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

**Worksheet author(s)**

| David G. Beiser | Date Submitted for review: 2/3/10 |

## Clinical question.

ALS/BLS-CPR&A-086B -- In adult cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of load distributing band (e.g. Autopulse) (I) compared with manual CPR (C), improve any outcomes (eg. ROSC, survival) (O)?

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

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

### Conflict of interest specific to this question

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

## Search strategy (including electronic databases searched).

**PubMed** *(Searched as text word in any field unless otherwise noted, 1/26/10)*

1. "load distributing band" OR "load-distributing" OR “LDB” OR hydraulic-pneumatic band: 189 hits
2. "autopulse": 16 hits
3. "cardiopulmonary resuscitation’[MeSH] OR (cardiopulmonary AND resuscitation) OR cardiopulmonary resuscitation: 12516 hits
4. “heart arrest’[MeSH] OR (heart AND arrest) OR heart arrest OR “death, sudden, cardiac’[MeSH]: 37086 hits

(#1 OR #2) AND (#3 OR #4): 22 hits

**Embase** *(Searched as free text in any field and preferred terminology unless otherwise noted, 10/7/09)*

1. ‘load distributing’ OR ‘load-distributing’ OR LDB OR autopulse OR ‘auto-pulse’: 179 hits
2. ‘cardiopulmonary resuscitation’ OR (‘cardiopulmonary’ AND ‘resuscitation’): 43898 hits
3. ‘heart arrest’ OR (‘heart’ AND ‘arrest’) OR ‘sudden death’ OR ‘sudden cardiac death’: 70739 hits

(#1 AND #2) OR #3: 27 hits

**Cochrane Database (Reviews, Central Register of Controlled Trials):** *(Searched as text word in any field, 10/7/09)*

1. (autopulse or auto-pulse or load-distributing or load distributing or LDB or hydraulic-pneumatic band).mp. [mp=ti, ot, ab, tx, kw, ct, sh, hw]: 10 hits
2. cardiopulmonary resuscitation OR (cardiopulmonary AND resuscitation): 575 hits
3. heart arrest OR (heart AND arrest) OR sudden death OR sudden cardiac death: 2550 hits

#1 AND #2 OR #3: 6 hits

**AHA Endnote Library** *(Any field contains, 24Mar08):*

LDB OR load-distributing OR load distributing OR autopulse OR auto pulse: 4 hits

### Additional references added outside of formal search strategy:

- **(Steinmetz, 2008, 908)** included in response to discussions held during preliminary worksheet evaluation (ILCOR ALS/BLS-CPR&A-086B, 11/7/08)

- **(Paradis, 2010, in press)** included after advance copy emailed to worksheet author on 1/26/10 by author.

- **(Halperin, 2010, in press)** included after advance copy emailed to worksheet author on 2/2/10 by author.

### State inclusion and exclusion criteria

Excluded reviews, editorials, abstract-only studies, manufacturer-sponsored white papers, and case reports.

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

11
# Summary of evidence

## Evidence Supporting Clinical Question

<table>
<thead>
<tr>
<th>Level of Evidence</th>
<th>Evidence Supporting Clinical Question</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Good</strong></td>
<td>[Hock Ong, 2006, 2629-37]ABC</td>
</tr>
<tr>
<td></td>
<td>[Ikeno, 2006, 109-18]ABDE</td>
</tr>
<tr>
<td><strong>Fair</strong></td>
<td>[Casner, 2005, 61-7]B</td>
</tr>
<tr>
<td></td>
<td>[Steinmetz, 2008, 908-13]A</td>
</tr>
<tr>
<td><strong>Poor</strong></td>
<td>[Halperin, 2000, N203-6]E</td>
</tr>
</tbody>
</table>

