AUSTRALASIAN JOURNAL OF **PARAMEDICINE**

Impact of loading and transport on effectiveness of external chest compressions – a simulation study

Reyna Chew
Western Sydney University, New South Wales

Clare Price
Western Sydney University, New South Wales

Hamed Moqadassi
Western Sydney University, New South Wales

Shaun Talbert
Western Sydney University, New South Wales

Tim Hilliar
Western Sydney University, New South Wales

Elizabeth Thyer
Western Sydney University, New South Wales

Paul M Simpson
Western Sydney University, New South Wales

Research

Impact of loading and transport on effectiveness of external chest compressions – a simulation study

Reyna Chew is a final year paramedicine student¹, Clare Price is a final year paramedicine student¹, Hamed Moqadassi is a final year paramedicine student¹, Shaun Talbert is a final year paramedicine student¹, Tim Hilliar is a final year paramedicine student¹, Elizabeth Thyer PhD, BSc(Hons), DipAmbParaStudies, GCTE, is Senior Lecturer in Paramedicine¹, Paul M Simpson PhD, MScM(ClinEpi), GCClinEd, GCPaeds, BEd, BHSc(PrehospCare), AdvDipParaScience, ICP, is Senior Lecturer in Paramedicine¹

Affiliation:

¹School of Science and Health, Western Sydney University, New South Wales

Abstract

Introduction

Effective external chest compressions (ECC) are recognised as being critical for increasing chances of survival in out-of-hospital cardiac arrest. The aim of this study was to: 1) determine the impact of movement and transport on effectiveness of ECC performed by student paramedics; 2) provide results to inform a future larger study; and 3) validate teaching methods in an undergraduate paramedicine program.

Methods

A prospective cohort design was utilised. Student paramedics performed ECC on a manikin under three different conditions: at ground level on a hard floor surface (ground ECC); at waist-height on a moving ambulance stretcher (extrication ECC; and during transport in the rear of a moving ambulance (transport ECC). Three minutes of ECCs was performed under each condition, with periods of rest between phases. The primary outcome was the composite 'compression score' (CS) (%).

Results

Twenty-seven student paramedics performed chest compressions under all three conditions. For the primary outcome comparison of CS, there were clinically significant differences in ECC quality across the three conditions. Ground ECC produced the highest CS (89%; IQR 46), followed by transport ECC (54%; IQR 40). Extrication ECC was least effective (CS 0%; IQR 14).

Conclusion

The conditions under which ECC are performed significantly affects ECC quality. The quality of ECC is substantially reduced if performed in the back of a moving ambulance, and futile if performed on a moving ambulance stretcher. Paramedics should consider these findings when deciding whether or not to move or transport patients before return of spontaneous circulation. Lower than expected CS on hard ground surfaces may indicate a need to review teaching of ECC in this cohort of students.

Keywords:

paramedic; chest compression; simulation; transport; effectiveness

Corresponding Author: Paul M Simpson, p.simpson@westernsydney.edu.au

Introduction

Despite advances in resuscitative care for patients experiencing out-of-hospital cardiac arrest, high quality external chest compressions (ECC) remain the cornerstone of treatment (1,2). International guidelines increasingly highlight the importance of effective ECCs ahead of advanced life support intervention including advanced airways and cardiac pharmacology (3). While high-quality ECC is advocated, the reality of out-of-hospital settings is that paramedics are frequently required to resuscitate cardiac arrest patients in diverse environments under less than optimal conditions that may not be conducive to achieving that goal.

While it is widely accepted that patient movement or transport should not be undertaken while ECCs are being performed, there are occasional circumstances in which this may be necessary. This could be in a situation where there is immediate danger to the patient or paramedics, necessitating early movement during resuscitation to another location. Another instance might be when spontaneous circulation is lost and ECCs become necessary during the extrication, loading or transport phases of care.

There are therefore three distinct phases during which ECC may be required to be performed in the out-of-hospital setting:

- on the floor/ground in an internal or external environment
- on a full-height stretcher during extrication and loading into an ambulance
- during transport on a stretcher in the back of a moving ambulance.

The aims of this study were to compare the impact of movement and transport on effectiveness of ECC and to assess feasibility of conducting a larger study.

Methods

Design and setting

This prospective pilot study used an observational cohort study design. The setting was an undergraduate paramedicine program at Western Sydney University. Data collection was undertaken between June and December 2015.

Participants

Participants were student paramedics in their second year of a three-year undergraduate paramedicine program. No exclusion criteria applied to prospective participants. All participants had received focussed education and training in relation to performance of ECC as part of their core undergraduate studies, and all had completed a 4 week clinical placement with an emergency ambulance service in which some engaged in 'real' ECC in a clinical setting. Participants received no additional specific ECC training or 'primer' practice before participating in the study.

