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

Worksheet author(s)

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Clinical question.

BLS-006A.R5 - In adult and pediatric patients with cardiac arrest (out-of-hospital and in-hospital) (P), does any specific compression depth (I) as opposed to standard care (ie. depth specified in treatment algorithm) (C), improve outcome (O) (eg. ROSC, survival)?

Is this question addressing an intervention/therapy, prognosis or diagnosis? ***Intervention***

State if this is a proposed new topic or revision of existing worksheet: ***Revision of existing worksheet.***

Conflict of interest specific to this question

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet? Prior grant support from Medtroncs, Laerdal, and Philips.

Search strategy (including electronic databases searched).

- PubMed (NLM) (January, 2004 – November 9, 2009)

- Ovid Medline (January, 2004 – November 9, 2009)

Query: “chest compression* depth”[All Fields]
Query: “depth*[All Fields] AND heart massage [MeSH Terms] AND cardiopulmonary resuscitation/methods[MeSH Terms] AND heart arrest [MeSH Terms]” – ***# hits 112***

- State inclusion and exclusion criteria

Inclusion: human, surrogate (manikin), animal and mathematical model studies.

Exclusion: Article that did not address chest compression depth, C:V ratio studies, alternative method for CPR (abdominal compression, 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.

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

34

Summary of evidence

Evidence Supporting Clinical Question:

"Compression depth of 5 cm"

Good			Kramer-Johansen J. Resusc 2006 B		Sutton 2009 E Kao 2009 E Braga 2009 E
Fair		Edelson, 2006 (E)	Edelson, 2008 A	Babbs, 2008 (A) Olasveengen, 2007 (E) Paradis, 1990 (A) Pickard, 2006 (E) Timerman, 2004 (E) Tomlinson, 2007 (E) Maher 2009E	*Babbs, 1983(E)* *Ditchey, 1982(E)* *Kern 1988 (B)* *Li, 2008 (B)* *Ristagno, 2007(A)* *Yannopoulos, 2005(E)*
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 Neutral to Clinical question

“Compression depth of 5 cm”

Good					
Fair				Abella, 2005 E Aufderheide, 2005 (E) Martin, 1986 (E) Wik, 2005 (E)	Anderson LO. Acta Anaesth Scand 2007 E Aufderheide TP. Resusc 2006 E Beckers SK Resusc 2007 E Dias JA Resusc 2007 E Mirza, 2008 (E) Odegaard S. Resusc 2006 E Perkins GD Resusc 2004 E Perkins GD. Intensive Care Med 2006 E *Pytte M. Resusc 2006 E* Trowbridge 2009
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

“Compression depth of 5 cm”

Good					
Fair					*Wik, 1996 (E)*
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:

References and Recommendations from C2005 Worksheet W167B Gabrielli/Fenici

Level 5

Ward, 1993[E] H-A

[mechanical thumper achieves better ETCO2 than manual CPR in human cardiac arrest]

Level 6

Kundra, 2000[E] H-A

[non-dominant hand directly in contact with sternum associated with incorrect depth of chest compression]

Larsen, 2002[E] H-A

[height and weight of the rescuer affect quality of CPR]

Perkins, 2004[E] H-A

[chest compression depth declines significantly after 1 minute CPR.
No difference with OTH-CPR]

Hackman, 1995[E] H-A

[three- rescuers CPR better depth than two-]

Elding, 1998[E] H-A

["CPR-Plus" device decreases the number of excessively deep compressions]

Donnelly, 2000[E] H-A

[ERC, ILCOR and Call-first CPR, all achieves standard depth in less than 50% of the cases]

Batcheller, 2000[E] H-A

[video self-instruction better depth of compression than traditional training]

Thoren 2001[E] H-A

[Cardiac Care Unit Nurses performs 40% of compressions too deep (> 5cm) and 4% too shallow (< 4 cm)]

Greingor, 2002 [E] H-A

[depth of chest compression better with ratio 5:1 than 15:2]

Larsen, 2002[E] H-A

[duty cycle 50% and depth of 4-5 cm for over 80% compression for 15:2 highly variable, better for taller individuals]

Ashton, 2002[E] H-A

[both rate and depth of chest compression from a standard of 4-5 cm decays statistically after 1 minute, worse in female]

Woollard, 2003[E] H-A

[compression-only telephone CPR rescuer achieves better depth of chest compression]

Handley, 2004[E] H-A

[OTH-CPR average compression depth is significantly less than standard CPR]

