Clinical question.

In adult and pediatric patients with cardiac arrest while on a bed (prehospital [OHCA], in-hospital [IHCA]) (P), does the performance of CPR on a hard surface like backboard or deflatable mattress (I) compared with performance of CPR on a regular mattress (C), improve outcome (eg. ROSC, survival) (O)?

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

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

Conflict of interest specific to this question

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet?

Commercial - none
Potential intellectual conflict of interest: Author of five papers cited in this review. Editor for Resuscitation

Search strategy (including electronic databases searched).


Search achieved 49 hits
Abstracts were reviewed for relevance. This reduced the number of papers to 10. One further paper was identified from the “related articles” field in PUBMED and two further paper from reviewing the reference lists of articles retrieved. This gave a total number of papers for review of 13.

Cochrane database of systematic reviews and clinical trials reviewed using terms “backboard”; “chest compression”; “resuscitation”. No reviews identified

AHA end-note database searched – no additional papers
Embase searched – no additional papers

• State inclusion and exclusion criteria

Inclusion: Clinical; laboratory; manikin; mathematical models relating to CPR on a bed versus the floor, the use of backboards or deflatable mattresses during chest compression / CPR in both children and adults

Exclusion criteria: studies not using a backboard or other rigid support device

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

There were 6 LOE 5 supportive studies (quality good-fair) and 1 LOE 4 study and 6 LOE 5 neutral studies (quality good – poor)
### Summary of evidence

#### Evidence Supporting Clinical Question

<table>
<thead>
<tr>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
<th>Anderson 2007&lt;sup&gt;E&lt;/sup&gt;</th>
<th>Delvaux 2009&lt;sup&gt;E&lt;/sup&gt;</th>
<th>Noordergraaf 2009&lt;sup&gt;E&lt;/sup&gt;</th>
<th>Perkins 2005&lt;sup&gt;E&lt;/sup&gt;</th>
<th>Perkins 2009&lt;sup&gt;E&lt;/sup&gt;</th>
<th>Boe 1999&lt;sup&gt;E+&lt;/sup&gt;</th>
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</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>Good</th>
<th>Fair</th>
<th>Poor</th>
<th>Nishisaki 2009&lt;sup&gt;E&lt;/sup&gt;</th>
<th>Chi 2008&lt;sup&gt;E&lt;/sup&gt;</th>
<th>Larsen 2002&lt;sup&gt;E&lt;/sup&gt;</th>
<th>Perkins 2003&lt;sup&gt;E&lt;/sup&gt;</th>
<th>Perkins 2006&lt;sup&gt;E&lt;/sup&gt;</th>
<th>Jones 2008&lt;sup&gt;E&lt;/sup&gt;</th>
<th>Tweed 2001&lt;sup&gt;E&lt;/sup&gt;</th>
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#### Evidence Opposing Clinical Question

<table>
<thead>
<tr>
<th>Good</th>
<th>Fair</th>
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A = Return of spontaneous circulation  
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C = Survival to hospital discharge  
D = Intact neurological survival  
E = Other endpoint  

**Italics** = Animal studies
Current ILCOR guidelines recommend that cardiac arrest victims should be placed supine on a firm surface (i.e. backboard or floor) during chest compressions to optimise the effectiveness of compressions(2005, 187). No studies evaluating the use of a back-board or rigid support surface in humans have been published to date.

**Bed versus floor**

The quality of CPR on a victim in a bed compared to the floor may be affected by (i) the effect of bed height influencing the rescuers ability to perform CPR and (ii) the mattress absorbing a proportion of compression force applied to the chest.

The effect of bed height alone was examined in four manikin studies that compared the effectiveness of chest compressions on the floor versus a rigid bed/table(Chi 2008, 69; Jones 2008, 417; Larsen 2002, 281; Perkins 2003, 2330). Three of these studies failed to demonstrate any difference between the effectiveness of chest compressions(Chi 2008, 69; Jones 2008, 417; Larsen 2002, 281) whilst a 4th study found reduced compression depth when CPR was performed on a rigid bed (with a deflated pressure relieving mattress) (Perkins 2003, 2330). The studies which used compression depth as an end-point are summarized in the Forest Plot below. Taken together these data show that the quality of chest compression performed on an elevated rigid surface are inferior to compressions performed with the manikin on the floor.

