-Johansen J, Wik L, Myklebust H, Barry AM, et al. Effects of compression depth and pre-shock pauses predict defibrillation failure during cardiac arrest. Resuscitation. 2006 Nov;71(2):137-45.
BACKGROUND: Cardiopulmonary resuscitation (CPR) and electrical defibrillation are the primary treatment options for ventricular fibrillation (VF). While recent studies have shown that providing CPR prior to defibrillation may improve outcomes, the effects of CPR quality remain unclear. Specifically, the clinical effects of compression depth and pauses in chest compression prior to defibrillation (pre-shock pauses) are unknown.
METHODS: A prospective, multi-center, observational study of adult in-hospital and out-of-hospital cardiac resuscitations was conducted between March 2002 and December 2005. An investigational monitor/defibrillator equipped to measure compression characteristics during CPR was used.
RESULTS: Data were analyzed from 60 consecutive resuscitations in which a first shock was administered for VF. The primary outcome was first shock success defined as removal of VF for at least 5s following defibrillation. A logistic regression analysis demonstrated that successful defibrillation was associated with shorter pre-shock pauses (adjusted odds ratio 1.86 for every 5s decrease; 95% confidence interval 1.10-3.15) and higher mean compression depth during the 30s of CPR preceding the pre-shock pause (adjusted odds ratio 1.99 for every 5mm increase; 95% confidence interval 1.08-3.66).
CONCLUSIONS: The quality of CPR prior to defibrillation directly affects clinical outcomes. Specifically, longer pre-shock pauses and shallow chest compressions are associated with defibrillation failure. Strategies to correct these deficiencies should be developed and consideration should be made to replacing current-generation automated external defibrillators that require long pre-shock pauses for rhythm analysis.

LOE 6 Fair (Supporting) and LOE 6 Fair (Neutral)
Patients with a higher mean compression depth during 30 seconds of CPR prior to defribrillation attempt were more likely to have a successful defibrillation, but had no increase in ROSC or survival to discharge.
No statement about funding.

The Veterinary School 7/6/11 9:09 PM
Formatted: No underline
The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline
The Veterinary School 7/6/11 9:34 PM
Formatted: Font:Not Bold
The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline
The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline
The Veterinary School 7/6/11 9:35 PM
Deleted: p

7. Hostler D, Everson-Stewart S, Rea TD, Stiell IG, Callaway CW, Kudenchuk PJ, et al. Effect of real-time feedback during cardiopulmonary resuscitation outside hospital: prospective, cluster-randomised trial. BMJ. 2011;342:d512.
OBJECTIVE: To investigate whether real-time audio and visual feedback during cardiopulmonary resuscitation outside hospital increases the proportion of subjects who achieved prehospital return of spontaneous circulation.
DESIGN: A cluster-randomised trial.
SUBJECTS: 1586 people having cardiac arrest outside hospital in whom resuscitation was attempted by emergency medical services (771 procedures without feedback, 815 with feedback).
SETTING: Emergency medical services from three sites within the Resuscitation Outcomes Consortium in the United States and Canada.
INTERVENTION: Real-time audio and visual feedback on cardiopulmonary resuscitation (CPR) provided by the monitor-defibrillator.
MAIN OUTCOME MEASURE: Prehospital return of spontaneous circulation after CPR.
RESULTS: Baseline patient and emergency medical service characteristics did not differ between groups. Emergency medical services muted the audible feedback in 14% of cases during the period with feedback. Compared with CPR clusters lacking feedback, clusters assigned to feedback were associated with increased proportion of time in which chest compressions were provided (64% v 66%, cluster-adjusted difference 1.9 (95% CI 0.4 to 3.4)), increased compression depth (38 v 40 mm, adjusted difference 1.6 (0.5 to 2.7)), and decreased proportion of compressions with incomplete release (15% v 10%, adjusted difference -3.4 (-5.2 to -1.5)). However, frequency of prehospital return of spontaneous circulation did not differ according to feedback status (45% v 44%, adjusted difference 0.1% (-4.4% to 4.6%)), nor did the presence of a pulse at hospital arrival (32% v 32%, adjusted difference -0.8 (-4.9 to 3.4)), survival to discharge (12% v 11%, adjusted difference -1.5 (-3.9 to 0.9)), or awake at hospital discharge (10% v 10%, adjusted difference -0.2 (-2.5 to 2.1)).
CONCLUSIONS: Real-time visual and audible feedback during CPR altered performance to more closely conform with guidelines. However, these changes in CPR performance were not associated with improvements in return of spontaneous circulation or other clinical outcomes.

LOE 6 Fair (Neutral)
With real-time audio and visual feedback, chest compression depth increased from 38 to 40mm, but ROSC rates were no different.
No statement about funding.