Ishibashi, 1990[E] H-A

[manikin training corrects "too shallow"compression more easily than compression "too deep" in a group of health professionals]

Hightower, 1995[E] H-A

[fatigue affects quality of compression depth after 1 minute]

Jawan, 1999[E] H-A

[3 cm and 5 cm depth have same rate of lung aspiration]

Wik, 2001[E] H-A

[computerized feedback improves quality of chest compressions = depth]

Handley, 2003[E] H-A

[computerized verbal feedback during manikin training results in better depth of compression]

Smith, 2004[E] H-A

[staged teaching achieves correct depth more frequently]

Depth of chest compression: Recommendations from C2005

- Adequate compression force is characterized by 1 ½ to 2 inches (4 to 5 cm) depression of the sternum with each compression for the normal-sized adult ***(Class IIa)***

- To maintain adequate chest compression, rescuers should alternate every minute to provide adequate chest compression regardless of the lack of subjective fatigue ***(Class Indeterminate)***

- Alternative methods of training (simplified staged teaching) CPR techniques (three rescuer CPR, over the head CPR, dominant hand on the sternum) or devices (CPR-plus) should be encouraged to improve the quality of chest compressions ***(Class IIb)*.**

Depth of Compression: Discussion from C2005

Current guidelines recommend compressing the sternum during CPR approximately 1 1/2 to 2 inches (4 to 5 cm) for the normal-sized adult. In small victims, lesser degrees of compression may be sufficient, and in large victims, a slightly greater depth of chest compression may be needed.

Sternal compression force is generally gauged as adequate if it generates a palpable carotid or femoral pulse. While this validation of pulses requires at least 2 healthcare providers (one provides compressions while the other attempts to palpate the pulse), it may yield misleading results. Detection of a pulse during CPR does not necessarily mean that there is optimal or even adequate blood flow, because a compression wave may be caused by venous compressions with retrograde flow in the absence of effective arterial blood flow. It is unlikely that a prospective randomized study of deep vs shallow compressions will be performed. Therefore, this issue might never be clarified. Data from animals showed an improved neurological outcome at 24 hours using deeper compressions during CPR ***[Kern, 1986]***.

Unfortunately, interpretation of data from animal studies is difficult because of the unique anatomy of the chest wall in humans. For this reason, depth of manual compression in dogs is often simply described as peak intrathoracic pressure (i.e., pleural pressure; best at 20 mmHg) measured in mmHg ***[Maier, 1984]*** or pounds of pressure ***[Jawan, 1999]***. In a recent mongrel dogs study, a chest pressure of 20 lbs has been correlated to 5 cm depth compressions ***[Jawan, 1999]***.

Several studies on manikins where depth of chest compression was monitored electronically revealed significant deterioration in the quality of chest compression after one minute despite lack of subjective awareness of fatigue up to 5 minutes by the lay rescuer ***[Ashton, 2002]***. Intuitively, the higher the speed of ventilation and the C:V ratio, the more frequent this phenomenon is manifested ***[Greingor, 2002]***. For example, a C:V ratio of 15:2 emphasized by the current 2000 AHA guidelines, is associated with earlier onset of fatigue and poorer quality (depth) of chest compression when compared to 5:1***[Greingor, 2002]***. A significant variability of rescuer's strength and depth of chest compression is related to the rescuer's height, weight ***[Larsen, 2002]*** and gender ***[Ashton, 2002]***; the latter secondary to lower average height. The decay of skill mastery is almost immediate after a CPR class with a trend to too shallow compressions in lay rescuers ***[Brennan, 1998]*** and too deep compressions in the health professionals ***[Thoren, 2001]***. In general repeated manikin training is more successful in correcting too shallow compressions than too deep ***[Ishibachi, 1990]***.

Alternative compression techniques can partially correct some of the problems related to fatigue and inadequate chest compression over time. For example 3 rescuer-CPR with 2 rescuers dedicated to ventilation allows the third rescuer to focus on rate and depth of chest compression ***[Hackman, 1995]***.

Simplified CPR increased the quality of compressions and skill retention. A sequential simpler approach increases the number of correct chest compression from 44% to 66% (p=0.003) ***[Smith 2004]***. Equally, a half-hour self instructional video ***[Batcheller 2000]*** and the removal of the respiratory component of BLS ***[Woollard 2003]*** can be more effective than a traditional CPR course in achieving a better depth of compression. In all these simplified approaches, an increase percentage of effective compressions is attributed to a better focus on the depth of compression task by the trainee who does not need to learn more complex CPR skills.