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

## Evidence Neutral to Clinical Question

<table>
<thead>
<tr>
<th>Level of Evidence</th>
<th>Evidence Neutral to Clinical question</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Good</strong></td>
<td>[Hallstrom, 2006, 2620-8]BC</td>
</tr>
<tr>
<td></td>
<td>[Hock Ong, 2006, 2629-37]D</td>
</tr>
<tr>
<td><strong>Fair</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[Krep, 2007, 86-95]ABCD</td>
</tr>
<tr>
<td><strong>Poor</strong></td>
<td>[Paradis, 2010, in press]C</td>
</tr>
</tbody>
</table>

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

## Evidence Opposing Clinical Question

<table>
<thead>
<tr>
<th>Level of Evidence</th>
<th>Evidence Opposing Clinical Question</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Good</strong></td>
<td>[Hallstrom, 2006, 2620-8]D</td>
</tr>
<tr>
<td><strong>Fair</strong></td>
<td>[Steinmetz, 2008, 908-13]E*</td>
</tr>
<tr>
<td><strong>Poor</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Level of evidence**
- A = Return of spontaneous circulation
- B = Survival of event
- C = Survival to hospital discharge
- D = Intact neurological survival
- E = Other endpoint
- E* = 30 day survival
- Italics = Animal studies
The load-distributing band (LDB) is a circumferential chest compression device composed of an electrically actuated constriction band and backboard that provides automatic circumferential compression to the thoracic cavity during CPR.

Consensus 2005 recommendations stated that “LDB-CPR may be considered for use by properly trained personnel as an adjunct to CPR for patients with cardiac arrest in the out-of-hospital or in-hospital setting (Class IIb). The C2005 treatment recommendation was based on clinical evidence of improved rates of sustained ROSC (B) from a case-control study (LOE 3) [Casner, 2005, 61-7] of 167 victims of out-of-hospital cardiac arrest who underwent LDB-CPR following failed manual CPR. In addition, the C2005 recommendation noted that LDB-CPR improved hemodynamics in one in-hospital cardiac arrest study (LOE 4) [Timerman, 2004, 273-80] of end-stage patients who underwent LDB-CPR following failed ALS care and 2 studies in large animal models of cardiac arrest (LOE 5) [Halperin, 2000, N203-6; Halperin, 2004, 2214-20]. These hemodynamic and survival benefits have been further confirmed in a recent laboratory study (LOE 5) [Ikeno, 2006, 109-18].

Since C2005, clinical studies of LDB-CPR have yielded conflicting results. The AutoPulse Pre-Hospital International Resuscitation (ASPIRE) trial (LOE 1) [Hallstrom, 2006, 2620-8] was a large multi-center, prospective, cluster-randomized study comparing LDB-CPR with standard EMS ACLS care. The study was halted after interim review by an independent DSMB identified no difference in the study’s primary endpoint of 4 hour survival, a trend towards decreased rates of survival to hospital discharge (p=0.06), and significantly lower risk of intact neurological survival in the experimental group. In addition, it is important to note that significantly longer time to first shock intervals were identified in the LDB-CPR arm.

A recent industry-funded post-hoc analysis of the Hallstrom (2006) study’s source data demonstrated significant heterogeneity between sites [Paradis, 2010, in press] (LOE 1). This reanalysis suggested one site (site C) reported significantly different overall survival to 4 hours as well as different trends over the enrollment period in this primary outcome. It should be noted that this reanalysis examined all patients enrolled in the study rather than the a priori defined primary study population of presumed cardiac origin arrest cases focused on in the original report.

Support for LDB-CPR comes from an observational cohort study (LOE 3) [Hock Ong, 2006, 2629-37] of out-of-hospital cardiac arrest within a single urban EMS demonstrated significantly improved rates of ROSC, survival to admission, and survival to discharge system. No improvement was noted in neurological outcomes. The use of historical controls is potentially relevant to the study’s interpretation as the LDB-CPR group exhibited a higher rate of EMS-witnessed events and shorter EMS response time intervals.

