Michigan Instruments INC.

In the Business of Saving Lives™

January 28, 2010

American Heart Association
AHA National Center
7272 Greenville Avenue
Dallas, TX 75231-4596

Re: ILCOR PUBLIC COMMENT – PISTON (THUMPER®) DEVICE CPR

Dear Sir/Madam:

This public comment relates to the ALS/BLS overlap topic *Piston (Thumper®) Device CPR* work in progress for mechanical CPR from ILCOR's advanced life support worksheets as posted on the American Heart Association's website[1]. As a means of declaring my conflict of interest, I am the current president of Michigan Instruments, Inc., (MII) the manufacturer of Thumper® piston CPR devices. The ILCOR instructions for reviewers to complete their evidence evaluation worksheets include, among other things, establishing a clinical question and clearly defined inclusion/exclusion criteria for the search strategy and results analysis. In summarizing the search results, reviewers are asked to determine the level of evidence (LOE) for each study cited along with methodological quality, determination of support for the clinical question (i.e., supporting, neutral, or opposing), and an assessment of the relevant outcomes.

In comparing the worksheets for Thumper®, AutoPulse®, and LUCAS® mechanical CPR devices, the clinical question posed is the same for each.

- **Thumper® Clinical Question:** In adult cardiac arrest (prehospital [OHCA]), in-hospital [IHCA] (P), does the use of a piston CPR device (e.g. Thumper) (1) compared with manual CPR (C) improve any outcomes (e.g. ROSC, survival) (O)?
- **AutoPulse® Clinical Question:** In adult cardiac arrest (prehospital [OHCA]), in-hospital [IHCA] (P), does the use of load distributing band (e.g. AutoPulse) (1) compared with manual CPR (C) improve any outcomes (e.g. ROSC, survival) (O)?
- **LUCAS® Clinical Question:** In adult cardiac arrest (prehospital [OHCA]), in-hospital [IHCA] (P), does the use of full (e.g. Lucas) or partial decompression (e.g. US version) (I) compared with manual CPR (C) improve any outcomes (e.g. ROSC, survival) (O)?

However the inclusion/exclusion criteria for the search strategy and results analysis for Thumper®, AutoPulse®, and LUCAS® mechanical CPR devices are significantly different.

- **Inclusion and exclusion criteria for mechanical CPR devices:**
  - **Thumper®:**
    - Inclusion criteria: only human studies; only peer-reviewed manuscripts; only studies in which a piston CPR device i.e. Thumper, was compared to manual chest compression; studies in which hemodynamics, quality of CPR and survival were investigated.

[1] http://www.americanheart.org/presenter.jhtml?identifier=3060062#CPR__amp__Adjuncts

- Exclusion criteria: review articles; technical measurements; engineering studies; abstract-only; case reports; animal studies; studies in which a piston CPR device, i.e. Thumper, was compared to other mechanical devices.

- **AutoPulse®:**

  - Inclusion criteria: NONE

  - Exclusion criteria: Reviews, editorials, abstract-only studies, manufacturer-sponsored white papers, and case reports.

- **LUCAS®:**

  - Inclusion criteria: Original animal and human studies.

  - Exclusion criteria: Review articles, case reports, letters, and editorials.

As a result of inconsistent inclusion and exclusion criteria, reviewers for both AutoPulse® and LUCAS® may include animal studies while those reviewing the Thumper® may not. In addition, Thumper® reviewers are limited to including peer-reviewed manuscripts only and must exclude articles involving technical measurements, engineering studies, and comparisons with other mechanical CPR devices while AutoPulse® and LUCAS® do not have these restrictions.

To better understand the clinical efficacy of using mechanical CPR devices, we are using a systematic review as suggested by Peter Morley (Morley, Peter T. [2009] Evidence evaluation worksheets: The systematic reviews for the evidence evaluation process for the 2010 International Consensus on Resuscitation Science. *Resuscitation*, 2009 Jul; 80[7]: 719-21):

> ***"The systematic reviews for the Consensus on Science document must include the best available evidence pertaining to resuscitation. For many aspects of resuscitation, there are no high-level studies, and the best available evidence may be a case series, or information from other populations (including other patient groups and nonhuman studies [including manikin, bench, mathematical models, and animal studies])."***

Therefore, it is important that both human and animal CPR studies be included in these criteria, as well as articles involving technical measurements, engineering studies and those using instrumented manikins. Also important are articles involving case studies since they can provide direct clinical evidence of both positive and negative effects related to mechanical CPR applications. We at Michigan Instruments, Inc. (MII) propose the inclusion/exclusion criteria for all mechanical CPR device reviews read as follows:

- Inclusion criteria: Published animal and human studies, technical measurements, engineering studies, and relevant case studies.

- Exclusion criteria: Review articles, abstract-only studies, manufacturer-sponsored white papers, and studies in which mechanical CPR devices were compared with each other.

MII staff routinely monitors the medical literature pertaining to manual and mechanical CPR and believe we have located some publications worthy of consideration for inclusion in the *Piston (Thumper®) Device CPR* review. Some of the literature cited consists of well-executed studies of manual CPR compliance with AHA Guidelines. These are included because of the relevance of their results showing inadequacies of manual CPR even under the best of circumstances, and can be compared with other literature which shows that once mechanical CPR has been established, it is consistent and without interruption. We have included Summary of Evidence tables (Tables 1-3) constructed in similar format to those posted by ILCOR and have tried to structure them according to the *Instructions for Completion of the C2010 Evidence Evaluation Worksheet*. Following this, we have attached bibliographic information including article citations, abstracts, and other supporting evidence (Table 4).

Based on the scientific evidence cited, Thumper® piston-type CPR provides advantages over manual CPR in the form of consistent, accurate, high-impulse external chest compressions at a set, AHA-compliant rate, duty cycle, and depth with interspersed ventilations. These devices can be deployed rapidly with proper user training and transfer from manual CPR to Thumper® CPR can be done in less than 5 seconds. Ever since the early 1970s the Thumper® has been used in patient transport on stretchers, spineboards and other patient-carry devices. Studies have shown it can be used to provide continuous CPR even for carrying patients on stairways or in elevators. In studies where quality of mechanical versus manual CPR was assessed using either mean arterial pressure or end-tidal CO_2, Thumper® piston-type devices were found to produce greater cardiac output in patients as compared to experts doing their best manual CPR. The ability of Thumper® devices to provide forward blood flow has allowed some patients to regain consciousness while attached to the device, and their ability to operate consistently and accurately for an extended period has aided in the recovery of victims of poisoning and hypothermia even up to 14.5 hours.

As a result of our research and analysis, we believe it is fair to add for the CONSENSUS ON SCIENCE evidence:

> *Based on this review of published medical literature, there is sufficient evidence to recommend the use of piston CPR devices because of better hemodynamics, circulation, perfusion, and consistency in performance of compressions than manual CPR. For EMS applications, properly-trained personnel need to deploy the piston CPR devices to the scene and utilize it correctly. Such application can eliminate problems of hands-off fraction, rate, depth, duty cycle, and full recoil associated with manual CPR. This allows for associative care to be effectively administered and the results of same to be evaluated in the presence of consistent, properly-applied, AHA-compliant CPR.*

We hope the ILCOR reviewers find this medical literature cited and our attempt to evaluate and categorize these

publications according to ILCOR criteria useful in your review of Thumper® mechanical CPR. Please feel free to contact us for any Thumper®-related material we might provide which could further assist you in your work.

Sincerely,

Bruce H. Barkalow, Ph.D., PE, CCE
President

4717 Talon Court SE ▪ Grand Rapids, Michigan 49512 ▪ Phone: 616-554-9696 ▪ Fax: 616-554-3067

www.michiganinstruments.com

Table 1. Evidence Supporting Clinical Question

Good	• **Taylor et al., 1978 ABC**[1] • **Ward et al., 1993 E**[2]	• **Dickinson et al., 1998 ABE**[3] • **Ornato et al., 1992 AB**[4] • **Roberts, 1979**[5] • **Stapleton, 1991 E**[6]		• **Lilja et al., 1979 ABCD**[7] • **Lewinter et al., 1989 A**[8] • **Schaar et al., 1985 ABCD**[9]	• ***Angelos et al., 1991 ABD***[10] • ***Betz et al., 2006 A***[11] • ***Jäntti et al., 2009 E***[12] • ***Moss et al., 1986 E***[13] • ***Ødegaard et al., 2009***[14] • ***Sugerman et al., 2009 E***[15] • ***Sutton et al., 2009 E***[16]
Fair		• **McDonald, 1981 E**[17] • **McDonald, 1982 E**[18] • **Wang et al., 2007 E**[19]		• **Drouven et al., 1986 ABCD**[20] • **Garnett et al., 1987 A**[21] • **Gómez-Arnau et al., 1981 ABCD**[22] • **Kashman, 1991 ABCD**[23] • **Little et al., 1974 ABCD**[24] • **Mackey et al., 1987 ABCD**[25] • **Roberts and Bryan, 1978 E**[26] • **Wang et al., 2000 AB**[27]	• ***Gudipati et al., 1988 AE***[28]
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

Table 2. Evidence Neutral to Clinical Question

Good		• **Callaham and Barton, 1990 A**[29]			• ***Ornato et al., 1989 E***[30] • ***Wik et al., 1996 ABD***[31]
Fair					
Poor					
	1	**2**	**3**	**4**	**5**
Level of evidence					

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

Table 3. Evidence Opposing Clinical Question

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

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

Ref #	Table 4: Medical Journal Article Analysis
1	***Supporting, LOE: 1, Quality: Good, Outcomes Assessed: A,B,C*** **Taylor, George J.; Richard Rubin; Michael Tucker; H. Leon Greene; Michael T. Rudikoff; and Myron L. Weisfeldt (1978) External cardiac compression. A randomized comparison of mechanical and manual techniques. *JAMA*, 1978 Aug 18; 240(7): 644-6.** **ABSTRACT:** To compare the effectiveness of manual and mechanical chest compression during cardiopulmonary resuscitation, 50 patients who suffered cardiac arrest were randomly allocated to receive manual or mechanical chest compression. Randomization was performed after failure of initial resuscitative measures but within ten minutes after the onset of cardiac arrest (mean, 6.4 +/- 1.2 min). Ten patients from each group survived longer than one hour following resuscitation. Three from the mechanical group and two from the manual group were eventually able to leave the hospital. Thus mechanical compression appears comparable with manual compression when manual compression is performed under ideal conditions. Mechanical chest compression may be employed