Recruitment

Recruitment took place via promotion of the study on social media pages, posters at paramedic conferences and public announcements. Participation was entirely voluntary, with all participants completing information and consent forms before commencement of data collection.

Study outcomes

The primary outcome for this study was 'ECC effectiveness'. This was measured as 'CPR score' (CS), a composite measure of CPR effectiveness devised by Laerdal™ based on internationally accepted criteria and associated definitions (3). The CS is a manikin-based measure produced by an accelerometer mechanism: it is a composite measure of CPR performance which converts the effectiveness of ECC into a percentage by combining individual measurements of compression depth, rate, release, hand position and number of compressions per cycle into a specific algorithm. The details of the CS composition are available at http://cdn.laerdal.com/downloads-test/f3784/Att_2_to_00021778.pdf

Study process and data collection

Following the provision of consent, each participant was required to perform three periods of ECC in different conditions, each of three minutes duration on a Laerdal™ simulation manikin using standard ECC technique in line with ILCOR guidelines. Period 1 (ground ECC) involved performing ECC on a manikin positioned on a stable hard floor surface. Period 2 (extrication ECC) involved performing ECC on a manikin lying on a moving DHS™ ambulance stretcher positioned at full height, pushed by another student at walking speed along a predetermined route along a flat pathway. Period 3 (transport ECC) involved ECC on a manikin placed on a DHS™ ambulance stretcher locked in position in the back of a moving ambulance travelling at a maximum speed of 40 km/h along a predetermined route around the university campus road system.

To mitigate the risk of ECC-induced fatigue potentially affecting the results of each ECC data collection period, participants were required to have a rest and recovery period of at least 15 minutes between performances. Additionally, participants did not complete periods 1, 2 and 3 in an ordered sequence; they pragmatically completed the three periods in varying order according to availability of resources and research assistants at the time of data collection. The majority of participants completed the three periods of ECC in two sessions over several days. Immediately following each individual participant's period of data collection, ECC performance data (the CS) was exported from the Laerdal Simpad device to an Excel spreadsheet, before being imported into Stata Version 13 (Stata Corporation) for statistical analysis. Participants, data collectors nor the statistician were blinded to the study aims, outcomes or data.

Sample size

As the study was a pilot study with an aim to assess feasibility of a larger, appropriately powered trial, no formal sample size calculation was performed. A pragmatic sample size of 30 participants was set in order to ensure validity of the planned statistical comparisons. This approach was adopted as there was insufficient data in existing literature on which sample size calculations could be performed.

Data analysis

Descriptive statistics were generated for participant demographics and for the primary outcome of compression score (CS) expressed as a percentage measure, presented as mean with standard deviation. Differences between the three phases were assessed using one-way ANOVA and Kruskal-Wallis tests for parametric and non-parametric distributions, respectively. Statistical significance was established at $\alpha = 0.05$.

Ethics approval

Approval to conduct the study was granted by the Western Sydney University Human Research Ethics Committee (H10936).

Results

Following promotion and recruitment activities, 33 student paramedics agreed to participate in this pilot study. Of these, 31 completed at least one ECC period, and 27 completed all three periods. Three participants were unable to attend any of the scheduled data collection days, and three withdrew after completing one period of data collection. Only data from the 27 participants who completed all three periods of ECC were included in the final analysis.

For the primary outcome, ECC performed on a hard floor surface produced the highest CS (89%; IQR 46), followed by ECC performed in the moving ambulance (54%; IQR 40)

(Table 1). Extrication ECC performed on the moving ambulance stretcher was least effective (CS 0%; IQR 14). The difference in CS across these three ECC conditions was statistically significant ($p=0.001$); the magnitude of the values suggest these differences would be clinically significant.

Statistically significant differences were seen across the three ECC conditions for all individual variables contributing to the overall CS except for the proportion of compressions with full release ($p=0.13$) (Table 1).

Discussion

This prospective cohort study contributes new knowledge to the field of out-of-hospital resuscitation research in that it is the only study comparing ECC across all three conditions under which paramedics may be called on to perform ECC (ie. on the floor, during extrication/loading and during ambulance transport). It suggests that manual ECC performed during extrication and loading is essentially futile, and when performed during ambulance transport, highly ineffective. It also suggests that retention of basic ECC skills may be less than optimal among this cohort of student paramedics. The overall findings are consistent with those previously reported in manikin-based simulation studies and human observational studies, which consistently demonstrate ineffectiveness of either ECC alone or CPR (ECC plus ventilations) when performed in situations other than on a flat floor surface (4–6). The results of the extrication period confirm what one would intuitively expect: ECC during this period is essentially futile. While research in emergency department settings has investigated the impact of varying stretcher heights on effectiveness of ECC, the impact of movement of the stretcher as would be required during loading of a patient in the out-of-hospital setting is less well described. Lei et al performed a randomised crossover trial in which medical students performed CPR either on the floor or on a stretcher while straddling a manikin (7). They reported that CPR quality did not decrease when performed by a person straddling the patient on the stretcher.