Another observational cohort study of out-of-hospital cardiac arrest patients LOE 3 [Steinmetz, 2008, 908-13] reported mixed outcomes for LDB-CPR. The study, which was conducted in a physician staffed single EMS system within a large urban center, was designed to measure the impact of implementing the 2005 ERC resuscitation guidelines on 30-day survival following OOHCA. During the study period, LDB-CPR was made available, but not uniformly implemented, within this EMS system. Unadjusted analysis using manual CPR controls from the implementation period revealed a higher rate of ROSC (A) in LDB-CPR treated patients. However, 30-day survival was not different between comparison groups. Furthermore, logistic regression analysis of a combined dataset utilizing pre- and post-implementation data revealed worse 30-day survival (E) in LDB-treated patients. Interpretation of this study is somewhat limited as the criteria for applying LDB-CPR were not explicitly listed in the manuscript.
Significant controversy exists regarding the disparity between the benefits reported in two observational studies ([Casner, 2005, 61-7] and [Hock Ong, 2006, 2629-37]), mixed results reported in 1 observational study [Steinmetz, 2008, 908-13], and potential harm identified in the prospective multi-center RCT [Hallstrom, 2006, 2620-8]. The recent post-hoc analysis by Paradis (2010, in press) suggests that site-specific factors may play a role in determining LDB-CPR benefit. Such factors may include differences in patient population, deployment, integration in to existing ACLS protocols, EMS transport time, as well as a variety of other performance variables.

One of the more contentious issues relates to the potential for delays in CPR initiation related to the deployment of LDB-CPR at the scene. An additional uncontrolled feasibility study in the out-of-hospital setting (LOE 4) [Krep, 2007, 86-95] reported mean deployment times for LDB-CPR (4.7 ± 5.9 minutes) suggesting the potential for equipment-related delays in CPR initiation. A recent multi-center manikin study using LDB-CPR reported deployment times of approximately 120 ± 56 seconds in trained professional rescuers (LOE 5) [Tomte, 2009, 1152-7]. The potential for deployment delays was minimized in both observational trials as LDB-CPR was deployed as either following failed CPR [Casner, 2005, 61-7], failed defibrillation [Hock Ong, 2006, 2629-37], or following a 90 second period of manual CPR [Hock Ong, 2006, 2629-37]. By contrast, EMS providers within the RCT [Hallstrom, 2006, 2620-8] were given the option to initiate LDB-CPR as initial therapy, shock first, or initiate manual CPR prior to LDB-CPR. This allowed for the possibility that CPR may have been delayed for some patients while the LDB-CPR device was deployed. Unfortunately, treatment option adherence was not uniformly tracked across all participating sites within the RCT [Hallstrom, 2006, 2620-8]. The existence of these treatment options within the protocol may have contributed to the longer time to first-shock intervals noted above. In addition, it raises the possibility that an interval of manual CPR may be a contributing factor to the beneficial effects observed in the observational studies.

**Acknowledgements:**
The author would like to acknowledge the editorial assistance of Dr. Terry Vanden Hoek.
**Citation List**

   - **LOE:** 3
   - **Quality:** Fair
   - **Supporting Outcomes:**
     - Sustained ROSC (to ED arrival) (B): Compared to matched historical controls, LDB-CPR group was associated with an increased risk of sustained ROSC

<table>
<thead>
<tr>
<th>Sustained ROSC (B)</th>
<th>ARR (%)</th>
<th>NNT (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-10</td>
<td>10</td>
</tr>
</tbody>
</table>

