Original Article

Cardiopulmonary resuscitation in the pregnant patient: a manikin-based evaluation of methods for producing lateral tilt*

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Summary

The importance of minimising aortocaval compression during cardiopulmonary resuscitation in late pregnancy is widely accepted. Current European guidelines suggest employing manual displacement of the uterus with left lateral tilt to achieve this. Several methods for producing lateral tilt have been described; however, the optimum method is unknown. By performing simulated cardiopulmonary resuscitation on a manikin, we compared four of these methods: a folded labour ward pillow; a pre-formed foam wedge; a custom-made hard wooden wedge; and the 'human wedge'. Primary outcome measures were maintenance of adequate tilt, stability and effectiveness of chest compressions (rate, depth and adequate release). Overall, the foam and wooden wedges were significantly more stable and reliable at maintaining tilt than the pillow ($p < 0.0001$); the wooden wedge was more stable and effective than the foam wedge ($p < 0.0001$). Chest compressions were least effective with the human wedge ($p = 0.02$). Effectiveness of chest compressions with lateral tilt was comparable to that reported previously in supine manikin studies. We recommend the use of dedicated foam or hard wedges rather than pillows or the human wedge for producing lateral tilt during cardiopulmonary resuscitation.

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Reports into maternal mortality highlight cardiopulmonary resuscitation (CPR) after cardiac arrest as a major area for improvement [1], with recent studies identifying effective delivery of chest compressions with left uterine displacement as a particular area of concern [2, 3]. Minimal maternal aortocaval compression by the gravid uterus is accepted as an important component of effective CPR in this context and methods described to achieve this include manual displacement of the uterus and the application of left lateral tilt [4]. Current guidance from the European Resuscitation Council recommends use of manual displacement with concurrent left lateral tilt of 15–30°, if feasible [5], although it gives no specific advice as to how to achieve the latter.

A recent national survey of UK obstetric units revealed wide variation in the methods used to achieve left lateral tilt for CPR [6]. These include the use of soft pillows, a pre-formed foam wedge, a pre-formed rigid wedge (similar to the Cardiff wedge [7]) and resting the mother on the thighs of a kneeling assistant (the 'human wedge' [8]). However, there is little published evidence on the effectiveness of any of these techniques and so the optimum method of producing left lateral tilt for

CPR is unknown. The aim of this study was to evaluate the four methods described above for achieving left lateral tilt. The maintenance of tilt and quality of chest compressions during CPR was assessed using a manikin-based trial, and the feasibility and ease of positioning in the clinical setting was evaluated using an observational study on mothers in late pregnancy.

Methods

The study protocol was approved by the local research ethics committee and written informed consent was obtained from all the participants. The study was performed in two parts. The first was a manikin-based experiment comparing the four methods described in the survey for producing lateral tilt [6]: a folded labour ward pillow ('soft' wedge); a pre-formed foam wedge ('firm' wedge); a custom-made wooden wedge ('hard' wedge); and a kneeling human participant ('human' wedge). The wedges were assessed during chest compressions performed with a manikin positioned on the floor and on a standard labour ward bed. The second part of the study was a comparison of the ease of positioning of three of the four wedges on mothers in late pregnancy (the hard wedge was excluded as this device had not been approved for use on patients).

Part 1

Forty participants were recruited to perform chest compressions on a manikin tilted to the left lateral position using each of the four wedges. Twenty participants performed compressions on the floor, and twenty on a labour ward bed. All participants were healthcare professionals (a mix of anaesthetists and midwives) with recent (< 1 year) training in basic and/or advanced adult life support. Participants took part in pairs: one participant performed chest compressions whilst the other participant assisted (either stabilising the manikin on the wedge or using their knees to provide the human wedge). Participants then swapped roles before the next wedge was used.

The order of testing was randomised by drawing lots. Left lateral tilt was applied by placing one out of four wedges under the manikin's back. The soft wedge was formed by folding a standard labour ward pillow in half across its short axis. The firm wedge was a preformed foam wedge measuring 55 cm by 51 cm by 20 cm (Anetic Aid, Guiseley, West Yorkshire, UK). The hard wedge was a custom-made wooden wedge of the same dimensions as the firm wedge. The human wedge was produced by a kneeling participant. When initially positioned, all of the wedges produced a baseline tilt angle of between 15° and 30°.