Another strategy that can improve the depth of chest compression includes placing the dominant hand on the sternum ***[Kundra, 2000]***, using devices on the chest that can monitor the depth of compression like the CPR-plus ***[Elding, 1988]*** and switching position of the rescuer to over-the-head CPR ***[Perkins, 2004]***.

Chest trauma and pulmonary aspiration are theoretical complications associated with deeper chest compression. Transtracheal jet ventilation has been shown to protect from silent lung aspiration of barium placed in the hypopharynx of the animal but it is unlikely that studies of this kind will be performed in humans during cardiac arrest ***[Jawan, 1999]***.

Finally, one cannot easily separate the technique of chest compression from chest decompression.

Recently an observational study in the emergency department revealed that incomplete decompressions are also frequent. ***[Aufderheide, 2005]***. Incomplete decompression has been correlated with decreased coronary and cerebral blood flow by Yannopulous ***[Yannopulous, 2005]***. Hand-off CPR, a technique recently proposed to obviate this problem, does not seem to influence the depth of compression although it reduced the duty cycle to approximately 30% ***[Aufderheide, 2005]***.

2005 Consensus on Science and Treatment Recommendation

It is reasonable for lay rescuers and healthcare providers to perform chest compressions for adults at a rate of at least 100 compressions per minute and to compress the sternum by at least 4 to 5 cm (11/2 to 2 inches). Rescuers should allow complete recoil of the chest after each compression. When feasible, rescuers should frequently alternate "compressor" duties, regardless of whether they feel fatigued, to ensure that fatigue does not interfere with delivery of adequate chest compressions. It is reasonable to use a duty cycle (ie, ratio between compression and release) of 50%).

Conclusion

C2010 Discussion

Current guidelines recommend using chest compressions with a depth of 1.5 to 2 inches (4 – 5 cm). Animal models of cardiac arrest have shown that coronary and carotid blood flow is proportional to the force and depth of chest compression [(Babbs 1983, Ditchey 1982, Kern 1988, Li 2008, Ristagno 2007)]. However, one animal study failed to show improved blood flow using a depth of 5 cm vs 4 cm [(Wik 1996)]. A human study showed that a minimum coronary perfusion pressure of 15 mm Hg is necessary for ROSC [(Paradis 1990)].

The relationship of increasing blood pressure and flow with increasing compression depths has also been replicated in human CPR studies [(Maher 2009, Martin 1986, Timerman 2004)]. Both animal models and human CPR studies have also shown that increasing compression depth is associated with improved rates of defibrillation success [(Edelson 2006 [human])], improved ROSC rates [(Babbs 2008 [human], Edelson 2008 [human], Li 2008, Ristagno 2007)], improved rates of survival to hospital admission [(Kramer-Johansen 2006 [human])], and a trend toward improved survival to hospital discharge (10% vs 16%, p=0.3)[(Olasveengen 2007 [human])].

A CT study of adult human chest anatomy showed that 25% of the mean chest anterior-posterior (AP) diameter is 5.9 cm for females and 6.3 cm for males [(Pickard 2006)]. An animal model of cardiac arrest showed that using a compression depth of 25% of the AP diameter during CPR, all animals had ROSC, while no animal could be resuscitated using an AP diameter of 17.5%, which is the depth that is currently recommended for human CPR [(Ristagno 2007)]. These two studies together suggest that using a compression depth of 6 cm might be more effective during human CPR.

Numerous human performance studies using manikin models show that it is possible for rescuers to compress the chest to a depth of 5 cm. However, both manikin model studies as well as human CPR studies show that a large proportion of rescuers often compress to a depth less than recommended [(Abella 2005, Beckers 2007, Kramer-Johansen 2006, Mirza 2008, Odegaard 2006, Perkins 2006, Trowbridge 2009, Wik 2005)]. Two manikin studies of human CPR performance showed that continuous chest compressions without a pause for ventilation resulted in faster fatigue and decreased compression depth [(Odegaard 2006, Trowbridge 2009)]. The greatest decline in compression depth occurred during the first two minutes of CPR, emphasizing the need to change the rescuer responsible for chest compressions every two minutes or less [(Trowbridge 2009)].