   - **Neutral Outcomes:** None
   - **Opposing Outcomes:** None
   - **Summary Statement:** This is a retrospective case-control study of the use of LDB-CPR for treating out-of-hospital cardiac arrest by late-responders within a single large urban EMS system. In contrast to the studies by Hock Ong (2006) and Hallstrom (2006), LDB-CPR devices were deployed by a small group of paramedic supervisors who and applied only after initial failed manual CPR. LDB-CPR cases were matched to cases of similar CPR duration and demographics by a blinded investigator. The quality of this study is diminished slightly by its relatively small sample size and a lack of long-term (e.g. hospital discharge) follow-up. Of note, in patients with initially shockable rhythms (VF/VT), LDB-CPR did not show a sustained ROSC benefit over manual CPR. **Limitations:** Extrapolation of the encouraging results reported in this retrospective study should be limited to out-of-hospital cardiac arrest victims who undergo prolonged (~ 15 minutes) of failed manual CPR.
   - **Industry Funding:** This is an industry (Revivant Corporation) funded study. No comment was made regarding author conflicts of interest or the role of Revivant Corporation in the editorial process.

   - **LOE:** 1
   - **Quality:** Good
   - **Supporting Outcomes:** None
   - **Neutral Outcomes:**
     - Survival to 4 hours (B)

<table>
<thead>
<tr>
<th>Survival to discharge (C)</th>
<th>ARR (%)</th>
<th>NNH (n)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.1</td>
<td>24</td>
<td>.06 (NS)</td>
</tr>
</tbody>
</table>

   - **Opposing Outcomes:**
     - Intact neurological survival (D): LDB-CPR was associated with a decreased risk of intact neurological survival (ARR = 4.5%, NNH = 22, P=.006).
     - Survival to hospital discharge (C): Among the primary population, LDB-CPR was associated with a decreased, though non-significant (P = .06) risk (ARR = 4.1%, NNH = 24) of hospital discharge.

<table>
<thead>
<tr>
<th>Intact neurological survival (D)</th>
<th>ARR (%)</th>
<th>NNH (n)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.5</td>
<td>22</td>
<td>.006</td>
</tr>
</tbody>
</table>

   - **Summary Statement:** This multicenter, randomized control trial of out-of-hospital cardiac arrest which compares standard EMS ACLS care with an LDB-CPR. The primary study group includes patients with cardiac arrest of presumed cardiac origin prior to EMS arrival. Primary endpoint was survival to 4 hours with additional secondary outcomes including survival to hospital discharge and neurological status at discharge. The study was halted after
interim review by an independent DSMB identified no difference in the study’s primary endpoint of 4 hour survival and a trend towards decreased survival to hospital discharge in the experimental group (P=0.06). In addition, the LDB-CPR group displayed significantly worse rates of intact neurological survival. Post-hoc subgroup analysis of patients with asystole identified a modest treatment benefit. **Limitations:** By practical necessity, rescuers were not blinded to the intervention. Extrapolation of the apparent harm identified in the treatment group to all potential applications of LDB-CPR should be tempered somewhat by problems within the study protocol. Specifically, in the study allowed for three different CPR protocol options: 1) quick-look ECG followed by 2 minutes of either manual CPR or LDB-CPR; 2) immediate manual CPR (regardless of randomization) until first shock followed by LDB or manual CPR; 3) rhythm analysis and appropriate shock followed by randomized CPR. The application of the LDB-CPR device has the potential to delay initial CPR and/or shock. This is relevant because the authors noted that LDB-CPR group had longer time intervals to first shock. Theoretically, CPR delays would be most pronounced for protocol Options 1 and 3, with Option 2 minimizing delays by the initial use of manual CPR. Unfortunately, post-hoc analysis of the role of protocol option on outcomes was limited to a single participating site as protocol adoption was not rigorously recorded across all sites. Personal communication with the authors (AH, MS) suggest that Option 2 may have been the preferred within most systems given 1) prevailing concerns about the importance of minimizing delays in CPR initiation, and 2) unwillingness of professional rescuers to withhold CPR during the LDB-CPR set-up interval.

**Industry Funding:** The study was sponsored by Revivant Corporation (Zoll Corporation) who provided LDB-CPR devices, training. The sponsor reviewed data prior to publication but did not reserve editorial rights.