Table 1. Comparison of CS and contributing variables for each phase of ECC (n=27)

Predictor variable	Floor ECC (median, IQR)	Extrication ECC (median, IQR)	Transport ECC (median, IQR)	p-value
Compression score (%)	89 (46)	0 (14)	54 (40)	<0.001
Flow fraction (%)	99 (1)	94 (69)	100 (1)	<0.001
Compressions with correct hand position (%)	100 (0)	96 (18)	100 (5)	0.06
Compressions fully released (%)	37 (88)	93 (82)	59 (69)	0.13
Compressions deep enough (%)	93 (70)	0 (0)	41 (73)	<0.001
Compressions with adequate rate (%)	98 (82)	38 (30)	86 (26)	<0.001
Rate of all compressions (/min)*	113 (12)	101 (19)	113 (10)	<0.001
Compression depth (mm)	54 (14)	24 (20)	48 (15)	<0.001

* Mean (standard deviation [SD]), p-value from ANOVA. All other p-values for non-normal variables calculated using Kruskal-Wallis equality-of-populations rank test

IQR=interquartile range; ECC=external chest compressions

In a similar study, Kim et al conducted a simulation-based cross over randomised controlled trial comparing two-person CPR on the ground to when performed in a non-straddling position on a moving stretcher (8). The participant performing compressions for 3 minutes was walking alongside the stretcher that was 90 cm in height, essentially the same technique and stretcher height as in this present study. They found major decreases in the percentage of compression performed correctly and in depth of compressions for those performed on the moving stretcher. That study also reported CPR data from two performers, as a two-person team was built into the design, with performers swapping from compressions to ventilations after 3 minutes, providing data across a 6-minute span. The present study involved a single person performing ECC without ventilation for 3 minutes, reducing the ability to directly compare results. While frequently seen in fictionalised media, the straddling CPR on a moving stretcher tested in the study by Lei et al is not permitted in Australian ambulance service jurisdictions due to the risk of harm to the paramedic performing the compressions, so walking alongside the stretcher as in the present study and that by Kim et al is the method most likely to be performed in real clinical practice. While the present study used a composite score not reported by Kim et al, the end result of severely compromised ECC makes for good comparison.

On the surface, these current data could be seen to add weight to the argument supporting the implementation of mechanical chest compression devices as a solution to ensuring quality continuous compressions during extrication, loading and subsequent transport. However, with multiple studies including meta-analyses unable to demonstrate survival benefits arising from the use of mechanical chest compression devices compared to conventional ECC, the widespread implementation of such devices remains uncommon and potentially infeasible from a health economic perspective in many ambulance services (9–11). Hence, the need to perform manual ECC during these periods remains a relevant area of investigation. These present findings are further evidence that attempts to extricate and load a patient in cardiac arrest on whom ECC are being performed should be delayed where at all possible until the return of spontaneous circulation (ROSC) has been achieved.

The quality of ECC deteriorated significantly during the 'transport ECC' period, a finding again consistent with the body of literature describing performance of CPR in the back of a moving ambulance. While not exactly futile, our data suggests that ECC performed in this setting would result in predominantly ineffective compressions, and would therefore not be contributing to the likelihood of greater chance of survival if extrapolated to a real clinical context. Effectiveness of CPR or ECC while in a moving ambulance has been studied extensively in simulation-based research and observational

studies (12–16). All have produced consistent findings indicating that this should be avoided wherever possible. In the absence of a mechanical chest compression device being in situ, a loss of circulation (pulse) during transport should result in the ambulance being stopped immediately so as to enable performance of effective ECC until ROSC occurs. With the knowledge that high quality, continuous ECCs are at the core of successful resuscitation efforts (17) and that ECC during transport is almost certainly less than therapeutic in quality as demonstrated in this present study, continuing on and attempting to provide ECC en route would have to be considered detrimental to the clinical needs of the patient. While the floor phase yielded the highest average compression score (89%), this was below recommended guidelines for what would be considered high quality CPR. This was an unexpected result given the participants were fit and healthy student paramedics who had completed ECC training that incorporated the use of feedback devices less than 1 year before the study commencing. The mean compression score of 89% would be considered less than optimal ECC and would have been detrimental to likelihood of patient survival if being performed on a real patient. There is no clear explanation for the lower than expected floor phase performance. The manikins used in the study were regularly serviced and maintained and were all in appropriate working order at the time the study commenced, as were the handheld devices on which the data were recorded. An explanation to be considered is that teaching of ECC to the students was inadequate, and that participants entered the study with a less than optimal ability to perform ECC. This could flag a need for the university program in which the students study to reassess the teaching of ECC at the undergraduate level. However, all participants were at a point in their course of study at which their performance had been assessed under examination conditions earlier in the program, with participants deemed to be of satisfactory standard. Finally a skill-retention issue could be at the core of this finding; they may have been originally taught well, but were not exposed to ongoing opportunities to regularly perform ECC as their study progressed. This phenomenon of skill depletion has been reported widely in studies of students and health professionals in live and simulated clinical settings (18–20).