Ref #	Table 4: Medical Journal Article Analysis
	when trained personnel are not readily available or where manual compression is technically difficult to perform. **ILCOR REVIEWER COMMENT:** Level 1 study, Good, Neutral. This study was a randomized trial assessing 80 victims of in-hospital cardiac arrest of whom 50 were included in the analyses. Victims were randomized to be subject to manual or mechanical chest compression after the arrival of the research team (within 10 minutes). Before that, patients were treated with manual chest compression, ventilation, cardioversion and drug therapy following standard protocols. Mechanical and manual chest compression were standardized in order to match 60 compression/min and with a compression/ventilation ratio of 5/1. In the study there was variability in the medical history, and specifically in the severity of systemic illness, and in the presentation of cardiac arrest (patients were monitored or not prior of occurrence of cardiac arrest). No differences in ROSC, one hour and 24 hour survival were observed. **MII PUBLIC COMMENT:** *This is a **Supportive** study because in the study results, Thumper® mechanical CPR "…compared with the best possible manual ECC." The manual CPR was performed under hospital, not EMS conditions. It is known today that manual CPR is usually not performed well. Even trained, in-shape rescuer manual CPR begins to deteriorate within only 1 minute. It is also known that manual CPR is particularly difficult to perform during patient transport whereas Thumper® CPR works well by providing continuous chest compressions and coordinated ventilation. The authors conclude "With less favorable circumstances for manual compression or when personnel are limited or are not optimally trained, mechanical ECC may have advantages over manual ECC." It is also important to note that in this study the compression rate was 60 compressions per minute – easier to perform than the present 100 compressions per minute rate. Thus, today, Thumper® CPR has even more of an advantage in providing continuous, properly-executed compressions. The sternal fracture noted occurred with use of the old Thumper® piston pad of the late 1970s. Since 1997, the Thumper® has used a new piston gel-pad that has a larger surface area and reduces the sharp impact of the compression. This piston pad has been found to perform well while reducing chest damage to levels below manual CPR.*
2	***Supporting, LOE: 1, Quality: Good, Outcomes Assessed: E*** **Ward, Kevin R.; James J. Menegazzi; Robert R. Zelenak; Robert J. Sullivan; and Norman E. McSwain (1993) A comparison of chest compressions between mechanical and manual CPR by monitoring end-tidal PCO2 during human cardiac arrest. *Annals of Emergency Medicine*, 1993 Apr; 22(4): 669-74.** **ABSTRACT:** STUDY OBJECTIVE: To compare the use of mechanical and manual chest compressions during cardiac arrest based on continuous monitoring of end-tidal PCO2 (PETCO2). DESIGN: Prospective, randomized, crossover design. SETTING AND PARTICIPANTS: Fifteen consecutive adults ranging in age from 33 to 78 years who presented in nontraumatic cardiac arrest to the emergency department of a large teaching hospital. INTERVENTIONS: Study protocols were begun late in the resuscitation after initial resuscitation attempts were unsuccessful. Patients

Ref #	Table 4: Medical Journal Article Analysis
	received four alternating five-minute trials (two manual and two mechanical), being randomized to begin with either technique. Mechanical compressions were performed by a mechanical device [Thumper®] at a compression depth of 2 in. Both mechanical and manual compressions were delivered at a rate of 80 with a ventilation delivered after every fifth compression. Persons performing manual CPR were experienced American Heart Association basic life support providers, and no person performed manual CPR more than once during the study period. No resuscitative drugs were administered during the study period. PETCO2 was monitored continuously; those performing manual CPR were blinded to the PETCO2 monitor. Data were analyzed with repeated-measures analysis of variance and Scheffé multiple comparisons with the alpha error rate set of .05. MEASUREMENTS AND RESULTS: Mean PETCO2 during mechanical CPR was 13.6 +/- 4.14 mm Hg compared with 6.9 +/- 2.42 mm Hg during manually performed CPR ($P < .001$), a difference of 97%. Average mechanical CPR PETCO2 was higher in all cases. No patient was resuscitated successfully. Capnography also indicated that most CPR providers were inconsistent in their chest compressions. CONCLUSION: This study suggests that cardiac output produced with mechanical chest compressions is greater than that produced with manual compressions as demonstrated by the significantly higher PETCO2 levels during mechanical CPR. Reasons for this are unclear. In addition, monitoring of PETCO2 may help optimize chest compressions during CPR. **ILCOR REVIEWER COMMENT:** Level 1, Good, Supportive. This is a prospective randomized crossover designed study conducted on 15 victims of cardiac arrest. After initial resuscitation attempts failed and the resuscitation team leader declared the impossibility to resuscitate the patients, victims were randomized to receive cycles of mechanical or manual chest compressions. The study did not investigate outcomes of cardiac arrest, but it was focused on end-tidal CO_2 generated by chest compression. Significantly greater end-tidal CO_2 is a surrogate of cardiac output generated by chest compression, this investigation may demonstrate that mechanical chest compression produces greater hemodynamics in humans compared to manual chest compression and there're may increase survival from cardiac arrest. However, there are limitations: the hemodynamics produced by chest compression were not assessed. Expired volumes were also not measured and therefore variability in the result due to not consistency in the minute ventilation could not be excluded. **MII PUBLIC COMMENT:** *It is not a significant limitation of this study to have not measured hemodynamic parameters produced by chest compressions because it is recognized today that measurement of end-tidal CO_2 is a superior indication of perfusion and perfusion effectiveness. Also, it is not a limitation to have measured the exhaled volumes as this was a comparative study and the same ventilator and ventilation method was used for manual CPR as for Thumper® CPR. This study clearly demonstrated the superiority of Thumper® CPR over manual CPR.*
3	***Supporting, LOE: 2, Quality: Good, Outcomes Assessed: A,B,E*** **Dickinson, Edward T.; Vincent P. Verdile; Robert M. Schneider; and Richard F. Salluzzo (1998) Effectiveness of mechanical versus manual chest compressions in out-of-hospital**

Ref #	Table 4: Medical Journal Article Analysis
	cardiac arrest resuscitation: a pilot study. *American Journal of Emergency Medicine*, 1998 May; 16(3): 289-92. **ABSTRACT:** A prospective, randomized effectiveness trial was undertaken to compare mechanical versus manual chest compressions as measured by end-tidal CO2 (ETCO2) in out-of-hospital cardiac arrest patients receiving advanced cardiac life support (ACLS) resuscitation from a municipal third-service, emergency medical services (EMS) agency. The EMS agency responds to approximately 6,700 emergencies annually, 79 of which were cardiac arrests in 1994, the study year. Following endotracheal intubation, all cardiac arrest patients were placed on 100% oxygen via the ventilator circuit of the mechanical cardiopulmonary resuscitation (CPR) device [Thumper®]. Patients were randomized to receive mechanical CPR (TCPR) or human/manual CPR (HCPR) based on an odd/even day basis, with TCPR being performed on odd days. ETCO2 readings were obtained 5 minutes after the initiation of either TCPR or HCPR and again at the initiation of patient transport to the hospital. All patients received standard ACLS pharmacotherapy during the monitoring interval with the exception of sodium bicarbonate. CPR was continued until the patient was delivered to the hospital emergency department. Age, call response interval, initial electrocardiogram (ECG) rhythm, scene time, ETCO2 measurements, and arrest outcome were identified for all patients. Twenty patients were entered into the study, with 10 in each treatment group. Three patients in the TCPR group were excluded. Measurements in the HCPR group revealed a decreasing ETCO2 during the resuscitation in 8 of 10 patients (80%) and an increasing ETCO2 in the remaining 2 patients. **No decrease in ETCO2 was noted in the TCPR group, with 4 of 7 patients (57%) actually showing an increased reading and 3 of 7 patients (43%) showing a constant ETCO2 reading**. The differences in the ETCO2 measurements between TCPR and HCPR groups were statistically significant. Both groups were similar with regards to call response intervals, patient ages, scene times, and initial ECG rhythms. One patient in the TCPR group was admitted to the hospital but later died, leaving no survivors in the study. **TCPR appears to be superior to standard HCPR as measured by ETCO2 in maintaining cardiac output during ACLS resuscitation of out-of-hospital cardiac arrest patients.** **ILCOR REVIEWER COMMENT:** Level 2 study, Fair, Neutral. This is a prospective, pseudo-randomized trial including 17 patients (10 subjected to manual chest compression and 7 subjected to mechanical chest compression). The study was not a true-randomized trial, because a pseudorandomization was employed, an "odd/even day" randomization. The investigation was focused on end-tidal CO2 generated by chest compression. Significantly greater End-tidal CO2 was observed during mechanical chest compression compared to manual chest compression. Since end-tidal CO2 is a surrogate of cardiac output generated by chest compression, this investigation may demonstrate that mechanical chest compression produces greater hemodynamics compared to manual chest compression in human victims of cardiac arrest. No victim of cardiac arrest survived when manual chest compression was performed and only one patient was resuscitated with mechanical chest compression and eventually died within 48 hours. Therefore no differences in outcome were reported. The study, however, was not powered to investigate survival, especially for the small number of patients enrolled.

Ref #	Table 4: Medical Journal Article Analysis
	MII PUBLIC COMMENT: *This is a **Supportive** study because "TCPR appears to be superior to standard HCPR as measured by $ETCO_2$ in maintaining cardiac output during ACLS resuscitation of out-of-hospital cardiac arrest patients."* *It is a **Level 2** study because it is pseudo randomized. Patients randomly present with heart attacks. Whether that occurs on an even day or an odd day is random but each incident is not treated randomly regardless of time of event.* *This is a **Good** study because it meets most of the LOE Meta-analysis criteria:* • *The study had a specific objective "… to compare the effectiveness of mechanical versus basic CPR, as measured by ETCO2 in out-of-hospital cardiac arrest patients undergoing advanced cardiac life support (ACLS) resuscitation"* • *The study was defined to compare manual to mechanical CPR on human patients in two treatment groups.* • *Selection criteria were defined as prospective, with odd/even day randomization.* • *The methodological quality of manual CPR and mechanical CPR were controlled by proper use of the Thumper® and by providing manual CPR by certified emergency personnel. Ventilation was provided by the same ventilator regardless of compression method.* *This study clearly shows end-tidal CO_2 values were significantly improved when Thumper® CPR was applied. It is also noteworthy that as a result of the study, the investigators decided to end the data collection and implement the Thumper® device on every cardiac arrest patient.*
4	***Supporting, LOE: 2, Quality: Good, Outcomes Assessed: A,B*** **Ornato, Joseph P.; Joshua B. Shipley; Edward M. Racht; Corey M. Slovis; Keith D. Wrenn; Paul E. Pepe; Sherri-Lyne Almeida; Vicki F. Ginger; and Terry V. Fotre (1992) Multicenter study of a portable, hand-size, colorimetric end-tidal carbon dioxide detection device. *Annals of Emergency Medicine*, 1992 May; 21(5): 518-23.** **ABSTRACT:** STUDY OBJECTIVES: To evaluate continuous, semiquantitative end-tidal carbon dioxide (ETCO2) monitoring in the prehospital and emergency department setting for confirming proper endotracheal tube placement and assessing prognosis and blood flow during CPR. TYPE OF PARTICIPANTS: Adult patients were included if an endotracheal tube was inserted by prehospital care providers or emergency physicians for cardiac arrest, respiratory arrest, respiratory insufficiency, or airway protection. DESIGN AND INTERVENTIONS: A small, portable, colorimetric ETCO2 detector was attached to the endotracheal tube immediately after each attempted endotracheal tube insertion. The color of the detector membrane was noted at the seventh breath following intubation. The color also was noted and recorded if there was return of spontaneous circulation (defined as a palpable pulse) immediately prior to and following conversion from manual to mechanical CPR. Survival to hospital admission was used as an end point to assess the prognostic value of the initial ETCO2 reading. MAIN RESULTS: A total of 227 patients (144 with cardiopulmonary arrest) were studied. In the 83 patients intubated but not in cardiopulmonary arrest, a reading on the ETCO2 detector signifying more than 0.5% ETCO2 was 100% sensitive and 93% specific in detecting proper endotracheal tube placement (100% specific with the endotracheal