   - **LOE:** 5
   - **Quality:** Fair
   - **Supporting Outcomes:**
     - Coronary perfusion pressure (E), (28±8 mmHg vs. 17±6 mmHg)
   - **Neutral Outcomes:** None
   - **Opposing Outcomes:** None
   - **Summary Statement:** This laboratory study compares an early hydraulically-actuated instantiation of LDB-CPR with pneumatic vest CPR, and manual CPR in a porcine model of cardiac arrest. Ten animals received sequential 30-40 second epochs of each of CPR technique in randomized order. LDB-CPR resulted in significant improvements in coronary perfusion pressure (CPP) as compared to manual CPR. **Limitations:** The quality of this study is limited somewhat by its focus on hemodynamic outcomes and lack of longer-term follow-up.
   - **Industry Funding:** The first author (HH) reports significant financial interest in Revivant Corporation.

   - **LOE:** 5
   - **Quality:** Fair
   - **Supporting Outcomes:**
     - Coronary perfusion pressure without epinephrine (E), (21±8 mmHg vs. 14±6 mmHg)
     - CPP with epinephrine (E), (45±11 mmHg vs. 17±6 mmHg)
     - Myocardial blood flow without epinephrine
     - Myocardial/cerebral blood flow with epinephrine
   - **Neutral Outcomes:** None
   - **Opposing Outcomes:** None
   - **Summary Statement:** This laboratory study compares LDB-CPR with conventional CPR in a swine model of cardiac arrest. The study demonstrates improvement hemodynamic outcomes and tissue blood flow with LDB-CPR. In addition, this is the first study to utilize MRI imaging to demonstrate that the mechanism of improved hemodynamics may be related to airway collapse during the compression phase of LDB-CPR. **Limitations:** The
quality of this study is limited somewhat by its focus on the early phase of cardiac arrest (~1 min) and lack of longer-term follow-up.

- **Industry Funding**: This is an industry funded study. Several of the authors report significant financial interest in Revivant Corporation.


- **LOE**: 5
- **Quality**: Fair
- **Supporting Outcomes**: ROSC (A), Myocardial blood flow (E), post-ROSC ejection fraction (E)
- **Neutral Outcomes**: None
- **Opposing Outcomes**: None
- **Industry Funding**: This is an industry funded study. Several of the authors report significant financial interest in Revivant Corporation.


- **LOE**: 5
- **Quality**: Good
- **Supporting Outcomes**:
  - ROSC (A)
  - Survival (B)
  - Coronary perfusion pressure (E), (20±12 mmHg vs. 15±11 mmHg)
  - Myocardial and cerebral blood flow (E)
- **Neutral Outcomes**: None
- **Opposing Outcomes**: None
- **Summary Statement**: This multi-arm randomized control trial compares LDB-CPR, 20% pneumatic-chest compressor CPR (C-CPR20), and 30% pneumatic CPR (C-CPR30) in an anesthetized swine model of electrically-induced cardiac arrest. Hemodynamic measurements were made after a 4 minute “BLS” phase (without epinephrine) of CPR. Animals that did not achieve initial ROSC were entered into a subsequent 4 minute period of “ALS” (with epinephrine) CPR phase. Animals receiving LDB-CPR displayed improved ROSC, 24 hour survival, cerebral performance; cerebral and myocardial blood flow as compared to C-CPR20 and C-CPR30. Of note, hemodynamic improvements relative were slightly more pronounced during the BLS phase. Finally, animals receiving C-CPR30 exhibited more evidence of rib and lung trauma on blinded necropsy. *Limitations*: The primary limitation of this study is its use of piston-CPR rather than the standard of care (manual CPR). In addition, the authors used different compression rates and ventilation:compression ratios in their experimental (80cc/min, 15:2) and control (60cc/min, asynchronous) which limits the power of this comparison.
- **Industry Funding**: This study was funded by Zoll, Sunnyvale, CA. Drs. Halperin, Zviman, and Lardo are consultants for ZOLL Circulation. Drs Lee and Paradis and Mr Illindala are employees of ZOLL.