For each of the four wedges, participants performed 2 min of uninterrupted chest compressions in time to an electronic beeper set at a rate of 105 beats.min^{-1}. They were asked to deliver compressions to a depth of 5–6 cm, in accordance with current European Resuscitation Council guidelines [5]. To minimise baseline variability in the quality of chest compressions, appropriate verbal feedback was given to the participant regarding optimum rate and depth of compressions during the first 10 s of each 2-min test phase. Each participant was allowed to take sufficient breaks between tests, and confirmed that they were adequately rested before proceeding to the next wedge. At the end of each 2-min test phase, both participants were asked to rate the wedge for stability, as 'very poor'; 'poor'; 'adequate'; 'good'; or 'very good' (recorded as a score of 1–5).

The magnitude of left lateral tilt during the performance of chest compressions was measured and recorded using the 'Tiltmeter' digital angle meter application (IntegrasoftHN, www.tiltmeterapp.com) running on an Apple iPhone® 3GS (Apple Inc., Cupertino, CA, USA). The application measured and recorded tilt angle every 0.5 s. The iPhone was taped to the lower abdomen of the manikin during testing.

The manikin used was a Laerdal ResusiAnne® manikin (Laerdal, Orpington, Kent, UK), connected to a computer equipped with Laerdal PC SkillReporting system software (http://www.laerdal.com/gb/doc/67/Laerdal-PC-SkillReporting-System). This software was used to assess the quality of all chest compressions performed on the manikin; rate, depth and adequate release of compressions were measured and recorded.

Part 2

Ten healthy, non-obese singleton parturients of at least 36 weeks' gestation were recruited. Ten midwives (representing the most likely first responders at a maternal collapse) were asked to assess the soft, firm and human wedges for ease of positioning of the mothers on a standard labour ward bed. One of the researchers (JPC) assisted by rolling the mother to the left, while the assessor positioned the wedge under the mother's back. The assessor and mother were then asked to rate the wedge for ease of positioning and comfort, respectively, as: 'very poor'; 'poor'; 'adequate'; 'good'; or 'very good' (recorded as a score of 1–5).

Data analysis was performed using StatsDirect statistical software (StatsDirect Ltd, Altrincham, Cheshire, UK). Results were analysed using either repeated measures ANOVA or the Friedman test; a value of $p < 0.05$ was considered statistically significant. Sample size selection was based on previous studies of tilt methods [7, 8].

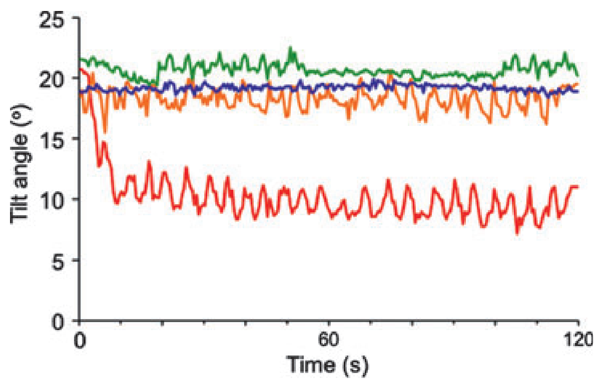

Figure 1 Data from a single participant showing the tilt angle measured during cardiopulmonary resuscitation on the floor with the soft (red), firm (orange), hard (blue) and 'human' (green) wedges.

Results

Results from one of the participants performing CPR on the bed were excluded from analysis due to incomplete data capture.

During CPR on the floor, the soft wedge was the least stable and reliable at maintaining tilt, and this is demonstrated by Fig. 1, which shows data over the entire 2-min period for all four wedges for a single participant on the floor. The firm and hard wedges were the most stable and reliable at maintaining adequate tilt (Table 1 and Fig. 2a and b). Depth of chest compressions was significantly reduced with the human wedge compared with the other wedges; all other wedges performed similarly in this respect (Fig. 2c and d). The type of wedge had no effect on the average rate or adequate release of chest compressions (Table 1).