8. Kramer-Johansen J, Myklebust H, Wik L, Fellows B, Svensson L, Sorebo H, et al. Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: a prospective interventional study. Resuscitation. 2006 Dec;71(3):283-92.
AIMS: To compare quality of CPR during out-of-hospital cardiac arrest with and without automated feedback.
MATERIALS AND METHODS: Consecutive adult, out-of-hospital cardiac arrests of all causes were studied. One hundred and seventy-six episodes (March 2002-October 2003) without feedback were compared to 108 episodes (October 2003-September 2004) where automatic feedback on CPR was given. Automated verbal and visual

feedback was based on measured quality with a prototype defibrillator. Quality of CPR was the main outcome measure and survival was reported as specified in the protocol.
RESULTS: Average compression depth increased from (mean +/- S.D.) 34 +/- 9 to 38 +/- 6 mm (mean difference (95% CI) 4 (2, 6), P < 0.001), and median percentage of compressions with adequate depth (38-51 mm) increased from 24% to 53% (P < 0.001, Mann-Whitney U-test) with feedback. Mean compression rate decreased from 121 +/- 18 to 109 +/- 12 min(-1) (difference -12 (-16, -9), P = 0.001). There were no changes in the mean number of ventilations per minute; 11 +/- 5 min(-1) versus 11 +/- 4 min(-1) (difference 0 (-1, 1), P = 0.8) or the fraction of time without chest compressions; 0.48 +/- 0.18 versus 0.45 +/- 0.17 (difference -0.03 (-0.08, 0.01), P = 0.08). With intention to treat analysis 7/241 control patients were discharged alive (2.9%) versus 5/117 with feedback (4.3%) (OR 1.5 (95% CI; 0.8, 3), P = 0.2). In a logistic regression analysis of all cases, witnessed arrest (OR 4.2 (95% CI; 1.6, 11), P = 0.004) and average compression depth (per mm increase) (OR 1.05 (95% CI; 1.01, 1.09), P = 0.02) were associated with rate of hospital admission.
CONCLUSIONS: Automatic feedback improved CPR quality in this prospective non-randomised study of out-of-hospital cardiac arrest. Increased compression depth was associated with increased short-term survival.

LOE 6 Fair (Supporting)
An automated verbal and visual feedback device was used. Patients that had an increased compression depth in this study had an increased short term survival rate.
No statement about funding.

9. Li Y, Ristagno G, Bisera J, Tang W, Deng Q, Weil MH. Electrocardiogram waveforms for monitoring effectiveness of chest compression during cardiopulmonary resuscitation. Crit Care Med. 2008 Jan;36(1):211-5.
BACKGROUND: Newer guidelines address the importance of effective chest compressions, citing evidence that this primary intervention is usually suboptimally performed during cardiopulmonary resuscitation. We therefore sought a readily available option for monitoring the effectiveness of chest compressions, specifically using the electrocardiogram.
METHODS AND RESULTS: Ventricular fibrillation was induced by coronary artery occlusion and untreated for 5 mins. Male domestic pigs weighing 40 +/- 2 kg were randomized to optimal or suboptimal chest compressions after onset of ventricular fibrillation. Optimal depth of mechanical compression in six animals was defined as a decrease of 25% in anterior posterior diameter of the chest during compression. Suboptimal compression, also in six animals, was defined as a decrease of 17.5% in anterior posterior diameter. For each group, the chest compressions were maintained at a rate of 100 per min. After 3 mins of chest compression, defibrillation was attempted with a 150-J biphasic shock. All animals had return of spontaneous circulation after optimal compressions. This contrasted with suboptimal compressions, after which none of the animals had return of spontaneous circulation. Amplitude spectrum area values, representing the electrocardiographic amplitude frequency spectral area computed from conventional precordial leads, like coronary perfusion pressure and end tidal

The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline, French
The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline
The Veterinary School 7/6/11 9:39 PM
Formatted: Font:Not Bold
The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline

PCO2, were predictive of outcomes.
CONCLUSION: The effectiveness of chest compressions was reflected in the amplitude spectrum area values. Accordingly, the amplitude spectrum area predictor may be incorporated in current automated external defibrillators to monitor and prompt the effectiveness of chest compression during cardiopulmonary resuscitation.

LOE 6 Good (Supporting)
Chest compressions in swine of 25% vs 17.5% of AP diameter were assosciated with a 100% vs 0% rate of ROSC in a ventricular fibrillation and defibbriation model.
Supported, in part, by the American Heart Association, Dallas, TX (WT).