- **LOE**: 4
- **Quality**: Fair
- **Supporting Outcomes**:
  - No injuries were reported (E)
- **Neutral Outcomes**:
  - ROSC (A)
Opposing Outcomes: None

Summary Statement: This is a small prospective observational trial of the use of LDB-CPR for the treatment of out-of-hospital cardiac arrest within a single urban EMS system. The authors report ROSC rates, survival to ICU admission, hospital discharge rates, and neurologic outcomes which are comparable with those in the literature; however, interpretation of these results is severely limited by a lack of a manual CPR comparison group (historical or concurrent). It should be noted that a limited number of comparisons were made with a concurrent group who received ACD-CPR. Importantly, this study reports a mean LDB-CPR set-up interval (4.7 ± 5.9 minutes).

Limitations: The quality of this study is somewhat limited by a lack of enrollment criteria, which raises the risk of selection bias.

Industry Funding: The authors confirmed that they had no financial conflict of interest in this study.


LOE: 3
Quality: Good
Supporting Outcomes:

<table>
<thead>
<tr>
<th></th>
<th>ARR (%)</th>
<th>NNT (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROSC (A)</td>
<td>-14.3</td>
<td>7</td>
</tr>
<tr>
<td>Survival to admission (B)</td>
<td>-9.8</td>
<td>10</td>
</tr>
<tr>
<td>Survival to discharge (C)</td>
<td>-6.8</td>
<td>15</td>
</tr>
</tbody>
</table>

Neutral Outcomes: Intact neurological outcome at discharge (D)

Opposing Outcomes: None

Summary Statement: This is a phased observational cohort study of out-of-hospital cardiac arrest within a single EMS system which compared LDB-CPR with historical manual CPR controls. Significant improvement in the primary outcome (ROSC rate) was demonstrated with a large magnitude of the observed effect. Secondary outcomes including survival to hospital admission and survival to hospital discharge also showed a positive improvement. No improvement was seen in neurologic outcome at discharge. Limitations: It is important to note that unwitnessed arrest victims in both arms received 90 seconds of manual CPR prior to randomization. Also, interpretation of this study is limited somewhat by its use of historical controls. In addition, the experimental cohort of this group displayed a higher percentage of EMS-witnessed events and shorter EMS response time intervals. Both of these potential confounders could confound the observed beneficial effect.

Industry Funding: LDB-CPR devices were loaned to the EMS system by Zoll Circulation. Dr. Ornato is a science advisor to the manufacturer for which he has received travel reimbursements and small honoraria (< $2K per annum). Dr. Ornato did not have access to the data.


LOE: 1
Quality: Poor (post-hoc analysis)
Supporting Outcomes: None
Neutral Outcomes:
Opposing Outcomes:

LOE 1, Neutral, Poor (post-hoc analysis)
A post-hoc analysis of the Hallstrom 2006 study (A cerebral performance category of 1 or 2 at hospital discharge was recorded in 7.5% of patients in the manual CPR group and in 3.1% of the LDB-CPR group (P = .006); survival to
hospital discharge was 9.9% in the manual CPR group and 5.8% in the LDB-CPR group (P = .06, adjusted for covariates and clustering)). Demonstrated significant heterogeneity between sites. One site (site C) had a substantive decrease in survival to hospital discharge, whereas the other sites did not reflect these “safety concerns,” and these sites appeared to demonstrate a steadily “improving four hour survival” with patient enrollment.