One study showed that using a backboard improved depth of compression [(Anderson 2007)], while another study showed a backboard had no effect on compression depth [(Perkins 2006)]. Use of a device to guide compression rate and depth can improve performance [(Beckers 2007)]. A number of studies of human CPR showed that giving rescuers feedback about compression rate and depth can improve CPR performance and outcome [(Edelson 2008, Kramer-Johansen 2006)].

An important simulation study of dispatcher telephone CPR instructions showed that advising a rescuer to “push as hard as you can” resulted in improved compression depth compared to the instruction “push down firmly 2 inches” [(Mirza 2008)].

In conclusion, results from recent human studies are consistent with results from decades of animal research and support the importance of adequate compression depth on good outcomes from cardiac arrest. A few studies suggest that a compression depth of 6 cm might improve ROSC, but this needs to be weighed against possible increased rescuer fatigue. Also, the feasibility of using a compression depth of 6 cm is unknown, especially in view of evidence that rescuers often fail to achieve a depth of 5 cm. The evidence supports recommending a compression depth of 5 cm and removing the current range of 4 – 5 cm. Instructions for rescuers need to be carefully studied to ensure that the instructions translate into the desired results. A change in wording a phrase can have substantial effects.

Summary Outcomes
Compression depth 5 cm or more

Patient group	Numbers	Hospital adm	Long term survivors
Adult C depth Kramer-Johansen '06	358	69/358 (19.3%)	12/358 (3.4%)
		Shock success	
Adult C depth Edelson 2006	60	44/60 (73%)	4/60 (7%)
Adult C Depth Babbs 2008		ROSC	ROSC
	202	8/93 vs 17/84	8.6% vs 20.2%

Knowledge Gaps

Complications from chest compressions > 5 cm

Is there a trade-off between chest compression rate and depth?

Specific research required:

Randomised trials in humans comparing standard CPR with alternative chest compression depths

Acknowledgements: I would like to thank Ms. Lorrie Burkhalter for her extraordinary help in gathering the references for this review.

Citation List

(Abella, Alvarado et al. 2005)

Abella, B. S., J. P. Alvarado, et al. (2005). "Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest." JAMA **293**(3): 305-310.

LOE 4, Fair, Neutral for 5 cm or more of compression depth. This human observational case series showed that compression depth was frequently less than 4 cm during CPR.

Andersen, L. O., D. L. Isbye, et al. (2007). "Increasing compression depth during manikin CPR using a simple backboard." Acta Anaesthesiol Scand **51**(6): 747-50.

LOE 5, Fair, Neutral for 5 cm or more of compression depth. This study showed that compression depth increased when a backboard was used during simulated CPR.

Aufderheide, T. P., R. G. Pirrallo, et al. (2005). "Incomplete chest wall decompression: a clinical evaluation of CPR performance by EMS personnel and assessment of alternative manual chest compression-decompression techniques." Resuscitation **64**(3): 353-362.

LOE 4, Fair, Neutral for 5 cm or more of compression depth. This study showed that compression depth was often less than recommended and that incomplete chest recoil was common.

Aufderheide, T. P., R. G. Pirrallo, et al. (2006). "Incomplete chest wall decompression: A clinical evaluation of CPR performance by trained laypersons and an assessment of alternative manual chest compression-decompression techniques." Resuscitation **71**(3): 341-51.

LOE 5, Fair, Neutral for 5 cm or more of compression depth. This study showed that compression depth was poor and that incomplete chest wall recoil could be improved by using modified hand position techniques.

Babbs, C. F., A. E. Kemeny, et al. (2008). "A new paradigm for human resuscitation research using intelligent devices." Resuscitation **77**(3): 306-15.

LOE 4, Fair, Supportive for 5 cm or more of compression depth. This human observational case series showed that shock success and ROSC was associated with chest compression depths >5 cm when CPR was prolonged (patients who had >3 shocks or shocks >5 min).

Babbs, C. F., W. D. Voorhees, et al. (1983). "Relationship of blood pressure and flow during CPR to chest compression amplitude: evidence for an effective compression threshold." Ann Emerg Med **12**(9): 527-532.

LOE 5, Fair, Supportive for 5 cm or more of compression depth. This classic lab study showed a linear relationship between compression depth and blood pressure and flow.

Beckers, S. K., M. H. Skorning, et al. (2007). "CPREzy improves performance of external chest compressions in simulated cardiac arrest." Resuscitation **72**(1): 100-7.

LOE 5, Fair, Neutral for 5 cm or more of compression depth. This study showed that a device which gives feedback can improve compression rate and depth during simulated CPR.