10. Maher KO, Berg RA, Lindsey CW, Simsic J, Mahle WT. Depth of sternal compression and intra-arterial blood pressure during CPR in infants following cardiac surgery. Resuscitation. 2009 Jun;80(6):662-4.
The optimal depth of sternal compressions during cardiopulmonary resuscitation (CPR) in infants is unknown; current guidelines recommend compressing to a depth of 1/3rd to 1/2 the anterior-posterior (AP) diameter of the chest. Our experience to compress the chest at 1/3rd the AP diameter often fails to provide an adequate blood pressure response. We reviewed our experience with CPR, depth of compressions, and arterial blood pressure response in a cohort of 6 infants having cardiac surgery and subsequent cardiac arrest. Pediatric advanced life support measures were initiated, with attempted compressions to 1/3rd the AP chest diameter. Depth of attempted compressions was increased to approximately 1/2 the AP chest diameter if systolic BP response was inadequate (i.e., <60mm Hg systolic). BP tracings were reviewed and contiguous recordings were evaluated as compressions were attempted at 1/3rd and 1/2 the AP chest diameter. The age range was from 2 weeks to 7.3 months, and median age was of 1.0 month. The mean systolic BP was 83.4mm Hg for the 1/2 AP chest diameter technique vs. 51.6mm Hg for the 1/3rd AP diameter approach, p<0.001. The mean diastolic pressure was similar with both strategies (30.5 vs. 30.6mm Hg, p=0.99). In this cohort of 6 infants having cardiac surgery and subsequent cardiac arrest, attempting to compress the chest at 1/2 the AP diameter increased systolic blood pressure by 62% compared to attempting to compress 1/3rd the AP diameter. Perhaps resuscitators should attempt to compress infants' chests 1/2 rather than 1/3rd the AP diameter of the chest.

LOE 6 Poor (supporting)
In 6 infants having cardiac surgery and subsequent cardiac arrest, attempting to compress the chest at 1/2 the AP diameter increased systolic blood pressure by 62% compared to attempting to compress 1/3rd the AP diameter.
No statement about funding

11. Meyer A, Nadkarni V, Pollock A, Babbs C, Nishisaki A, Braga M, et al. Evaluation of the Neonatal Resuscitation Program's recommended chest compression depth using computerized tomography imaging. Resuscitation. 2010 May;81(5):544-8.
BACKGROUND: Neonatal Resuscitation Program (NRP) guidelines recommend chest compression depths of 1/3 the anterior-posterior (AP) chest depth.
Appropriateness of this recommendation has not been rigorously assessed.

The Veterinary School 7/6/11 9:42 PM
Formatted: Font:Not Bold

The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline

OBJECTIVE: To compare the efficacy and safety of neonatal chest compression depths of 1/4, 1/3, and 1/2 AP chest depth during cardiopulmonary resuscitation. DESIGN/METHODS: Anterior-posterior internal and external chest depth, heart dimensions, and non-cardiac thoracic tissue depth were measured from neonatal chest CTs. Using these measurements, residual internal chest depth, the remaining depth of the chest between the sternum and spine after external compression, was calculated for compression depths of 1/4, 1/3 and 1/2 anterior-posterior chest depth. Compression sufficient to compress the chest to <10mm of residual internal chest depth was defined as over-compression. Using a mathematic model, an estimated ejection fraction (EF) was calculated for each chest compression depth. Compression inadequate to obtain a predicted 50% EF was defined as under-compression. Descriptive statistics, Fisher's exact test and Student's t-test were used to analyze data, where appropriate.
RESULTS: Fifty-four neonatal chest CT scans were evaluated. Estimated chest compression induced EF increased incrementally with increasing chest compression depth (EF was 51+/-3% with 1/4 AP chest depth vs 69+/-3% with 1/3 AP chest depth, and 106% with 1/2 AP chest depth, p<0.001). Under-compression was predicted in 29/54 patients with 1/4 AP compression depth, but none of the patients with 1/3 or 1/2 AP compression depth, p<0.001. Over-compression, or lack of adequate residual chest depth, was predicted in 49/54 patients with 1/2 AP compression depth, but none of the patients with 1/4 or 1/3 AP compression depth, p<0.001.
CONCLUSIONS: Mathematical modeling based upon neonatal chest CT scan dimensions suggests that current NRP chest compression recommendations of 1/3 AP chest depth should be more effective than 1/4 compression depth, and safer than 1/2 AP compression depth.

LOE 6 Poor (supporting)
Mathematical modeling based upon neonatal chest CT scan dimensions suggests that current chest compression recommendations of 1/3 AP chest depth should be more effective than 1/4 compression depth, and safer than 1/2 AP compression depth.
No statement about funding.