Ref #	Table 4: Medical Journal Article Analysis
	tube cuff inflated). In cardiac arrest patients, a longer period of estimated arrest appeared to be associated with a lower ETCO2 detector reading. A reading signifying more than 0.5% ETCO2 was 69% sensitive and 100% specific in detecting proper endotracheal tube placement. After proper endotracheal tube placement, all cardiac arrest patients who survived to hospital admission had an initial ETCO2 measurement signifying more than 0.5% ETCO2. Return of spontaneous circulation was usually accompanied by an improved ETCO2 value. **Mechanical CPR always produced an ETCO2 value that was as high or higher than that produced by manual CPR.** CONCLUSION: The colorimetric ETCO2 device is highly accurate for confirming endotracheal tube position in nonarrest patients. In cardiac arrest patients, a reading signifying more than 0.5% ETCO2 confirms correct endotracheal tube placement, while a value signifying less than 0.5% ETCO2 during resuscitation suggests that something is wrong (e.g., esophageal intubation, inadequate circulatory flow, prolonged down-time interval, hypothermia, or significant ventilation/perfusion mismatch). **ILCOR REVIEWER COMMENT**: NONE – Not Reviewed **MII PUBLIC COMMENT:** *This study is **Supportive** of Thumper® CPR. While the study objective was to evaluate the use of end-tidal CO_2 monitoring during CPR for proper endotracheal tube placement and to ascertain blood flow during CPR, Thumper® CPR was used and compared to manual CPR. "Mechanical (Thumper) CPR always produced an $ETCO_2$ value that was as high or higher than that produced by manual CPR."* *This was study was **LOE 2** because it prospective, multicenter study carried out in six urban emergency medical services systems with at total of 227 patients (144 with cardiopulmonary arrest). There was a concurrent control – the same patient was used to compare exhaled CO_2 just before CPR was changed from manual to Thumper® CPR and then just after Thumper® CPR was established.* *The study is **Good** because the study objective is stated as "To evaluate continuous, semiquantitative end-tidal carbon dioxide ($ETCO_2$) monitoring in the prehospital and emergency department setting for confirming proper endotracheal tube placement and assessing prognosis and blood flow during CPR." The study is well defined, and selection criteria was stated as adult patients having an endotracheal tube inserted by a prehospital care provider or an emergency physician for treatment of cardiac arrest, respiratory arrest, respiratory insufficiency, or airway protection. The characteristics of the methodology were well defined and as stated, the methodology that compared $ETCO_2$ during manual CPR and mechanical used the same patient with measurements taken during manual CPR and then with subsequent Thumper® CPR thus allowing a meaningful comparison.*
5	***Supporting, LOE: 2, Quality: Good, Outcomes Assessed: E*** **Roberts, Bill G. (1979) Machine vs. manual cardiopulmonary resuscitation in moving vehicles. *The EMT Journal*, 1979 Mar; 3(1): 30-4.** **ABSTRACT (MII-authored abstract):** After 1,500 applications of Thumper® CPR, its use was reevaluated. A set of scenario based tests using a recording manikin were executed to compare

Ref #	Table 4: Medical Journal Article Analysis
	manual CPR to Thumper® CPR. The participants had no previous training on the use of the Thumper®. • The first scenario placed the patient (manikin) on the 8th floor of a building and manual CPR was carried out on site as well as in transport on a stretcher down the corridor and into an elevator then to a series of steps and on to the ambulance. CPR was continued en route with one EMT driver and two EMTs providing CPR. • The second scenario was the same as the first but Thumper® CPR was used. Only a short indoctrination on how to use the Thumper® was provided. • The third through six scenarios involved comparison of manual CPR to Thumper® CPR for application on the scene and transport within a building. The authors found Thumper® CPR performs better than manual CPR. --- **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This is a **Supportive** study that compares Thumper® CPR to manual CPR in terms of adherence to proper CPR technique and protocols for realistic scenarios. It is **Good** in that participants were trained well in manual CPR but had only a brief orientation to Thumper® CPR. The authors conclude after their experience with 1,500 uses of the Thumper® and this study, "Together with the study from Johns Hopkins University, we have concluded from all tests that the mechanical CPR is far superior in comparison to any manual CPR efforts."*
6	***Supporting, LOE: 2, Quality: Good, Outcomes Assessed: E*** **Stapleton, Edward R. (1991) Comparing CPR during ambulance transport. Manual vs. mechanical methods. *JEMS*, 1991 Sep; 16(9): 63-4, 66, 68, 71-72.** **ABSTRACT:** Performance of CPR during ambulance transport can be a difficult and dangerous activity for prehospital personnel. The efficacy of compressions and ventilation is questionable even under ideal circumstances. A study at Booth Memorial Medical Center in Flushing, NY was conducted in which CPR performance was measured during transport using a recording manikin. It was found that under all conditions, a manually triggered demand –valve resuscitator performed the best ventilation and Thumper CPR provided the best chest compressions as compared to manual techniques. --- **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This is a **Supportive** study that was well designed with controls and executed to objectively determine the quality and compliance of ventilation and chest compressions under a variety of situations between manual and mechanical means. The gas-powered compressor (Thumper®) showed a 97% overall compression performance compared to manual compressions rated at only 37%.*
7	***Supporting, LOE: 4, Quality: Good, Outcomes Assessed: A,B,C,D***

Ref #	Table 4: Medical Journal Article Analysis
	Lilja, G. Patrick; Martin Hill; Ernest Ruiz; and Joseph Clinton (1979) Clinical assessment of patients undergoing CPR in the emergency department. *JACEP*, 1979 Feb; 8(2): 81-3. **ABSTRACT:** A problem frequently encountered in the emergency department is assessing the effectiveness of cardiopulmonary resuscitation (CPR), particularly when it is continued over a period of time. To evaluate the effectiveness of CPR in our emergency department we use a mechanical cardiopulmonary resuscitator (Michigan Instruments, Thumper®) together with early invasive monitoring of pulse and blood pressure. This also allows for frequent monitoring of blood gases. Three patients are presented who underwent long term CPR (i.e., longer than one hour), and invasive monitoring. Results indicate that better management of the clinical status of patients undergoing prolonged resuscitation can be obtained by using continuous blood pressure and pulse monitoring, and frequent blood gas analysis. In addition, when frequent arrhythmias are taking place, this system allows for better determination of appropriate procedures and medications. **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This publication reviews experience in treating cardiac arrest patients using Thumper® CPR in the emergency department. In this reported protocol patients have arterial blood pressure and when possible a central arterial pressure. Blood gases were monitored. There were 3 case reports:* • *Case 1 was a 67 year-old female who arrested and had standby CPR and CPR during transport. She presented with bradycardia and no pulse. Thumper® CPR was applied for **2 hours and 10 minutes**. In this time the patient regained consciousness and neurological function from the Thumper® CPR but could not be saved.* • *Case 2 was a 45 year-old woman presented with hypothermia and cardiac arrest. She was placed on the Thumper® CPR in the ED and an arterial pressure line was used to compare results from manual and Thumper® CPR. Thumper® CPR consistently showed high systolic pressure with 50% to 60% duration, where as manual CPR had some steeper peak pressures but very short flow durations. The patient was on Thumper® CPR about **1 hour and 45 minutes**. During that time she transferred with the Thumper® operating to a surgical suite for further warming. She survived neurologically intact.* • *Case 3 was a 52 year-old male found by paramedics in VF. CPR was performed on the scene and enroute to the ED. On arrival Thumper® CPR was applied along with resuscitation attempts. The patient attained ROSC.* *The authors conclude: "We believe that cardiac arrest should be aggressively managed in the emergency department. This involves assuring adequate perfusion by using a mechanical external cardiac compressor to maximize cardiac output." While Case 3 is not remarkable, Cases 1 and 2 demonstrate how longer resuscitation attempts are possible with continuous application of Thumper® CPR. At the time of this study an arterial line was useful. Today, perhaps end-tidal CO_2 would be a better parameter to measure.*
8	***Supporting, LOE: 4, Quality: Good, Outcomes Assessed: A***

Ref #	Table 4: Medical Journal Article Analysis
	Lewinter, Jody R.; Donna L. Carden; Richard M. Nowak; Enrique Enriquez; and Gerard B. Martin (1989) CPR-dependent consciousness: evidence for cardiac compression causing forward flow. *Annals of Emergency Medicine*, 1989 Oct; 18(10): 1111-5. **ABSTRACT:** We present the case of a patient with cardiac arrest and resuscitation in whom, consistent with direct cardiac compression, large aortic-to-right atrial systolic pressure gradients occurred. Forward blood flow during CPR was sufficient for the patient to maintain consciousness. Although aortic-to-right atrial diastolic gradients adequate to maintain coronary perfusion in experimental models were generated, in our patient, cardiac function could not be restored and the resuscitation was ultimately unsuccessful. --- **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This is the case report of a 60 year-old woman who suffered cardiac arrest 33 minutes after arrival in the ED. She was placed on Thumper® CPR and femoral arterial pressure was monitored as well as Ao-RA pressures.* *Thumper® CPR was provided for 3 hours and 15 minutes. The recorded pressures were in the range of (initial – after 2 hours of Thumper® CPR)* *Ao systolic: 122 to 100 mm Hg* *RA systolic: 48 to 40 mm Hg* *Ao – RA systolic: 74 to 60 mm Hg* *Ao diastolic: 36 to 38 mm Hg* *RA diastolic: 15 to 15 mm Hg* *Ao – RA diastolic: 21 to 23 mm Hg* *This case study is **Supportive** because it shows the remarkable pressures and pressure gradients indicative of good forward flow as produced over a long period of Thumper® CPR application.*
9	***Supporting, LOE: 4, Quality: Good, Outcomes Assessed: A,B,C,D*** **Schaar, H.; A. Reininghaus; and H. Schmitt (1985) Long-term mechanical cardiac massage in a case of intoxication with a lethal dose of beta-blocker, antidepressants and flurazepam. Proceedings of the Ludwig-Boltzmann Symposium, Academic Teaching Hospital of RWTH Aachen, 1985 Mar; 1-3.** **ABSTRACT:** We describe the treatment of a depressive, internally healthy 32 year old patient who attempted suicide with a mixed intoxication of beta-blocker, Amitriptyline and Flurazepam, each in potentially lethal dose, combined with alcohol. Poisoning stage IV according to Reed developed, with total electromechanical decoupling, which was successfully dealt with by **prolonged [Thumper®*] heart massage for 14.5 hours**. The patient was discharged internally healthy after 7 days. --- **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed

Ref #	Table 4: Medical Journal Article Analysis
	MII PUBLIC COMMENT: *This article is **Supportive** because it is a case report showing how long term (14.5 hours) application of Thumper® CPR for a younger, otherwise healthy patient resulted in a neurologically intact outcome with no collateral damage. It is highly doubtful this patient could have ever been treated with 14.5 hours of manual CPR.* *Thumper® device marketed in Europe with the name *Sirepuls*.
10	***Supporting, LOE: 5, Quality: Good, Outcomes Assessed: A,B,D*** **Angelos, Mark; Peter Safar; and Harvey Reich (1991) External cardiopulmonary resuscitation preserves brain viability after prolonged cardiac arrest in dogs. *The American Journal of Emergency Medicine*, 1991 Sep; 9(5): 436-43.** **ABSTRACT:** Standard external cardiopulmonary resuscitation (CPR) steps A-B-C produce a low blood flow that may or may not preserve brain viability during prolonged cardiac arrest. A dog model was used with ventricular fibrillation (VF) of 20 minutes, reperfusion with brief cardiopulmonary bypass, controlled ventilation to 20 hours, and intensive care to 96 hours. A retrospective comparison was made of the results of one series, now called "group I" (n = 10)--which received CPR basic life support interposed from VF 10 to 15 minutes, and CPR advanced life support with epinephrine (without defibrillation) from VF 15 to 20 minutes--to the results of another series, now "control group II" (n = 10)--which received VF no flow (no CPR) for 20 minutes. All 20 dogs within protocol were resuscitated. All 10 of group I and 7 of 10 of group II survived to 96 hours. Pupillary light reflex returned after the start of cardiopulmonary bypass at 7.7 +/- 3.7 minutes in CPR group I, versus 16.3 +/- 7.4 minutes in control group II (P = .032). At 96 hours postarrest, final overall performance categories (1, normal; 5, brain death) were better in group I. Six of 10 dogs achieved normality (overall performance category 1) in group I, as compared with none of 10 in group II (P = .004). Final neurologic deficit score (0%, best; 100% worst) was lower (better) in group I (15% +/- 20%) than in group II (51% +/- 6%; P less than .001). Final canine coma score (15, best; 3, worst) was higher (better) in group I (13.0 $\pm$ 2.8) than in group II (8.0 $\pm$ 1.3; P = .002). It was concluded that optimal standard external CPR steps A-B-C can sustain cerebral viability during prolonged VF cardiac arrest, even after no flow of 10 minutes. **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This study is **Supportive** of Thumper® CPR because the Thumper® was used and acknowledged by the authors as providing optimized standard external CPR-BLS-ALS. Using the Thumper® in this study the authors were able to preserve cerebral function. The authors state, "**The results of this study show that even after a 10-minute period of normothermic no flow, another 10 minutes of standard external CPR [provided by the Thumper® in this study] can restore and preserve brain viability.**" While this is not a direct comparison to manual CPR, the Thumper® was used to provide consistent, high quality "manual CPR."*

Ref #	Table 4: Medical Journal Article Analysis
11	***Supporting, LOE: 5, Quality: Good, Outcomes Assessed: A*** **Betz, Amy E.; James J. Menegazzi; Eric S. Logue; Clifton W. Callaway; and Henry E. Wang (2006) A randomized comparison of manual, mechanical and high-impulse chest compression in a porcine model of prolonged ventricular fibrillation. *Resuscitation*, 2006 Jun; 69(3): 495-501.** **ABSTRACT:** BACKGROUND: Elevated coronary perfusion pressure (CPP) during CPR is associated with return of spontaneous circulation (ROSC). We compared CPP achieved with three methods of chest compression: manual (MAN), mechanical (MECH) and high-impulse mechanical (HI) in a porcine model of prolonged ventricular fibrillation (VF). We hypothesized that HI (very rapid acceleration of the down-stroke) would produce greater CPPs than MAN or MECH, and that HI would also produce a higher rate of ROSC. METHODS: Twenty-eight domestic swine (mean 27.8 kg) were randomly assigned to three methods of chest compression. Animals were instrumented under anesthesia, and VF was induced and untreated for 8 min. After 2 min of CPR, Epinephrine (adrenaline) (0. 1 mg/kg), Vasopressin (40 U) and Propranolol (1.0 mg) were administered. CPR continued for three more minutes, after which up to three rescue shocks were delivered. CPP was determined in an automated fashion by measuring the difference between aortic and right atrial pressures 0.1s prior to the down-stroke of each compression (i.e., end-relaxation). ROSC was defined as a systolic pressure greater than 80 mm Hg sustained for at least 1 min. We analyzed CPP and ROSC using repeated measures ANOVA and Fisher's exact test. RESULTS: Over the 5 min of CPR, CPP increased more with HI compression than with MAN compression (p=0.017). ROSC was attained in 4/9 MAN, 6/9 MECH and 10/10 HI (HI versus MAN p=0.01). CONCLUSIONS: Over the course of CPR, HI compression increased CPP more than MAN compression. HI compression produced a significantly higher rate of ROSC than MAN, but not MECH compression. **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This is a **Supportive** study because it compares mechanical CPR to manual CPR in a randomized animal study. It is important to note that the current versions of the Thumper® all use the high-impulse waveform as described in this study. The author states "**In this porcine model of prolonged VF the increase in CPP over time was greater with high-impulse chest compressions than with manual compressions. High-impulse did not achieve higher CPP than standard mechanical compression. High-impulse compression led to a higher rate of ROSC than manual but not mechanical CPR.**" NOTE: Both Thumper® Models 1005 and 1007 outperformed manual CPR.*
12	***Supporting, LOE: 5, Quality: Good, Outcomes Assessed: E*** **Jäntti, Helena; Tom Silfvast; A. Turpeinen; V. Kiviniemi; and Ari Uusaro (2009) Influence of chest compression rate guidance on the quality of cardiopulmonary resuscitation performed on manikins. *Resuscitation*, 2009 Apr; 80(4): 453-7.**

Ref #	Table 4: Medical Journal Article Analysis
	ABSTRACT: AIMS: The adequate chest compression rate during CPR is associated with improved haemodynamics and primary survival. To explore whether the use of a metronome would affect also chest compression depth beside the rate, we evaluated CPR quality using a metronome in a simulated CPR scenario. METHODS: Forty-four experienced intensive care unit nurses participated in two-rescuer basic life support given to manikins in 10min scenarios. The target chest compression to ventilation ratio was 30:2 performed with bag and mask ventilation. The rescuer performing the compressions was changed every 2min. CPR was performed first without and then with a metronome that beeped 100 times per minute. The quality of CPR was analysed with manikin software. The effect of rescuer fatigue on CPR quality was analysed separately. RESULTS: The mean compression rate between ventilation pauses was 137+/-18 compressions per minute (cpm) without and 98+/-2cpm with metronome guidance ($p<0.001$). The mean number of chest compressions actually performed was 104+/-12cpm without and 79+/-3cpm with the metronome ($p<0.001$). The mean compression depth during the scenario was 46.9+/-7.7mm without and 43.2+/-6.3mm with metronome guidance ($p=0.09$). The total number of chest compressions performed was 1022 without metronome guidance, 42% at the correct depth; and 780 with metronome guidance, 61% at the correct depth ($p=0.09$ for difference for percentage of compression with correct depth). CONCLUSIONS: Metronome guidance corrected chest compression rates for each compression cycle to within guideline recommendations, but did not affect chest compression quality or rescuer fatigue. **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This published study is well done (**Good**) and controlled. It clearly demonstrates the failings of manual CPR even when significant efforts are made to improve quality and consistency of compressions. It is **Supportive** of Thumper® CPR because once applied, Thumper® CPR simply provides consistent, accurate, unwavering compressions. This cannot be done with manual CPR except for short durations by a few individuals.*
13	***Supporting, LOE: 5, Quality: Good, Outcomes Assessed: E*** **Moss, Jerry F.; Michael Haklin; Harry W. Southwick; and David L. Roseman (1986) A model for the treatment of accidental severe hypothermia. *Journal of Trauma*, 1986 Jan; 26(1): 68-74.** **ABSTRACT:** Central to the controversy that surrounds the treatment of accidental severe hypothermia is the question of how the method of rewarming affects myocardial performance, and therefore survival. We induced severe hypothermia and cardiac arrest in 15 mongrel dogs. Each dog was rewarmed by one of three methods: partial cardiac bypass (Group I); peritoneal dialysis (Group II); or external rewarming with a fluid-circulated blanket (Group III). The cardiac arrest state was supported by partial cardiac bypass in Group I and by standard mechanical cardiopulmonary resuscitation (CPR) in Groups II and III. In all dogs, the hypothermically depressed myocardial performance returned to normal upon rewarming. Groups I and II had similar rewarming times and

Ref #	Table 4: Medical Journal Article Analysis
	required similar volumes of crystalloid and bicarbonate solutions to maintain adequate cardiac filling pressures and arterial pH. However, Group III had a significantly slower rewarming time and required significantly greater volumes of crystalloid and bicarbonate solutions. The sole procedural death occurred in Group III. Our results show that partial cardiac bypass, peritoneal dialysis, and the fluid-circulated blanket are equally effective in rewarming severely hypothermic dogs with cardiac arrest, provided that the cardiac arrest is relieved by partial cardiac bypass or standard mechanical CPR and that physiologic levels of intravascular volume, oxygenation, and pH are maintained. **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This is a prospective animal study on treatment of severe hypothermia. It is a **Supportive** study because the authors used Thumper® CPR on their subjects with success. The authors compared manual CPR to Thumper® CPR for provision of circulation in the re-warming of patients. "The faster rewarming also avoided a lengthy period of CPR that, without the reproducibility of the mechanical device, could result in less effective perfusion (we chose mechanical CPR [Thumper® CPR] because it produces consistent chest deflection with peak arterial pressures similar to those of manual CPR).*
14	***Supporting, LOE: 5, Quality: Good, Outcomes Assessed: E*** **Ødegaard, Silje; Theresa Olasveengen; Petter Andreas Steen; and Jo Kramer-Johansen (2009) The effect of transport on quality of cardiopulmonary resuscitation in out-of-hospital cardiac arrest. *Resuscitation*, 2009 Aug; 80(8): 843-8.** **ABSTRACT:** INTRODUCTION: Most manikin and clinical studies have found decreased quality of CPR during transport to hospital. We wanted to study quality of CPR before and during transport for out-of-hospital cardiac arrest patients and also whether quality of CPR before initiation of transport was different from the quality in patients only receiving CPR on scene. MATERIALS AND METHODS: Quality of CPR was prospectively registered with a modified defibrillator for consecutive cases of out-of-hospital cardiac arrest in three ambulance services during 2002-2005. Ventilations were registered via changes in transthoracic impedance and chest compressions were measured with an extra chest compression pad placed on the patients' sternum. Paired t-tests were used to analyse quality of CPR before vs. during transport with ongoing CPR. Unpaired t-tests were used to compare CPR quality prior to transport to CPR quality in patients with CPR terminated on site. RESULTS: Quality of CPR did not deteriorate during transport, but as previously reported overall quality of CPR was substandard. Quality of CPR performed on site was significantly better when transport was not initiated with ongoing CPR compared to episodes with initiation of transport during CPR: fraction of time without chest compressions was 0.45 and 0.53 ($p<0.001$), compression depth 37 mm and 34 mm ($p=0.04$), and number of chest compressions per minute 61 and 56 ($p=0.01$), respectively. **CONCLUSION: CPR quality was sub-standard both before and during transport. Early decision to transport might have negatively affected CPR quality from the early stages of resuscitation.**