<table>
<thead>
<tr>
<th>Author</th>
<th>Surfaces compared</th>
<th>Parameter</th>
<th>Control</th>
<th>Bed</th>
<th>Signif</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jones n=56</td>
<td>Floor versus table</td>
<td>% effective compressions</td>
<td>66.8(35)</td>
<td>59.7(39.1)</td>
<td>NS</td>
</tr>
<tr>
<td>Larsen n=20</td>
<td>Floor versus table</td>
<td>Compression depth (mm)</td>
<td>42(6)</td>
<td>38(8)</td>
<td>NS</td>
</tr>
<tr>
<td>Chi n=18</td>
<td>Floor versus high</td>
<td>Compression depth (mm)</td>
<td>43.5(3.4)</td>
<td>42(5.4)</td>
<td>NS</td>
</tr>
<tr>
<td>Perkins n=20</td>
<td>Floor versus deflated mattress</td>
<td>Compression depth (mm)</td>
<td>44.2(5.2)</td>
<td>39.1(5.6)</td>
<td>P&lt;0.05</td>
</tr>
</tbody>
</table>

Performing chest compressions on a bed with a non-rigid surface e.g. a mattress will influence actual chest compressions depth as compressions will compress not only the chest but also the underlying mattress.

Three manikin studies (from the same group) have shown that compressions performed on a bed with a mattress are associated with reduced sternal spinal displacement(Perkins 2003, 2330; Perkins 2009, 79; Tweed 2001, 179). These studies are summarized in the Table and Forest plot below. The Tweed study did not report standard deviations and so has been excluded from analysis. The authors have been unable to provide this data retrospectively.
The I² value indicates significant heterogeneity between these studies. On average hospital mattresses compared to the floor are associated with significant under compression of the chest (effect size 12.64; 95% CI 9.96 – 15.33). These data suggest that routine chest compressions performed on a non rigid support surface (e.g. bed and mattress) may fail to achieve adequate compression depth.

This hypothesis is supported by an observational study by Nishisaki (Nishisaki 2009, 540) which performed forensic reconstruction of cardiac arrest cases involving 12 children on different mattresses. The investigators calculated the degree of mattress compression for each case and re-calculated actual chest compression depths from data recorded during the cardiac arrest. This showed that 88.4% of compressions were reported as correct prior to compensation for mattress compression which fell to 31.8% when compensated for standard ITU mattresses (P<0.001). This effect was still present although less pronounced on the more rigid stretcher beds (86.3% vs 64.7%, P<0.001).

### Options for managing a cardiac arrest in a bed

There are a number of options for improving chest compression depth in this situation. These include moving the patient to a rigid surface such as the floor, increase compression force to compensate for underlying mattress compression or increase rigidity of the bed (e.g. alter rescuer position, use a calibrated CPR prompt device) or increase mattress rigidity (e.g. insert a backboard; deflate an air filled mattress).

### Moving patient to the floor

No studies were identified that considered the risks of moving a patient from a bed to the floor. Hypothetical risks include injury to the healthcare provider or patient through being moved and line / tube displacements.

### Altering rescuer position

Altering rescuer position relative to the patient on a bed was examined in three manikin studies. Chi (Chi 2008, 69) compared compression depth performed by 18 health care professionals on a manikin placed on a high versus low table. This had no effect on compression depth, rate, perceived exertion or discomfort. Perkins (Perkins 2006, 1632) similarly found no improvement in compression depth when CPR was performed by 20 medical students with a bed at mid thigh height as opposed to its lowest position. The study also found no incremental benefit from the CPR provider kneeling on the bed next to the patient compared to CPR with the CPR provider standing on the floor. Consistent with
this finding Jones (Jones 2008, 417) found no improvement in chest compression quality between CPR providers standing on the floor or kneeling on the bed next to a manikin.