- LOE: 3
- Quality: Fair
- Supporting Outcomes: ROSC (A)
  - Unadjusted subgroup analysis of implementation period patients revealed a higher rate of ROSC at admission (A) in patients receiving LDB-CPR as compared with patients treated without device.
- Neutral Outcomes: None
- Opposing Outcomes: 30-day survival (E)
  - Multivariate logistic regression modeling identified the use of LDB-CPR as an independent factor associated with a decreased rate of 30-day survival (OR 0.4 (0.2 – 1.0), p = 0.04)
- Summary Statement: This was an observational cohort study of out-of-hospital cardiac arrest patients conducted in a physician staffed single EMS system within a large urban center. It was designed to measure the impact of implementing the 2005 ERC resuscitation guidelines on 30-day survival following OOHCA. During the study period, LDB-CPR was made available, but not uniformly implemented, within this EMS system. Unadjusted analysis using manual CPR controls from the implementation period revealed a higher rate of ROSC (A) in LDB-CPR treated patients. However, 30-day survival was not different between comparison groups. Furthermore, logistic regression analysis of a combined dataset utilizing pre- and post-implementation data revealed worse 30-day survival (E) in LDB-treated patients. Limitations: Interpretation of this study is somewhat limited as the criteria for applying LDB-CPR were not explicitly listed in the manuscript. The small size of the LDB-CPR group and additional interventions under study during the implementation period limit the interpretation of this study with regard to LDB-CPR.
- Industry Funding: Authors report contributions from The Novo Nordisk Foundation.

- LOE: 4
- Quality: Good
- Supporting Outcomes:
  - Coronary Perfusion Pressure (E), (20±12 mmHg vs. 15±11 mmHg)
- Neutral Outcomes: None
- Opposing Outcomes: None
- Summary Statement: This is a pilot clinical hemodynamic study of LDB-CPR following failed ACLS (10 minutes including manual CPR) on victims of in-hospital cardiac arrest. Following instrumentation, patients received alternating 90s bouts of manual CPR and LDB-CPR, thus serving as their own controls. The authors report improved hemodynamic parameters including peak aortic pressure, peak right atrial pressure, and (importantly) coronary perfusion pressure (CPP) in the LDB-CPR group. Limitations: As a pilot study, this quality of this study is impacted somewhat by its small sample size. In addition, while these results indicate improvements in CPP following failed manual CPR, it is possible that a different outcome would have been observed during early resuscitation. Finally, while improvements in CPP have been previously associated with increased ROSC rates, the results of this study do not necessarily imply improved clinical efficacy.
- Industry Funding: This is an industry-funded study. The senior author (HH) reports significant financial interest in Revivant Corporation; however, this author had no roll in enrollment or analysis of the raw data.

- **LOE:** 5
- **Quality:** Good
- **Supporting Outcomes:** None
- **Neutral Outcomes:** HOF (E)
  - HOF (E). Improved at sites with highest HOF during manual CPR
  - HOF (E). Worsened at sites with lowest HOF during manual CPR
- **Opposing Outcomes:** Time to Initial Defibrillation (E)
  - Delayed by 29 (3, 55, \(p = 0.032\)) s vs. manual CPR

**Summary Statement:** This was a multi-center (4 international sites) manikin study where highly-trained professional rescuers were randomized to manual CPR or LDB-CPR during simulated cardiac arrest scenarios. Primary outcomes included hands-off-fraction (HOF) and time required to achieve predefined ALS milestones including start of manual chest compressions, defibrillator on, pads on, randomization, start deployment and running the LDB device, intubation, IV access with fluid infusion, administration of ACLS medications. The use of LDB-CPR had mixed, site-dependent, impact on HOF which tended to reduce HOF at sites with high manual CPR HOF and increase it at sites with low manual CPR HOF. Regarding ALS milestones, LDB-CPR delayed initial defibrillation time but tended to shorten other ALS milestones. **Limitations:** As a simulation study, this study lacks real-life clinical outcomes and scenario variation. The authors note a significantly high percentage (19%) of scenarios with unintentional stops and attribute this to accidental displacement of the manikin during intubation. It also appears that simulations were performed at the scene and did not involve factors related to patient transport.

- **Industry Funding:** Authors report significant involvement in clinical trials sponsored by JoLife (competitor) and ZOLL Medical (manufacturer of Autopulse). ZOLL Medical provided significant funding for this study.