During CPR on the bed, the soft wedge was notably poor whilst the hard and human wedges were the most stable and reliable (Table 1 and Fig. 3a and b). Depth, rate and adequate release of chest compressions did not differ significantly between the wedges (Fig. 3c and d and Table 1).

Positioning of mothers was significantly easier using the soft wedge than the firm and human wedges, but the wedges did not differ significantly with respect to comfort (Table 1).

Discussion

Despite the longstanding availability of several methods of producing left lateral tilt during CPR, to our knowledge, there has been no direct comparison of them. Our results suggest that, overall, the pre-formed firm and hard wedges are superior to the soft and human wedges with respect to stability, maintenance of tilt and effectiveness of chest compressions.

The soft wedge received significantly lower stability scores than the firm and hard wedges and it was particularly poor at maintaining tilt. A single-folded labour ward pillow was used (using two pillows was considered, but rejected as it produced a tilt greater than 30º and was extremely unstable) and, while the initial tilt was always 15–30º, this rapidly fell in the majority of cases. These findings can be accounted for by the highly compressible nature of standard labour ward pillows compared with the other wedges.

The hard wedge performed better than the firm wedge in terms of stability and maintenance of tilt, on both the floor and the bed; however, there was no difference with respect to compression depth. Although the human wedge provided a greater degree of tilt, it was significantly less stable than the hard wedge, and resulted in significantly reduced depth of chest compressions than the firm and hard wedges during CPR on the floor. This is in keeping with a study demonstrating a reduction in transmitted axial force with increasing tilt angle [7]. Importantly, several participants stated that discomfort from acting as the human wedge (primarily pain in the knees and ankles) would have prevented them from continuing for more than one cycle of CPR; having to change the person

Table 1 Comparison of rate, adequate release of chest compressions and stability during CPR using the soft wedge (pillow), firm wedge (foam-rubber), hard wedge (wooden) or 'human wedge'. Comfort and ease of positioning on actual mothers are also shown. Values are mean (SD) or median (IQR [range]).

	Soft	Firm	Hard	Human	p value
Floor	n = 20	n = 20	n = 20	n = 20	
Compressions; min^{-1}	106.7 (3.8)	105.6 (3.3)	105.8 (2.9)	106.0 (3.3)	NS
Proportion of compressions adequately released; %	99.8 (96.3–100.0 [68.1–100 0])	99.3 (93.1–100.0 [52.6–100.0])	99.6 (95.1–100.0 [54.5–100.0])	100.0 (98.4–100.0 [18.6–100.0])	NS
Stability	3 (2–4 [1–5])	4 (3–4 [2–5])	5 (5–5 [4–5])	3 (1–4 [1–5])	< 0.0001*
Bed	n = 19	n = 19	n = 19	n = 19	
Compressions; min^{-1}	105.8 (4.3)	105.4 (2.1)	104.9 (3.6)	106.1 (3.9)	NS
Proportion of compressions adequately released; %	99.6 (94.0–100.0 [78.3–100.0])	100.0 (97.7–100.0 [86.6–100.0])	100.0 (99.5–100.0 [84.4–100.0])	100.0 (98.6–100.0 [76.3–100.0])	NS
Stability	2 (1–3 [1–5])	4 (3–4 [2–5])	4 (3–4 [2–5])	4 (3–5 [1–5])	< 0.0001**
Ease of positioning (on mothers)	5.0 (4.0–5.0 [4.0–5.0])	3.0 (2.3–3.8 [2.0–4.0])	-	3.0 (2.0–4.0 [1.0–5.0])	0.0008***
Comfort	3.5 (3.0–4.0 [2.0–4.0])	3.0 (2.0–3.0 [2.0–5.0])	-	3.5 (3.0–4.0 [2.0–4.0])	NS

*p < 0.0001 for all comparisons except Soft vs Human (NS) and Soft vs Firm (p = 0.0027).
**p < 0.0001 for all comparisons except Firm vs Human (NS), Hard vs Human (p = 0.0186) and Firm vs Hard (0.0159).
***p = 0.0004 for Soft vs Firm, p = 0.0019 for Soft vs Human, and p = NS for Firm vs Human.