Braga, M. S., T. E. Dominguez, et al. (2009). "Estimation of optimal CPR chest compression depth in children by using computer tomography." Pediatrics **124**(1): e69-74.

LOE 5, Good, Supportive for 1/3 AP chest diameter compression depth in children. This CT scan study of children showed that a compression depth of 1/2 the AP diameter may be too much.

Dias, J. A., T. B. Brown, et al. (2007). "Simplified dispatch-assisted CPR instructions outperform standard protocol." Resuscitation **72**(1): 108-14.

LOE 5, Fair, Neutral for 5 cm or more of compression depth.

Ditchey, R. V., J. V. Winkler, et al. (1982). "Relative lack of coronary blood flow during closed-chest resuscitation in dogs." Circulation **66**(2): 297-302.

LOE 5, Fair, Supportive for 5 cm or more of compression depth. Lab study showing that 100 lbs or more of chest compression force was necessary to produce coronary blood flow.

Edelson, D. P., B. S. Abella, et al. (2006). "Effects of compression depth and pre-shock pauses predict defibrillation failure during cardiac arrest." Resuscitation **71**(2): 137-45.

LOE 2, Fair, Supportive for 5 cm or more of compression depth. This key study showed that shock success was proportional to compression depth and that compression depths >5 cm were associated with 100% success. There was a trend toward improved survival to hospital discharge.

Edelson, D. P., B. Litzinger, et al. (2008). "Improving in-hospital cardiac arrest process and outcomes with performance debriefing." Arch Intern Med **168**(10): 1063-9.

LOE 3, Fair, Supportive for 5 cm or more of compression depth. This human before and after study showed that improved CPR quality (decreased ventilation rate and increased compression depth to 5 cm) was associated with increased ROSC.

Kao, P. C., W. C. Chiang, et al. (2009). "What is the correct depth of chest compression for infants and children? A radiological study." Pediatrics **124**(1): 49-55.

LOE 5, Good, Supportive for 1/3 AP chest diameter compression depth in children. This CT scan study of children showed that a compression depth of 1/2 the AP diameter may be too much.

Kern, K. B., G. A. Ewy, et al. (1988). "Myocardial perfusion pressure: a predictor of 24-hour survival during prolonged cardiac arrest in dogs." Resuscitation **16**: 241-250.

LOE 5, Fair, Supportive for 5 cm or more of compression depth.

Kramer-Johansen, J., H. Myklebust, et al. (2006). "Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: a prospective interventional study." Resuscitation **71**(3): 283-92.

LOE 3, Good, Supportive for 5 cm or more of compression depth. This key study showed that rate of survival to hospital admission was associated with increased compression depth during CPR and the best rate was associated with the highest depth range (42 - 51 mm).

Li, Y., G. Ristagno, et al. (2008). "Electrocardiogram waveforms for monitoring effectiveness of chest compression during cardiopulmonary resuscitation." Crit Care Med **36**(1): 211-5.

LOE 5, Fair, Supportive for 5 cm or more of compression depth.

Maher, K. O., R. A. Berg, et al. (2009). "Depth of sternal compression and intra-arterial blood pressure during CPR in infants following cardiac surgery." Resuscitation **80**(6): 662-4.

LOE 4, Fair, Supportive for 5 cm or more of compression depth. This pediatric study showed that systolic blood pressure was increased with greater compression depth.

Martin, G. B., D. L. Carden, et al. (1986). "Aortic and right atrial pressures during standard and simultaneous compression and ventilation CPR in human beings." Ann Emerg Med **15**(2): 125-130.

LOE 4, Fair, Neutral for 5 cm or more of compression depth.

Mirza, M., T. B. Brown, et al. (2008). "Instructions to "push as hard as you can" improve average chest compression depth in dispatcher-assisted cardiopulmonary resuscitation." Resuscitation **79**(1): 97-102.

LOE 5, Fair, Neutral for 5 cm or more of compression depth. This important study showed that specific wording of telephone CPR instructions can have a substantial effect on improving compression depth.

Odegaard, S., E. Saether, et al. (2006). "Quality of lay person CPR performance with compression: ventilation ratios 15:2, 30:2 or continuous chest compressions without ventilations on manikins." Resuscitation **71**(3): 335-40.

LOE 5, Fair, Neutral for 5 cm or more of compression depth.