Ref #	Table 4: Medical Journal Article Analysis
	ILCOR REVIEWER COMMENT: NONE – Not Reviewed **MII PUBLIC COMMENT:** *This is a well-done study carefully examining the quality of manual CPR. It is **Supportive** of Thumper® CPR because Thumper® CPR requires a one-time less than 5 second switch-over from manual to Thumper® CPR. Thereafter, there are no issues with rate, depth, duty cycle, full chest recoil or hands-off time. Also, Thumper® CPR allows for continuous, uninterrupted CPR during patient movement from the patient scene to the emergency vehicle and within the emergency vehicle. This study shows such continuous uninterrupted manual CPR is not likely if not impossible to achieve. The authors state in regard to mechanical CPR, "Mechanical chest compressions have not been shown to improve outcome, but should eliminate some safety risks to the personnel in the moving vehicle." **NOTE: The references cited in the statement "Mechanical chest compressions have not been shown to improve outcome but should eliminate some safety risks to the personnel in the moving vehicle" do not include any Thumper® CPR studies. Thumper® CPR has evidence that it improves circulation and end-tidal CO_2 even over manual CPR performed by experts who are doing the compressions correctly under controlled conditions. For example, see Taylor, 1978; Ward, 1993; and Betz et al., 2006 as cited herein.***
15	***Supporting, LOE: 5, Quality: Good, Outcomes Assessed: E*** **Sugerman, Noah T.; Dana P. Edelson; Marion Leary; Elizabeth K. Weidman; Daniel L. Herzberg; Terry L. Vanden Hoek; Lance B. Becker; and Benjamin S. Abella (2009) Rescuer fatigue during actual in-hospital cardiopulmonary resuscitation with audiovisual feedback: a prospective multicenter study . *Resuscitation*, 2009 Sep; 80(9): 981-4.** **ABSTRACT:** BACKGROUND: Rescuer fatigue during cardiopulmonary resuscitation (CPR) is a likely contributor to variable CPR quality during clinical resuscitation efforts, yet investigations into fatigue and CPR quality degradation have only been performed in simulated environments, with widely conflicting results. OBJECTIVE: We sought to characterize CPR quality decay during actual in-hospital cardiac arrest, with regard to both chest compression (CC) rate and depth during the delivery of CCs by individual rescuers over time. METHODS: Using CPR recording technology to objectively quantify CCs and provide audiovisual feedback, we prospectively collected CPR performance data from arrest events in two hospitals. We identified continuous CPR "blocks" from individual rescuers, assessing CC rate and depth over time. RESULTS: 135 blocks of continuous CPR were identified from 42 cardiac arrests at the two institutions. Median duration of continuous CPR blocks was 112s (IQR 101-122). CC rate did not change significantly over single rescuer performance, with an initial mean rate of 105+/-11/min, and a mean rate after 3 min of 106+/-9/min (p=NS). However, CC depth decayed significantly between 90s and 2 min, falling from a mean of 48.3+/-9.6mm to 46.0+/-9.0mm (p=0.0006) and to 43.7+/-7.4mm by 3 min (p=0.002). **CONCLUSIONS: During actual in-hospital CPR with audiovisual feedback, CC depth decay became evident after 90s of CPR, but CC rate did not change. These data provide clinical evidence for rescuer fatigue during actual resuscitations and support current guideline recommendations to rotate rescuers during CC delivery.**

Ref #	Table 4: Medical Journal Article Analysis
	ILCOR REVIEWER COMMENT: NONE – Not Reviewed **MII PUBLIC COMMENT:** *This is a well done (**Good**) human study that carefully examines and analyzes manual CPR as a function of rescuer fatigue. The study clearly illustrates rescuers cannot maintain quality compression even though Q-CPR feedback was used. "Therefore, our results likely underestimate the actual CPR decay from rescuer fatigue, as some fraction of rescuers may have maintained CPR quality despite initial fatiguing in response to feed back massages." The study is **Supportive** of Thumper® CPR because Thumper® CPR requires a onetime less than 5 second switch-over from manual to Thumper® CPR. Thereafter, there are no issues with rate, depth, duty cycle, full chest recoil or hands-off time. Rescuer fatigue is no longer a factor in provision of AHA-compliant compressions.*
16	***Supporting, LOE: 5, Quality: Good, Outcomes Assessed: E*** **Sutton, Robert M.; Matthew R. Maltese; Dana Niles; Benjamin French; Akira Nishisaki; Kristy B. Arbogast; Aaron Donoghue; Robert A. Berg; Mark A. Helfaer; and Vinay Nadkarni (2009) Quantitative analysis of chest compression interruptions during in-hospital resuscitation of older children and adolescents. *Resuscitation*, 2009 Nov; 80(11): 1259-63.** **ABSTRACT:** AIM: To quantitatively describe pauses in chest compression (CC) delivery during resuscitation from in-hospital pediatric and adolescent cardiac arrest. We hypothesized that CPR error will be more likely after a chest compression provider change compared to other causes for pauses. METHODS: CPR recording/feedback defibrillators were used to evaluate CPR quality for victims >/=8 years who received CPR in the PICU/ED. Audiovisual feedback was supplied in accordance with AHA targets. Etiology of CC pauses identified by post-event debriefing/reviews of stored CPR quality data. RESULTS: Analysis yielded 205 pauses during 304.8 min of CPR from 20 consecutive cardiac arrests. Etiologies were: 57.1% for provider switch; 23.9% for pulse/rhythm analysis; 4.4% for defibrillation; and 14.6% "other." Provider switch accounted for 41.2% of no-flow duration. Compared to other causes, CPR epochs following pauses due to provider switch were more likely to have measurable residual leaning (OR: 5.52; CI(95): 2.94, 10.32; p<0.001) and were shallower (43+/-8 vs. 46+/-7 mm; mean difference: -2.42 mm; CI(95): -4.71, -0.13; p=0.04). Individuals performing continuous CPR>or=120 s as compared to those switching earlier performed deeper chest compressions (42+/-6 vs. 38+/-7 mm; mean difference: 4.44 mm; CI(95): 2.39, 6.49; p<0.001) and were more compliant with guideline depth recommendations (OR: 5.11; CI(95): 1.67, 15.66; p=0.004). CONCLUSIONS: Provider switches account for a significant portion of no-flow time. Measurable residual leaning is more likely after provider switch. Feedback systems may allow some providers to continue high quality CPR past the recommended switch time of 2 min during in-hospital resuscitation attempts. **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This study is **Supportive** of Thumper® CPR because it clearly*

Ref #	Table 4: Medical Journal Article Analysis
	*demonstrates 2 minute switch-over leads to significant no-flow time. The only no-flow time with Thumper® CPR occurs during the transition from manual to Thumper® CPR, a single switch-over that takes less than 5 seconds. This is a **Good** study with accurate data recording using Philips QCPR along with other means of recording and observing. Rescuer switch-over accounted for 41 percent of no-flow time when compared to other no-flow interruptions of pulse/rhythm check, defibrillation and "other." Thumper® CPR would eliminate the 41% no-flow time from 2 minute rescuer switch-over.*
17	***Supporting, LOE: 2, Quality: Fair, Outcomes Assessed: E*** **McDonald, John L. (1981) Systolic and mean arterial pressures during manual and mechanical CPR in humans. *Critical Care Medicine*, 1981 May; 9(5): 382-3.** **ABSTRACT:** The presence or absence of a peripherally palpable pulse during CPR is a major clinical sign upon which the effectiveness of chest compression is based. If a pulse is present, adequate pressure in inferred. As well, in many cases, the inductive leap is made that because pressure is present, so too, must flow be present. Both mechanically and manually performed chest compression during CPR can produce a peripherally palpable pulse in most cases; the relationship of that peripherally palpable pulse to systolic arterial pressure (SAP) is obvious. To study the relationship of SAPs to mean arterial pressures (MAPs) resulting from the use of mechanical and manual chest compression, as well as the individual ability of the mechanical and manual forms of chest compression to produce such pressures in the same person, the author did a study of 14 patients undergoing CPR in this emergency department. All these persons had had CPR initiated outside the hospital and each was in a late stage (at least 30 min post arrest and, in some cases, greater than 1 hour post arrest) of the resuscitative process. All had failed to respond adequately to methods utilized at the scene and enroute, including defibrillation and chemical therapy. Thus, they were a highly selected group. **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This study was controlled as it was conducted on 14 people comparing manual to Thumper® CPR in the same person. The mechanical CPR rate was 60 with the 50% compression for the first 10 cases and 60% compression for the next 4 cases. Manual CPR was done by one person, except for one subject having manual CPR performed by a different person. The intention was to compare mechanical to manual compression techniques to generate comparative arterial pressures in the same person. Mean arterial pressure is more reflective of forward flow than systolic arterial pressure. The Thumper® CPR was found to be superior to manual CPR in generating mean arterial pressures. This is interpreted to be **Supportive** of Thumper® CPR.*
18	***Supporting, LOE: 2, Quality: Fair, Outcomes Assessed: E*** **McDonald, John L. (1982) Systolic and mean arterial pressures during manual and**