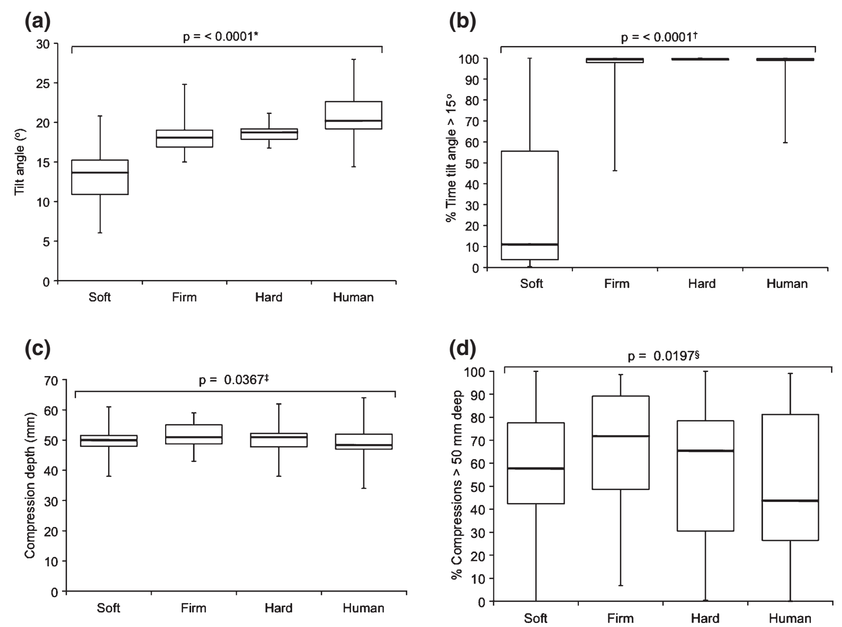

Figure 2 Efficacy of cardiopulmonary resuscitation with the soft wedge (pillow), firm wedge (foam-rubber), hard wedge (wooden) or 'human' wedge, with the manikin on the floor: (a) average tilt angle, *p < 0.0001 for all comparisons except Firm vs Hard (NS) and Hard vs Human (p = 0.0008); (b) proportion of time > 15º tilt, †p < 0.0001 for all comparisons except Firm vs Human (NS), Firm vs Hard (p = 0.001) and Hard vs Human (p = 0.025); (c) depth of compressions, ‡p = NS for all comparisons except Firm vs Human (p = 0.009) and Hard vs Human (p = 0.015); (d) proportion of compressions > 50 mm, §p = NS for all comparisons except Firm vs Human (p = 0.0033), Hard vs Human (p = 0.0160) and Soft vs Human (p = 0.0474). Plots indicate median (horizontal line) IQR (box) and range (whiskers).