*Increase compression force e.g. by using calibrated CPR feedback / prompt devices*

A bench study and two manikin studies have shown that increasing compression force can compensate for the effects of underlying mattress compression. Noordergraaf et al applied sequentially increasing weights to a manikin on a number of different mattresses and showed that if sufficient force was applied to the manikins chest adequate sternospinal displacement could be achieved (Noordergraaf 2009, 546). Perkins demonstrated in two separate manikin studies that adequate chest compression depth could be achieved if CPR feedback was calibrated to take account of the underlying mattress compression (Perkins 2005, 103; Perkins 2009, 79).

*Increase mattress rigidity*

*Backboard*

No studies have examined the logistics or potential risks (e.g interruptions in CPR; line / tube displacement) of placing a backboard under a patient during CPR.

Boe and Babbs (Boe 1999, 754) examined the theoretical effects of using a backboard during CPR using two mathematical models (constant compression force or constant sterna-spinal displacement models). Both the constant displacement and constant force models found significant under compression of the chest would occur when CPR is performed on a bed with a soft mattress. In the constant force model, this could be reduced dramatically by increasing mattress stiffness with a backboard. The same was true for the constant displacement model, although the magnitude of improvement in compression depth was substantially less. Consistent with these findings, Noordergraaf (Noordergraaf 2009, 546) found by applying increasing weights to a manikins chest on a variety of hospital mattresses that the degree of mattress compression could be reduced by 50% through use of a backboard thus decreasing the work required to perform adequate chest compressions. Delvaux (Delvaux 2009, 195) used a mechanical chest compression device to compare efficiency of chest compressions between a table top, hospital mattress, mattress plus backboard and a novel deflating mattress. The study reported chest compression efficiency (ratio of actual chest compression depth / total compression depth) was highest on a table (95%), lowest on a standard mattress (42%) which improved with the insertion of a backboard 53%). The novel deflating mattress restored compression efficiency to 81%.

Three manikin studies have examined the effect of placing a backboard between a manikin and a foam mattress during simulated CPR on a bed and evaluated the effect on compression depth. One study (Perkins 2006, 1632) used 20 medical student volunteers in a randomized controlled cross over trial to examine the impact of a backboard (1535 x 635 x 4mm) on chest compression depth (dimensions provided by researcher, not in paper). The study found no difference in compression depth between the no backboard arm (29mm (95%CI 25.9-21.1)) and backboard arms (31mm (95%CI 26.2-35.8)). In contrast a subsequent randomized controlled cross over trial (Andersen 2007, 747) comparing CPR performed by 23 male hospital orderlies with and without a backboard (dimensions 440 x 580 x 10mm) found that mean compression depth increased from 43mm to 48mm (95% CI diff = 3.6 – 7.5mm) when the backboard was used. However there was no improvement in the proportion of compressions with a correct depth (40-50mm) suggesting that a significant proportion of compressions in the backboard arm exceeded 50mm. The third study (Perkins 2009, 79), used an accelerometer device (Q-CPR) to provide feedback on compression depth during chest compressions on a foam mattress with either no board, a narrow (457 x 1826 x 37mm) backboard or wide backboard (635 x 1509 x 4mm) (n=8). This study found a marginal improvement in compression depth compared to control with both the narrow (1.9mm increase (95% CI diff 0.1 – 3.7mm)) and wide boards (2.6mm increase (95% CI diff 0.9 – 4.5mm)). The increase in chest compression depth was attributed to a reduction in the degree of compression of the underlying mattress.

These effects are summarized in the table and Forest plot below. Note data from the wide backboard from reference (Perkins 2009, 79) have been used for this comparison.
These studies indicate that the use of a backboard will increase mattress stiffness, which will reduce the amount of work required for effective chest compression and improve compression depth.