Ref #	Table 4: Medical Journal Article Analysis
	mechanical CPR in humans. *Annals of Emergency Medicine*, 1982 Jun; 11(6): 292-5. **ABSTRACT:** The standard manual method of performing chest compression during cardiopulmonary resuscitation (CPR) was compared with a pneumatic compression device for the ability to generate systolic arterial pressure (SAP) and mean arterial pressure (MAP) in the same person. Fifteen patients, all in the late stages of the resuscitative effort, were studied. In 14, manual chest compression resulted in SAPs which were either higher than (13 cases) or equivalent to (1 case) those generated by the mechanical technique. In 13 of the 15 cases, mechanical compression resulted in MAPs which were either higher than (11 cases) or equivalent to (2 cases) MAPs generated by the manual method. Mechanical chest compression is superior to manual chest compression in generating higher MAPs. Direct measurement of arterial pressure and the use of mechanical chest compression results in a more informed and a less frenetic environment during CPR. --- **ILCOR REVIEWER COMMENT:** Level 2 study, Fair, Supportive. The study is a paired comparison of hemodynamics during chest compression (manual or mechanical) including 15 patients. There are several confounding variables such as the administration of vasopressor drugs, bicarbonate, different duty cycle (compression/relaxation) employed during chest compression (50/50 and 60/40) and different methods of ventilation (manually operated positive pressure ventilation and positive pressure ventilation synchronized with the mechanical chest compressor). Moreover, the study was conducted in the late stage of resuscitative efforts (at least 30 minutes post arrest). The study did not investigate outcome of cardiac arrest, but arterial pressure generated by manual and mechanical chest compression. The investigation demonstrated that mechanical chest compression generated significantly greater mean arterial pressure and therefore hemodynamics in comparison to manual chest compression. Accordingly, it is recognized that greater hemodynamics generated during chest compression are related to success of resuscitation and outcome of cardiac arrest patients. **MII PUBLIC COMMENT:** *MII review is consistent with the ILCOR review.*
19	***Supporting, LOE: 2, Quality: Fair, Outcomes Assessed: E*** **Wang, Hui-Chih; Wen-Chu Chiang; Shey-Ying Chen; Yi-Ling Ke; Chun-Lin Chi; Chih-Wei Yang; Pei-Ching Lin; Patrick Chow-In Ko; Yao-Cheng Wang; Tsung-Che Tsai; Chien-Hwa Huang; Kuan-Hwa Hsiung; Matthew Huei-Ming Ma; Shyr-Chyr Chen; Wen-Jone Chen; and Fang-Yue Lin (2007) Video-recording and time-motion analyses of manual versus mechanical cardiopulmonary resuscitation during ambulance transport. *Resuscitation*, 2007 Sep; 74(3): 453-60.** **ABSTRACT:** INTRODUCTION: The quality of cardiopulmonary resuscitation (CPR) plays a crucial role in saving lives from out-of-hospital cardiac arrest (OHCA). Previous studies have identified sub-optimal CPR quality in the prehospital settings, but the causes leading to such deficiencies were not fully elucidated. OBJECTIVE: This prospective study was conducted to

Ref #	Table 4: Medical Journal Article Analysis
	identify operator- and ambulance-related factors affecting CPR quality during ambulance transport; and to assess the effectiveness of mechanical CPR device in such environment. MATERIALS AND METHODS: A digital video-recording system was set up in two ambulances in Taipei City to study CPR practice for adult, non-traumatic OHCAs from January 2005 to March 2006. Enrolled patients received either manual CPR or CPR by a mechanical device (Thumper). Quality of CPR in terms of (1) adequacy of chest compressions, (2) instantaneous compression rates, and (3) unnecessary no-chest compression interval, was assessed by time-motion analysis of the videos. RESULTS: A total of 20 ambulance resuscitations were included. Compared to the manual group (n=12), the Thumper group (n=8) had similar no-chest compression interval (33.40% versus 31.63%, P=0.16); significantly lower average chest compression rate (113.3+/-47.1 min(-1) versus 52.3+/-14.2 min(-1), P<0.05), average chest compression rate excluding no-chest compression interval (164.2+/-43.3 min(-1) versus 77.2+/-6.9 min(-1), P<0.05), average ventilation rate (16.1+/-4.9 min(-1) versus 11.7+/-3.5 min(-1), P<0.05); and longer no-chest compression interval before getting off the ambulance (5.7+/-9.9s versus 18.7+/-9.1s, P<0.05). The majority of the no-chest compression interval was considered operator-related; only 15.3% was caused by ambulance related factors. CONCLUSIONS: Many unnecessary no-chest compression intervals were identified during ambulance CPR, and most of this was operator, rather than ambulance related. Though a mechanical device could minimise the no-chest compression intervals after activation, it took considerable time to deploy in a system with short transport time. Human factors remained the most important cause of poor CPR quality. Ways to improve the CPR quality in the ambulance warrant further study. --- **ILCOR REVIEWER COMMENT:** Level 2 study, Fair, Opposing. This is a prospective not randomized study including 19 victims of cardiac arrest (12 subjected to manual chest compression and 7 to mechanical chest compression). The investigation did not focus on outcome of patients treated with manual or mechanical chest compression, but it focused on chest compression quality during ambulance transport and specifically on rate and duration of interruption of chest compression and interval with no chest compression. Surprisingly, mechanical chest compression yielded significant lower average chest compression rate in comparison with manual chest compression. One explanation might be represented by the default setting of the mechanical device, i.e. 5 compressions and 1ventilation in a 4 sec cycle. The longer interval with no chest compression, however, was related not to the chest compressor itself, but it was operator related and specifically dependent on the time to set up the mechanical device (and therefore the time to load the patient in the ambulance and place into the compressor) and removal of the device from the patient. **MII PUBLIC COMMENT:** *This study is **Supportive** of Thumper® CPR over manual CPR especially when one considers there is a major flaw in the study. Manual CPR protocol was for continuous compressions at a rate of 100 per minute, but the Thumper® used was an older model unit running at a 5:1 compression-to-ventilation ratio. The authors state "**The manual CPR group achieved an adequate average chest compression rate as recommended by current CPR guidelines after 40s. The Thumper group never achieved this average rate due to its default setting, i.e. five compressions plus one ventilation in a 4-s cycle.**" If the authors had not used an obsolete Thumper®, but had chosen the then-current Thumper® Model 1007 CCV, the results would*

Ref #	Table 4: Medical Journal Article Analysis
	*have been dramatically changed in favor of Thumper® CPR. The Thumper® Model 1007 CCV would have provided a constant 100 compressions per minute, not the 5:1 ratio with a 4 second ventilation pause. Also, it is obvious the personnel used in this study were improperly trained on the use of the Thumper®. Proper use would have been for a rescuer to have performed manual CPR while the Thumper® was being set up. Once set up (no more than 1 minute) the transfer from manual CPR to Thumper® CPR takes less than 5 seconds. After that, the Thumper® CPR would have been continuous at 100 compressions per minute. Assuming the authors would have used a proper model Thumper® and would have trained the staff to use the device properly according to its instructions, the Thumper® CPR chest compressions would have a histogram with a single line at a rate of 100 compressions per minute. The only hands-off time would be less than 5 seconds during the transfer from manual to Thumper® CPR. This would have matched the advanced airway setup per the AHA 2005 CPR Guidelines the authors used. In spite of the obvious flaw and unfair comparison, the obsolete Thumper® using the 2000 AHA CPR Guidelines competed favorably with manual CPR using the 2005 AHA Guidelines. "**In this study, the no-chest compression interval in the Thumper group showed no significant difference to the manual CPR group**."*
20	***Supporting, LOE: 4, Quality: Fair, Outcomes Assessed: A,B,C,D*** **Drouven, D.; A. Reininghaus; H. Schaar; and H. Schmitt (1986) Cardiopulmonary and Cerebral Reanimation Subject: Mechanical vs. Manual CPR. Proceedings of the Ludwig-Boltzmann Symposium, Academic Teaching Hospital of RWTH Aachen, 1986; 1-8.** **ABSTRACT:** Since 1984 we have been using Sirepuls O_2 [Thumper®] the pneumatically driven cardiopulmonary life-saving apparatus of Siemens, for cardiopulmonary and with that, secondary cerebral reanimation. Up to now the use of this equipment has not been generally accepted because one is afraid of a higher complication rate as compared to manual reanimation. However, the method offers some advantages for the practical use of reanimation and is indispensable in a few cases with special indications. In the following, we want to report about 72 reanimations which we did with Sirepuls O_2 since 1984 comparing the experiences gained there from with other methods as for example the manual reanimation. **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This is a retrospective study of 141 patients, concentrating on 72 treated with the Sirepuls O_2 (Thumper®) in the period of July 1984 through October 1986. In this group, 9 patients survived CPR. Three case histories were presented.* • *Case 1 was a 32 year-old drug overdose who was treated with continuous Thumper® CPR for 14.5 hours and who survived neurologically intact.* • *Case 2 was a 52 year-old female with aortic-mitral valve defect and who had a valve replacement. She presented later in ventricular fibrillation and asystole. She was treated with 95 minutes of Thumper® CPR and made an intact neurological survival.* • *Case 3 was a 66 year-old male presenting with pulmonary embolism and cardiac arrest. The Thumper® was used for 55 minutes while the embolism was treated. The patient*

Ref #	Table 4: Medical Journal Article Analysis
	survived the CPR and was successively treated over the next few days for the pulmonary embolisms – apparently another intact neurological survival. *"In conclusion, we want to mention once again the advantages of mechanical reanimation. Mechanical reanimation secures efficient circulation and ventilation over a long period of time, even under unfavorable circumstances. It clearly has advantages in terms of organization and coordination. The need for personnel is lower. During mechanical reanimation, the patient can be treated without interruption of CPR and without loss to time."*
21	***Supporting, LOE: 4, Quality: Fair, Outcomes Assessed: E*** **Garnett, A. Randolph; Joseph P. Ornato; Edgar R. Gonzalez; and E. Bruce Johnson (1987) End-tidal carbon dioxide monitoring during cardiopulmonary resuscitation. *JAMA*, 1987 Jan 23-30; 257(4): 512-5.** **ABSTRACT:** The end-tidal carbon dioxide (CO2) concentration has been found to correlate with cardiac output during and after cardiopulmonary resuscitation (CPR) in animal models. We monitored end-tidal CO2 values continuously during cardiac resuscitation in 23 humans while ventilation was held constant with a computer-controlled CPR Thumper. This report focuses on ten of the 23 patients who experienced return of spontaneous circulation (ROSC) during monitoring. There was no significant difference in the end-tidal CO2 value of patients without ROSC (1.8% +/- 0.9%) and the end-tidal CO2 value of patients before ROSC in patients who had ROSC (1.7% +/- 0.6%). The end-tidal CO2 concentration increased immediately in all patients who had ROSC, from 1.7% +/- 0.6% to 4.6% +/- 1.4%, then gradually returned to a new baseline (3.1% +/- 0.9%). Change in the end-tidal CO2 value was often the first clinical indicator that ROSC had occurred. Our findings suggest that end-tidal CO2 monitoring may provide clinically useful information that can be used to guide therapy during CPR. ——————————————————— **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This is taken to be a **Supportive** retrospective review of 23 patients treated with the use of Thumper® CPR in which 10 patients achieved ROSC – a significant ROSC outcome of 43%. "After ED arrival, CPR was performed by a programmable Thumper® (Model 1013), which delivers 60 compressions per minute and 12 ventilations per minute in a five-compression-to-one ventilation duty cycle." All the patients were intubated and the Thumper® ventilator used provided 0.8 FIO_2. Two cases were presented:* • *Case 1: A 78 year-old male arrested in the ambulance 5 minutes before arrival at the ED but received manual CPR. In the ED, VF converted to asystole after a defibrillation attempt. The patient received Thumper® CPR and end-tidal CO_2 was 1.7%. After about 1 minute and 15 seconds of Thumper® CPR, the end-tidal CO_2 increased to 2.4% and CPR was interrupted. A sinus bradycardia rhythm was noted at 50 bpm. This converted to sinus tachycardia at 120 beats per minute. The patient was further treated and then transferred to the CCU.* • *Case 2: A 38 year-old man was struck by lightning. Bystander CPR was given immediately.*