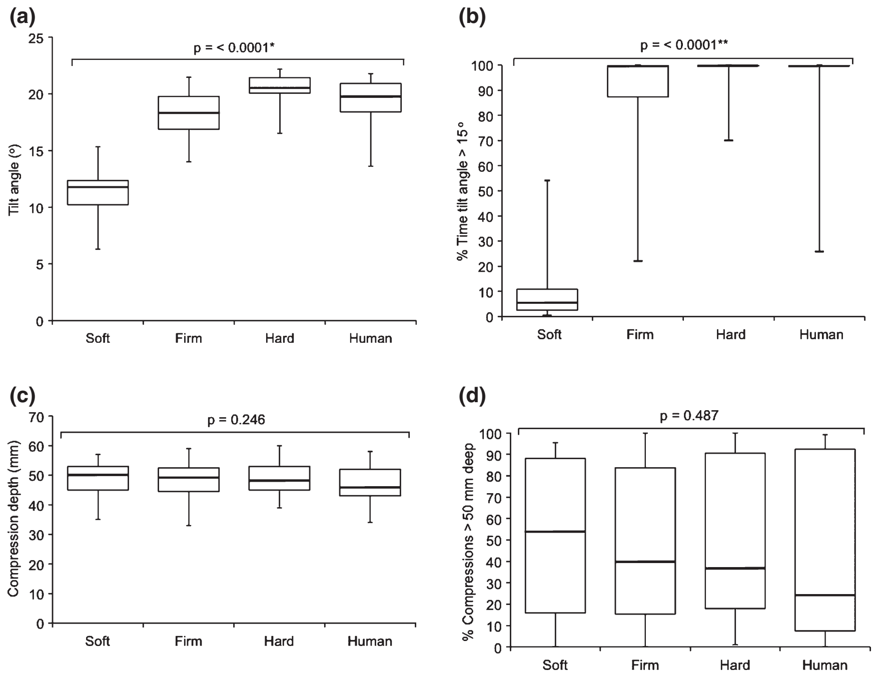

Figure 3 Efficacy of cardiopulmonary resuscitation with the soft wedge (pillow), firm wedge (foam-rubber), hard wedge (wooden) or 'human' wedge, with the manikin on the bed: a) average tilt angle, **p < 0.0001 for all comparisons except Hard vs Human (NS) and Firm vs Human ($p = 0.0106$); (b) proportion of time $> 15^o$ tilt, ††p < 0.0001 for all comparisons except Hard vs Human (NS); (c) depth of compressions; (d) proportion of compressions > 50 mm. Plots indicate median (horizontal line) IQR (box) and range (whiskers).

providing the human wedge during an actual resuscitation could result in interruptions to CPR, compromising its effectiveness.

Concern regarding the negative impact of left lateral tilt on the effectiveness of chest compressions has led some to argue that it should be abandoned in favour of manual displacement only [9]. Although we did not directly compare left lateral tilt with the supine position, the effectiveness of CPR (median compression depth and the proportion of compressions of adequate depth) for the firm and hard wedges was similar to that reported previously in supine manikin studies [8, 10–13]. We suggest that it would be fairly easy for the assistant keeping the wedge in place also to perform manual displacement of the uterus. This would be in keeping with current European Resuscitation Council recommendations [5].

Two major caveats should be borne in mind while interpreting our findings. Firstly, our manikin was much lighter than the average pregnant patient, and this may well have an impact on the stability of the wedges in the clinical setting. Secondly, while we attempted to assess the ease of positioning on actual mothers, the transferability of the performance of the wedges during controlled, simulated, CPR to the stressful environment of an actual resuscitation remains unclear. Not surprisingly, participants found it easier to position women using soft pillows than using the other methods, although we would suggest that most staff on labour wards will be familiar with the use of wedges, e.g. for use during operative delivery.

A survey of UK labour wards revealed that most units have multiple methods available for producing lateral tilt during CPR; 50% reported that they would use pillows on the floor and the bed, whereas 96% said that they would use the human wedge on the floor [6]. Although the availability of several recognised methods for producing lateral tilt may be helpful (the first description of the human wedge highlights its usefulness when specialised equipment is unavailable [8]), it may also contribute to confusion or hesitation during a resuscitation attempt. Cardiac arrests are stressful and time-critical events that would benefit from the use of simple algorithms with clearly defined roles and equipment. We suggest that custom-made wedges are better suited to this context than pillows (which our results suggest are relatively ineffective) and the human wedge (which is difficult to maintain for more than a few minutes), as they deliver a relatively fixed performance with minimal ambiguity as to how they should be used and can be kept in a specific place (e.g. on the resuscitation trolley) to be used solely for that purpose.

In conclusion, our results suggest that custom-made wooden and firm wedges are superior to soft and human wedges for producing left lateral tilt during CPR. Although the wooden wedge was more stable and reliable than the foam wedge, a similar 'hard' wedge licensed for clinical use is not, to our knowledge, commercially available in the UK and, anecdotally, the original Cardiff wedge is not widely available either, despite common reference to it. In view of this, we would suggest that a pre-formed foam wedge would be an acceptable alternative and would certainly be superior to using pillows or the human wedge. The foam wedge could be kept on or near the resuscitation trolley, with local guidelines and training recommending its use as the default method to deliver standardised care. Such wedges are in widespread use for providing left lateral tilt during operative delivery and many, if not most, delivery suites will already be familiar with their use [6].

Competing interests

All equipment and support were provided from institutional and/or departmental resources. SMY is Editor-in-Chief of *Anaesthesia* and this manuscript has undergone an additional external review as a result.

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