Deflating an air filled mattress

A pilot study (n=4) using a manikin (Tweed 2001, 179) showed that emergency deflation of 3 different air filled mattresses failed to improve chest compression depth. However this study lacked sufficient power to draw any meaningful interpretations from the data. A subsequent study from the same group (Perkins 2003, 2330) was powered to detect a 5mm difference in compression depth with mattress deflation. In this study compression depth was measured on a manikin placed on an inflatable mattress whilst the mattress was inflated, deflating and deflated. There was no difference in average compression depth between the inflated (37.2mm) and deflated mattress (39.1mm) nor during deflation. Delvaux (Delvaux 2009, 195) examined the properties of a CPR mattress which incorporated a central mattress insert which forms a rigid surface for chest compression with mattress deflation. Activation of this function increased compression efficiency from 42% to 81%.

Acknowledgements:


LOE 5 (manikin study) Quality - good
Randomized controlled cross over trial (Andersen 2007, 747-50) comparing CPR performed by 23 male hospital orderlies with and without a backboard (dimensions 440 x 580 x 10mm) found that mean compression depth increased from 43mm to 48mm (95% CI diff = 3.6 - 7.5mm) when the backboard was used. However there was no improvement in the proportion of compressions with a correct depth (40-50mm) suggesting that a significant proportion of compressions in the backboard arm exceeded 50mm.


LOE 5 (manikin study); LOE 5
Mathematical simulation study which examined the theoretical effects of using a backboard during CPR using two mathematical models (constant compression force or constant sterna-spinal displacement models). Both the constant displacement and constant force models found significant under compression of the chest would occur when CPR is performed on a bed with a soft mattress. In the constant force model, this could be reduced dramatically by increasing mattress with a backboard. The same was true for the constant displacement model, although the magnitude of improvement in compression depth was substantially less.


LOE 5, quality good, neutral. Manikin study with 18 HCP's comparing CPR on floor versus high and low tables. Examined effect on body postures primarily. Found no difference in depth, rate, exertion or discomfort with different positions


LOE 5 quality good, supportive. Bench study using mechanical chest compression device to compare efficiency of chest compressions on different surfaces. Rigid surface achieved 95%; standard mattress 43%; backboard plus standard mattress 53%; new CPR deflating mattress 81%.

LOE 5, quality poor, neutral. non-randomised study comparing kneeling on floor, standing or kneeling on bed on quality of CPR, spinal kinetics and energy consumption. Numerous post hoc analyses undertaken to search for significance. No significant differences found (except increase in oxygen consumption when standing)


LOE 5, quality good, neutral. Interrogation of study looking for patterns in chest compressions which included a comparison of CPR on floor versus table


LOE 4, quality good, supportive. Forensic reconstruction of cardiac arrest cases involving 12 children on different mattresses. The investigators calculated the degree of mattress compression for each case and re-calculated actual chest compression depths from data recorded during the cardiac arrest. This showed that 88.4% of compressions were reported as correct prior to compensation for mattress compression which fell to 31.8% when compensated for standard ITU mattresses (P<0.001). This effect was still present although less pronounced on the more rigid stretcher beds (86.3% vs 64.7%, P<0.001).


LOE 5, quality good, supportive. Applied increasing weights to a manikins chest on a variety of hospital mattresses that the degree of mattress compression could be reduced by 50% through use of a backboard thus decreasing the work required to perform adequate chest compressions


LOE 5 quality good, neutral. RCT demonstrating that CPR performed on a hospital bed can be improved by using CPR prompt device which has been calibrated for performing CPR on a bed


LOE 5, quality good, neutral


LOE 5, quality good, supportive

LOE 5 (manikin study); Quality good; opposing

Randomised controlled cross over trial involving 20 medical student volunteers to examine the impact of a backboard (1535 x 635 x 4mm) on chest compression depth (dimensions provided by researcher, not in paper). The study found no difference in compression depth between the no backboard arm (29mm (95%CI 25.9-21.1)) and backboard arms (31mm (95%CI 26.2-35.8).


LOE 5 manikin study; quality poor; opposing

A pilot study (n=4) using a manikin which showed that emergency deflation of 3 different air filled mattresses failed to improve chest compression depth. However this study lacked sufficient power to draw any meaningful interpretations from the data.