Ref #	Table 4: Medical Journal Article Analysis
	Paramedics arrived 5 minutes later and used the defibrillator. The patient converted from VF to asystole. Manual CPR and treatment were provided en route but the patient remained in asystole. On arrival to the ED 50 minutes after the arrest, Thumper® CPR was applied. The patient was resuscitated with Thumper® CPR to ROSC after 10 minutes of application with drug treatments. The end-tidal CO_2 increased within the 10 minutes from 0.8% to 1.6% and then the Thumper® CPR was halted. Sinus bradycardia was noted at 50 bpm and ventilation continued but no chest compressions. The patient achieved ROSC but then developed VF that could not be resolved and he was pronounced dead.
22	***Supporting, LOE: 4, Quality: Fair, Outcomes Assessed: A,B,C,D*** **Gómez-Arnau, Juan; Antonio Criado; Maria V. Martinez; Maria G. Aguilar; and Fernando Avello (1981) Hyperkalemic cardiac arrest: prolonged heart massage and simultaneous hemodialysis. *Critical Care Medicine*, 1981 Jul; 9(7): 556-7.** **ABSTRACT:** Hyperkalemia represents a frequent cause of cardiac arrhythmias and, less frequently of cardiac arrest, with difficult management due to the conduction disorders induced. In these situations, the procedures for rapid removal of serum potassium are most useful. The authors present one case of successful resuscitation in a patient with ventricular fibrillation due to hyperkalemia, by means of hemodialysis and simultaneous external heart massage associated with the classical [mechanical] CPR measures. **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *A 36 year-old male who had been treated with hemodialysis presented with cardiac arrest. He was given Thumper® CPR for 145 minutes with simultaneous dialysis for 75 minutes. The patient was then successfully resuscitated and survived neurologically intact. This is **Supportive** of Thumper® CPR because it demonstrates not only sufficient perfusion for an intact outcome but sufficient perfusion to perform effective dialysis at the same time.*
23	***Supporting, LOE: 4, Quality: Fair, Outcomes Assessed: A,B,C,D*** **Kashman, James (1991) Hypothermia. *Canadian Emergency News*, 1991 Jul/Aug; 5(4): 23.** **ABSTRACT (MII-authored abstract):** This is a case report of a 59 year-old male who succumbed to hypothermia after falling asleep outside after an evening of drinking. He was resuscitated with a Thumper® as his body was re-warmed. Two weeks following the incident the patient was released from the hospital. **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This patient presented with severe hypothermia in asystole on arrival*

Ref #	Table 4: Medical Journal Article Analysis
	to the hospital Thumper® CPR was applied to provide speculation for the rewarming therapy. The Thumper® was used continuously for 3.5 hours and the patient was discharged neurologically intact. It would have been nearly impossible for this level of continuous CPR to have been provided by manual CPR.
24	***Supporting, LOE: 4, Quality: Fair, Outcomes Assessed: A,B,C,D*** **Little, K.; J. M. Auchincloss; and C.S. Reaves (1974) A mechanical cardiopulmonary life-support system. *Resuscitation*, 1974; 3(1): 63-8.** **ABSTRACT:** A mechanical cardiopulmonary resuscitator is described. Its use in cardiac arrest is discussed and the machine is shown to be safe, simple to operate, and more efficient than manual technique, both in the hospital and in the ambulance services. ——————————————— **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This publication is **Supportive** of the Thumper® and is an inherent comparison to manual CPR. It reviews 2 years of use of the Thumper® and presents a set of 5 case studies for the application of the Thumper® with the built-in synchronized ventilator. This is a Model 1004 Thumper® that had been in use for 2 years at the time of the publication and used on 150 patients in the early management stage of cardiac arrest. It was assessed in this time with the ability to oxygenate the patient and to produce blood flow. Blood flow was assessed by palpation of the peripheral pulses and by visualizing the capillary blood flow in the finger. PO_2 of the circulating arterial blood was measure in 9 successive cases of cardiac arrest which had been continuously subjected to 5 min of Thumper® CPR. The Thumper® could be set up quickly and freed staff to perform other medical tasks. Rib fracture was not found post Thumper® CPR in the large majority of patients.* • *Case 1: A 13 year-old pedestrian was struck and suffered multiple injuries. He was found by EMS to be pulseless with fixed and dilated pupils. He was given 10 minutes of manual CPR and then Thumper® CPR which then allowed for limb splintage, transfusion, etc. by the attending staff. Thumper® CPR was continuous for 3 hours and 10 minutes at the scene, in transport to the hospital and in the hospital ED after which resuscitation measures were abandoned.* • *Case 2: In response to a call, the 62 year-old male was found to be pulseless, apneic, with dilated pupils. The Thumper® was applied at the scene along with an intubation so the Thumper® controlled compressions and ventilation. The patient was transferred by ambulance with the Thumper® running. At the hospital the patient's pupils reverted to normal and he appeared well oxygenated. His rhythm was VF and he was resuscitated and transferred to the CCU.* • *Case 3: A 66 year-old man in a public house collapsed in cardiac arrest. Bystander manual CPR was started. The Thumper® arrived and was set up including intubation for the ventilator. The patient was transferred with the Thumper® in operation all the while down a winding staircase, to the ambulance, then in the ambulance to the ED. His general state*

Ref #	Table 4: Medical Journal Article Analysis
	from the Thumper® CPR remained excellent but the underlying dysrhythmia could not be corrected and he died 2 hours after collapse. • *Case 4: An 11 year-old girl was rushed to the hospital after choking on a piece of meat. She arrived pulseless and cyanosed with her EKG in asystole. She was placed on the Thumper® for automated CPR while the meat was removed and she was then intubated for ventilation. She was resuscitated successfully but died after 1 week of cerebral infarction.* • *Case 5: A 52 year-old man presented to the ED with a large inferior MI. He went in to VF and the cardiac arrest routine was begun. He reverted to sinus rhythm and then back to VF 5 times. The Thumper® provided the CPR as needed. The patient had the dysrhythmia controlled and he recovered uneventfully.* *The authors state: "**These cases demonstrate some of the applications of the cardiopulmonary resuscitator. Even under difficult conditions it is easy to use, and diminishes the physical strain of the resuscitator occurring after prolonged cardiac arrest. The tissue is oxygenated and perfused more efficiently than is possible when a series of medical personnel use the manual technique, although the final outcome rests with the nature and severity of the causative pathology.**"*
25	***Supporting, LOE: 4, Quality: Fair, Outcomes Assessed: A,B,C,D*** **Mackey, J.; D. McAreavey; and C.E. Robertson (1987) Prolonged mechanical cardiopulmonary resuscitation. *The British Journal of Accident & Emergency Medicine,* 1987 Mar; 15.** **ABSTRACT:** A case in which prolonged mechanical cardiopulmonary resuscitation was performed is presented. The patient survived without neurological deficit following 3.5 hours of cardiopulmonary resuscitation. ——————————————————— **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This article is **Supportive** because it demonstrates how Thumper® CPR can be applied for a long period of time – way beyond what is usually accomplished with manual CPR – and result in a neurologically intact outcome. A 32 year-old male suffered an out-of-hospital cardiac arrest. The ambulance arrived 10 minutes later and manual CPR with face mask ventilation began. Manual CPR continued for 30 minutes. Thumper® CPR was then applied along with intubated oxygen ventilation. The patient was transported to the hospital while the Thumper® continued compressions and ventilation for approximately 170 minutes. The patient was successfully resuscitated with a neurologically-intact outcome. The authors state "**The use of mechanical CPR means that prolonged resuscitation attempts can be performed with an efficient, constant and precise technique. Since 1978 we have routinely used a Thumper® Cardiopulmonary Resuscitator Model 1004 for cardiac arrests within the Accident and Emergency Department with good results. While potential disadvantages such as an increase in the incidence of sternal fractures and cost are recognized, we feel that these are by the ease of use and efficacy of the technique.**"*

Ref #	Table 4: Medical Journal Article Analysis
26	***Supporting, LOE: 4, Quality: Fair, Outcomes Assessed: E*** **Roberts, Bill G. and Jane M. Bryan (1978) Dallas EMS system advocates mechanical CPR. *Emergency Medical Services*, 1978 Jul-Aug; 7(4): 39-40, 42, 94.** **ABSTRACT (MII-authored abstract):** This article discusses the history of the Dallas, Texas EMS System's decision to utilize [Thumper®] mechanical CPR equipment as an alternative to manual CPR. Over the course of several months in 1976, testing was conducted on 34 cases using mechanical CPR with favorable results. Additional testing was conducted comparing mechanical CPR with manual CPR. Aside from the initial set-up of the machine, no beats were missed using Mechanical CPR. This was not the case with manual CPR, where numerous beats were missed during loading transporting of the patient. The Dallas EMS System's conversion from manual to mechanical CPR has had a significant impact on the quality of emergency medical care available to cardiac arrest victims and on the overall efficiency of the system. --- **ILCOR REVIEWER COMMENT**: NONE – Not Reviewed **MII PUBLIC COMMENT:** *This study is **Supportive** because of the reported attributes of Thumper® CPR:* • *Compressions were at a constant rate and stroke depth.* • *There was a reduction in missed compressions.* • *Incorrect compression placement was eliminated.* • *Thumper® CPR aided in the establishment of IV lines when manual CPR was ineffective for this process.* • *Medical staff reported significantly improved patient oxygenation and some improvement in pH factors when using the Thumper®.* • *In transport while using the Thumper, there were no missed compressions but significant manual compression gaps of over 20 seconds were noted.* • *Less attending staff were required.* *This study was rated as **LOE 4** because there is no control group for the 37 patients studied and the second half of the study used an instrumented manikin for two manual versus Thumper® CPR simulated scenarios.* *The study is rated as **Fair** because the outcomes measured were performance characteristics of the Thumper® CPR as opposed to clinical measurements except for oxygenation, pH, and IV insertions. The outcomes using the manikin were quantitative in comparing manual CPR to Thumper® CPR by use of the recording of compression data.* *The outcomes assessed were E – parameters associated with performing CPR correctly and efficiently.*
27	***Supporting, LOE: 4, Quality: Fair, Outcomes Assessed: A,B***