The Veterinary School 7/6/11 9:44 PM
Formatted: Font:Not Bold

The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline

12. Ristagno G, Tang W, Chang YT, Jorgenson DB, Russell JK, Huang L, et al. The quality of chest compressions during cardiopulmonary resuscitation overrides importance of timing of defibrillation. Chest. 2007 Jul;132(1):70-5.
BACKGROUND: We address the quality of chest compressions and the impact on initial defibrillation or initial chest compressions after sudden death.
METHODS: Ventricular fibrillation was induced by occlusion of the left anterior descending coronary artery in 24 domestic pigs with a mean (+/- SD) weight of 40 +/- 2 kg. Cardiac arrest was left untreated for 5 min. Animals were then randomized to receive chest compressions-first or defibrillation-first and were further randomized to "optimal" or "conventional" chest compressions. A total of four groups of animals were investigated using a factorial design. For optimal chest compressions, the anterior posterior diameter of the chest was reduced by 25%, representing approximately 6 cm. Only 70% of this depth, or approximately 4.2 cm, represented conventional chest compressions. Chest compressions were delivered with a mechanical chest compressor. Defibrillation was attempted with a

single biphasic 150-J shock. Postresuscitation myocardial function was echocardiographically assessed.
RESULTS: Coronary perfusion pressures and end-tidal Pco(2) were significantly lower with conventional chest compressions. With optimal chest compressions, either as an initial intervention or after defibrillation, each animal was successfully resuscitated. Fewer shocks were required prior to the return of spontaneous circulation after initial optimal chest compressions. No animals were resuscitated when conventional chest compressions preceded the defibrillation attempt. When defibrillation was attempted as the initial intervention followed by conventional chest compressions, two of six animals were resuscitated.
CONCLUSIONS: In this animal model of cardiac arrest, it was the quality of the chest compressions, rather then the priority of either initial defibrillation or initial chest compressions, that was the predominant determinant of successful resuscitation.

LOE 6 Good (Supporting)
In this ventricular fibrillation model increasing chest compression depth was associated with increased coronary perfusion pressures, end tidal CO2, and decreased number of shocks required to obtain ROSC.
No statement about funding.

13. Wik L, Naess PA, Ilebekk A, Nicolaysen G, Steen PA. Effects of various degrees of compression and active decompression on haemodynamics, end-tidal CO2, and ventilation during cardiopulmonary resuscitation of pigs. Resuscitation. 1996 Feb;31(1):45-57.
The effects of various degrees of compression and active decompression during cardiopulmonary resuscitation were tested in a randomized cross-over-design during ventricular fibrillation in eight pigs using an automatic hydraulic chest compression device. Compared with 4/0 (compression/decompression in cm), mean carotid arterial blood flow rose by 60% with 5/0, by 90% with 4/2 and 4/3, and 105% with 5/2. Two cm active decompression increased mean brain and myocardial blood flow by 53% and 37%, respectively, as compared with 4/0. Increasing standard compression from 4 to 5 cm caused no further increase in brain or heart tissue blood flow whether or not combined with active decompression. Tissue blood flow remained unchanged or decreased when active decompression (4/3) caused that 50% of the pigs were lifted from the table due to the force required. Myocardial blood flow was reduced with 5/0 vs. 4/0 despite no reduction in end decompression coronary perfusion pressure ((aortic-right atrial pressure) (CPP), (7 +/- 8 mmHg with 4/0, 14 +/- 11 mmHg with 5/0)(NS)). End decompression CPP increased by 186% with 4/2 vs. 4/0, by 200% with 4/3, and by 300% with 5/2. Endo-tracheal partial pressure of CO2 was significantly increased during the compression phase of active decompression CPR compared with standard CPR. Active decompression CPR generated an significantly increased ventilation compared with standard CPR.
Conclusion: Carotid and tissue blood flow, ventilation, and CPP increase with 2 cm of active decompression. An attempt to further increase the level of active decompression or increasing the compression depth from 4 to 5 cm did not improve organ blood flow.

LOE 6 Fair (Opposing)
Increasing the compression depth from 4-5 cm in swine did not increase blood flow to the brain and heart.

The Veterinary School 7/6/11 9:45 PM
Formatted: Font:Not Bold

The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline

The Veterinary School 7/6/11 9:45 PM
Deleted: a

The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline

The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold

The Veterinary School 7/6/11 9:54 PM
Comment [3]: Would this be more of a neutral paper? It seems that the decrease in CPP seen was not statistically significant and the only finding that showed a trend in this direction. The rest was unchanged. Also, it seems that the same amount of active decompression (2) lead to significantly improved CPP with 5 cm compared to 4 cm compression. Please just verify whether this is truly opposing (I admittedly did not read the full text paper).

The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline

The Veterinary School 7/6/11 9:09 PM
Formatted: Font:Not Bold, No underline

No statement about funding.

The Veterinary School 7/6/11 9:08 PM

Deleted: 1. Babbs CF, Kemeny AE, Quan W, Freeman G. A new paradigm for human resuscitation research using intelligent devices. Resuscitation. 2008 Jun;77(3):306-15. ... [1]