Olasveengen, T. M., L. Wik, et al. (2007). "Is CPR quality improving? A retrospective study of out-of-hospital cardiac arrest." Resuscitation **75**(2): 260-6.

LOE 4, Fair, Supportive for 5 cm or more of compression depth. Cognitive knowledge of CPR guidelines can improve quality of CPR performance , which in this study resulted in a trend toward increased survival to discharge.

Paradis, N. A., G. B. Martin, et al. (1990). "Coronary perfusion pressure and the return of spontaneous circulation in human cardiopulmonary resuscitation." JAMA **263**(8): 1106-1113.

LOE 4, Fair, Supportive for 5 cm or more of compression depth.

Perkins, G. D., C. M. Smith, et al. (2006). "Effects of a backboard, bed height, and operator position on compression depth during simulated resuscitation." Intensive Care Med **32**(10): 1632-5.

LOE 5, Fair, Neutral for 5 cm or more of compression depth. This study failed to show improvement in compression depth with use of a backboard, in contrast to the Anderson study above.

Perkins, G. D., B. T. Stephenson, et al. (2004). "A comparison between over-the-head and standard cardiopulmonary resuscitation." Resuscitation **61**(2): 155-161.

LOE 5, Fair, Neutral for 5 cm or more of compression depth.

Pickard, A., M. Darby, et al. (2006). "Radiological assessment of the adult chest: implications for chest compressions." Resuscitation **71**(3): 387-90.

LOE 4, Fair, Supportive for 5 cm or more of compression depth. This important study showed that current guidelines for compression depth (4-5 cm) results in an AP diameter compression of 16% to 21%. If the goal is to achieve 25% AP diameter compression depth, then 6 cm of depth should be used.

Pytte, M., J. Kramer-Johansen, et al. (2006). "Haemodynamic effects of adrenaline (epinephrine) depend on chest compression quality during cardiopulmonary resuscitation in pigs." Resuscitation **71**(3): 369-78.

LOE 5, Fair, Neutral for 5 cm or more of compression depth.

Ristagno, G., W. Tang, et al. (2007). "The quality of chest compressions during cardiopulmonary resuscitation overrides importance of timing of defibrillation." Chest **132**(1): 70-5.

LOE 5, Fair, Supportive for 5 cm or more of compression depth. An animal model of cardiac arrest showed that using a compression depth of 25% of the AP diameter during CPR, all animals had ROSC, while no animal could be resuscitated using an AP diameter of 17.5%, which is the depth that is currently recommended for human CPR. This study together with the Pickard study above suggest that using a compression depth of 6 cm might be more effective during human CP

Sutton, R. M., D. Niles, et al. (2009). "Pediatric CPR quality monitoring: analysis of thoracic anthropometric data." Resuscitation **80**(10): 1137-41.

LOE 5, Good, Supportive for 1/3 AP chest diameter compression depth in children. This CT scan study of children showed that a compression depth of 1/2 the AP diameter may be too much.

Timerman, S., L. F. Cardoso, et al. (2004). "Improved hemodynamic performance with a novel chest compression device during treatment of in-hospital cardiac arrest." Resuscitation **61**(3): 273-280.

LOE 4, Fair, Supportive for 5 cm or more of compression depth.

Tomlinson, A. E., J. Nysaether, et al. (2007). "Compression force-depth relationship during out-of-hospital cardiopulmonary resuscitation." Resuscitation **72**(3): 364-70.

LOE 4, Fair, Supportive for 5 cm or more of compression depth. Compression depth is proportional to compression force.

Trowbridge, C., J. N. Parekh, et al. (2009). "A randomized cross-over study of the quality of cardiopulmonary resuscitation among females performing 30:2 and hands-only cardiopulmonary resuscitation." BMC Nurs **8**: 6.

LOE 5, Fair, Neutral for 5 cm or more of compression depth.

Wik, L., J. Kramer-Johansen, et al. (2005). "Quality of cardiopulmonary resuscitation during out-of-hospital cardiac arrest." JAMA **293**(3): 299-304.

LOE 4, Fair, Neutral for 5 cm or more of compression depth. Observational study showing poor CPR quality is common.

Wik, L., P. A. Naess, et al. (1996). "Effects of various degrees of compression and active decompression on haemodynamics, end-tidal CO2, and ventilation during cardiopulmonary resuscitation of pigs." Resuscitation **31**(1): 45-57.

LOE 5, Fair, Opposed for 5 cm or more of compression depth. This study showed no effect on blood pressure or flow with increased depth of compression.