Ref #	Table 4: Medical Journal Article Analysis
	Wang, Lee-Min; Chen-Hsen Lee; Low-Tone Ho; and Chi-Houng Chang (2000) Successful resuscitation from cardiac arrest using mechanical CPR. *The American Journal of Emergency Medicine*, 2000 Jul; 18(4): 509-10. **ABSTRACT (MII-authored abstract):** A 65 year-old man presented to the ED in cardiac arrest – pulseless and apneic. After 10 minutes of manual CPR he was placed on the Thumper®. His EKG showed asystole. After 30 minutes of Thumper® CPR, he regained consciousness but if the Thumper® was turned off, he lost consciousness. He was treated with a drug regime and regained his pulse. He was released 3 weeks later neurologically intact. **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This is a **Supportive** case report on the use of the Thumper® because it demonstrated the effectiveness of Thumper® CPR to the point that a patient presenting with asystole was perfused and oxygenated by the Thumper® to the point he regained consciousness. After resuscitation, this patient had a neurologically-intact outcome. The authors state: "**The mechanical-CPR approaches are complementary models of advanced cardiac life support, can provide more effective, consistent and safe CPR and improve cardiac output, increase MAPs and reduce fatigue in CPR performers.**"*
28	***Supporting, LOE: 5, Quality: Fair, Outcomes Assessed: A,E*** **Gudipati, Chalapathirao V.; Max H. Weil; Jose Bisera; Hanumant G. Deshmukh; and Eric C. Rackow (1988) Expired carbon dioxide: a noninvasive monitor of cardiopulmonary resuscitation. *Circulation*, 1988 Jan; 77(1): 234-9.** **ABSTRACT:** End-tidal CO_2 concentration ($ETCO_2$) may serve as a simple noninvasive measurement of the blood flow generated by precordial compression during cardiopulmonary resuscitation (CPR). In a mechanically ventilated porcine preparation of ventricular fibrillation, onset of fibrillation was associated with a rapid decrease in $ETCO_2$ from 4.0 +/- 0.2% to less than 0.7 +/- 0.2%. With precordial compression, it increased to 1.9 +/- 0.3%. Animals that were successfully defibrillated after 12 min of [Thumper®] CPR demonstrated an immediate increase in $ETCO_2$. The $ETCO_2$ increased from 1.9 +/- 0.3% to 4.9 +/- 0.3% over an interval of between 30 and 60 sec. These changes in $ETCO_2$ were closely related to proportionally similar decreases and increases in cardiac output (CO), and a close correlation between $ETCO_2$ and CO was demonstrated (r = .92). A similar highly significant correlation between $ETCO_2$ and CO was also demonstrated during open-chest cardiac massage (r = .95). $ETCO_2$ therefore serves as a noninvasive measure of pulmonary blood flow and therefore CO. In 17 successfully-resuscitated animals, $ETCO_2$ during precordial compression averaged 1.7 +/- 0.2%, whereas it was only 0.5 +/- 0.1% in five animals in whom resuscitation procedures were unsuccessful (p less than .001). Accordingly, $ETCO_2$ prognosticates outcome during CPR and immediately identifies restoration of spontaneous circulation.

Ref #	Table 4: Medical Journal Article Analysis
	ILCOR REVIEWER COMMENT: NONE – Not Reviewed **MII PUBLIC COMMENT:** *This animal study is included as **Supportive** because it does demonstrate the effectiveness of Thumper® CPR regarding end-tidal CO_2. The subjects were put in VF for 1 minute and then Thumper® CPR applied for 12 minutes. The recordings of aortic pressure and right atrial pressure indicate significant circulation resulting from the Thumper® CPR. There were 22 animals in the study and 17 survived (77%). Thumper® CPR compared favorably to open-chest direct cardiac massage. It is also worthy of note that on average, the end-tidal CO_2 at the 9 minute interval of Thumper® CPR was 1.87±.3 %, a value greater than the 1 minute value of 1.0±0.2 %. This is consistent with gradual build-up of forward flow with continuous uninterrupted chest compressions. Also, the average $ETCO_2$ 9-minute value is 47% of the initial $ETCO_2$ of 4.0±0.2 %.*
29	***Neutral, LOE: 2, Quality: Good, Outcomes Assessed: A*** **Callaham, Michael and Christopher Barton (1990) Prediction of outcome of cardiopulmonary resuscitation from end-tidal carbon dioxide concentration. *Critical Care Medicine,* 1990 Apr; 18(4): 358-62**. **ABSTRACT:** Capnography is a valuable tool in the management of cardiac arrest, since end-tidal CO2 (PetCO2) correlates well with cardiac output and there are no other suitable noninvasive ways to measure this important variable during resuscitation. Animal studies also suggest that PetCO2 correlates well with the likelihood of resuscitation, but this has never been confirmed in humans. We prospectively studied 55 adult, nontraumatic prehospital cardiac arrest patients. PetCO2 was monitored with an in-line sensor on arrival in the ED and throughout the arrest, which was managed by the usual advanced cardiac life-support treatment guidelines. **Chest compression was carried out mechanically.** Patients were assessed for return of spontaneous pulse as evidence of initial resuscitation; hospital discharge and long-term survival were not examined. Fourteen patients developed spontaneous pulses and were resuscitated, and 41 were not. The length and aggressiveness of treatment and CPR were not different between the two groups, nor were there differences in down time, resuscitation time, or other factors known to affect outcome. Patients who developed a pulse had a mean PetCO2 of 19 +/- 14 (SD) torr at the start of resuscitation, and those who did not had a mean PetCO2 of 5 +/- 4 torr (p less than .0001). This difference was significant both in nonperfusing rhythms (asystole and ventricular fibrillation) and in potentially perfusing rhythms (electromechanical dissociation). An initial PetCO2 of 15 torr correctly predicted eventual return of pulse with a sensitivity of 71%, a specificity of 98%, a positive predictive value of 91%, and a negative predictive value of 91%. A receiver operating curve was generated for sensitivity and specificity of the test at varying PetCO2 thresholds. **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This is a prospective study to investigate predicted outcomes from CPR attempts by measuring end-tidal CO_2. It is not a comparative study of manual vs. mechanical*

Ref #	Table 4: Medical Journal Article Analysis
	*CPR and therefore is **Neutral** to the primary question. However, in this study, a Thumper® was used to perform the CPR (compressions and ventilation). The outcome of the study was ROSC, not long-term survival. Of the 55 patients studied, 14 had ROSC. The length of time for chest compressions was long – an average of 63 minutes. The chest compressions in this study were continuous and the ventilation was asynchronous – similar to current AHA CPR Guidelines for advanced airway ventilation. Therefore, this study suggests Thumper® is effective, can be used for long resuscitation attempts, and also suggests the current continuous compression mode with asynchronous ventilation is effective.*
30	***Neutral, LOE: 5, Quality: Good, Outcomes Assessed: E*** **Ornato, Joseph P.; Ronald L. Levine; Denis S. Young; Edward M. Racht; A. Randy Garnett; and Edgar R. Gonzalez (1989) The effect of applied chest compression force on systemic arterial pressure and end-tidal carbon dioxide concentration during CPR in human beings. *Annals of Emergency Medicine*, 1989 Jul; 18(7): 732-7.** **ABSTRACT:** Twelve adult (nine men and three women) cardiac arrest patients were studied as they received CPR by a computerized Thumper to determine the influence of the applied chest compression force on blood flow (as assessed by the end-tidal carbon dioxide concentration) and arterial pressure. At the end of a resuscitation when the decision was made by the senior physician to cease resuscitative efforts, the applied force on the CPR Thumper was decreased from 140 to 0 pound-force (lbf) in 20-lbf increments at 30-second intervals. Radial artery cutdown blood pressure and end-tidal carbon dioxide (ETCO2) were recorded continuously. Arterial systolic blood pressure was linearly related (r = .59, P less than .0001) to applied force (systolic blood pressure, 31 +/- 6 mm Hg at 20 lbf to 60 +/- 7 mm Hg at 140 lbf). ETCO2 (r = .42, P less than .0001) was also linearly related to applied force (ETCO2, 0.7 +/- 0.1% at 20 lbf to 1.5 +/- 0.2% at 140 lbf). Diastolic pressure did not change significantly with change in applied force (17 +/- 2 mm Hg from 20 to 140 lbf). Our findings indicate that higher compression force than that currently recommended may improve arterial systolic pressure and flow in human beings receiving closed-chest compression during CPR. **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *The importance of this study is the demonstration of higher compression forces that tend to improve arterial systolic pressure and flow in closed-chest compressions. This formed the basis for the Thumper® Model 1007 and current Life-Stat® (Thumper® Model 1008) patented improvements in piston application.*
31	***Neutral, LOE: 5, Quality: Good, Outcomes Assessed: A,B,D*** **Wik, Lars; Nicholas G. Bircher; and Peter Safar (1996) A comparison of prolonged manual and mechanical external chest compression after cardiac arrest in dogs. *Resuscitation*, 1996 Oct; 32(3): 241-50.**

Ref #	Table 4: Medical Journal Article Analysis
	ABSTRACT: The effects of manual and a new mechanical chest compression device (Heartsaver 2000 [piston device similar to Thumper®]) during prolonged CPR with respect to haemodynamics and outcome were tested in a prospective, randomized, controlled experimental trial during ventricular fibrillation in 12 dogs of 9-13 kg body weight after 1 min of cardiac arrest. During the first 10 min of CPR the dogs were resuscitated according to the Basic Life Support (BLS) algorithm, followed by 20 min of Advanced Life Support (ALS) algorithm. After 30 min of CPR both manual and mechanical CPR groups were resuscitated following a standardized ALS protocol. During CPR, coronary perfusion pressure and end tidal CO2 were greater with mechanical CPR. All animals were successfully resuscitated and neurological deficit scores were not different. The CPR trauma score was less in the mechanical group. Mechanical external chest compression provided better haemodynamics than the manual technique, though outcome did not differ. Both optimally performed manual and mechanical techniques produce flow sufficient to maintain organ viability for 30 min of CPR after a 1 min arrest interval. **ILCOR REVIEWER COMMENT:** NONE – Not Reviewed **MII PUBLIC COMMENT:** *This is a canine study to compare the clinical differences between manual and piston CPR. The dogs were randomly assigned to manual or mechanical chest compressions with manual ventilations. The compression rate was 80 per minute with compression duration of 50 % and a 5:1 compression-to-ventilation ratio. Hemodynamic variables and $ETCO_2$ were measured. The authors conclude: "Mechanical external chest compressions provided better hemodynamics than the manual technique, though outcome did not differ in this model. Both mechanical and optimally [emphasis added] performed manual techniques produce flow sufficient to keep the heart and brain viable for 30 minutes of CPR after a 1 minute arrest interval."*