Limitations

There are several limitations that must be considered when analysing the data presented in this study. The observational, non-randomised design of the study inherently introduces the prospect of bias. A randomised trial design was not used as such a study was beyond the capacity of the research team, which was functioning within the context of a student research capacity-building initiative and therefore restricted in terms of funding and logistics.

An inability to blind participants to the setting in which they were performing each of the three period of compressions may introduce bias into the results. The absence of blinding makes the study vulnerable to the risk of a participant or participants performing compressions with varying effort depending on which period of compressions was being undertaken in order to influence study outcomes. This risk was unable to be mitigated, as the nature of the interventions in the study made blinding impossible.

There may have been a degree of 'intra-group' variability in the stretcher and driving periods as it was not possible to ensure the speed of the stretcher and ambulance were identical for all participants. This could impact on the quality of compressions for each participant and therefore serve as a confounder to the overall group result, however it was a variable we could not adjust for so it remains a limitation without mitigation. Additionally the project was designed as a pilot study with the aim of generating data that could be subsequently used to inform design and scope of a larger clinical trial on the same topic should a funding opportunity come to fruition. A further limitation leading on from this is the small sample size, again largely due to the pilot study context of the study. This leads to the study being underpowered, and therefore at risk of type II error in the analysis. The results must therefore be viewed as hypothesis generating, rather than as definitive outcomes on which change in practice could be implemented. The study was single centre in its recruitment, so the results from this cohort of student participants should be extrapolated to other student or clinician populations with caution. The study originally aimed to recruit students from several similar institutions to increase external validity, however this approach to recruitment proved unsuccessful, leading to a reversion to a single centre design. Finally, the study was conducted in a simulation context, which limits the ability to generalise to 'live' clinical settings. However, as performing this type of experimental research on human patients would most likely be ethically unsound, manikin-based simulation research such as this study provides valuable data that otherwise could not be achieved.

Conclusion

The circumstances in which CPR is performed in the out-of-hospital setting significantly impacts the quality of ECC. Performance of ECC during extrication and loading, and during road transport in an ambulance appears to be futile and predominantly ineffective, respectively. Paramedics should consider these findings when deciding to move or transport patients before return of spontaneous circulation, or when a patient being loaded or transported reverts to cardiac arrest. Lower than expected CS on hard ground surfaces may indicate a need to review teaching of ECC in this cohort of students, or

consideration of embedded strategies aimed at minimising skill deterioration across the duration of an undergraduate degree program.

Acknowledgements

This study was funded by a Catalysing Innovative Learning and Teaching grant from the School of Science and Health, Western Sydney University, Australia. The study was conducted by a team of undergraduate student investigators under the supervision of post-doctoral researchers as part of the [removed for blind review], a student research engagement and capacity building initiative. The authors would like to thank Mr Pieter Fouche for his assistance with biostatistical analysis.

Conflict of interest

The authors of this paper declare no competing interests.

References

1. Idris AH, Guffey D, Aufderheide TP, et al. The relationship between chest compression rates and outcomes from cardiac arrest. *Circulation* 2012;125:3004–12.
2. Wik L. Rediscovering the importance of chest compressions to improve the outcome from cardiac arrest. *Resuscitation* 2003;58:267–69.
3. Berg R, Hemphill R, Abella B, et al. Part 5: Adult basic life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular care. *Circulation* 2010;122:S685–705.
4. Tweed M, Tweed C, Perkins G. The effect of differing support surfaces on the efficacy of chest compressions using a resuscitation manikin model. *Resuscitation* 2001;52:179–83.
5. Lewinsohn A, Sherren P, Wijayatilake D. The effects of bed height and time on the quality of chest compressions delivered during cardiopulmonary resuscitation: a randomised crossover simulation study. *Emerg Med J* 2012;29:660–8.
6. Soppi E, Iivanainen A, Sikanen L, Jouppila-Kupiainen E. Performance of different support surfaces during experimental resuscitation (CPR). *Heliyon* 2016;19:e74.
7. Lei Z, Qing H, Yaxiong Z. The efficacy of straddling external chest compression on a moving stretcher. *Resuscitation* 2010;81:1562–5.
8. Kim JA, Vogel D, Guimond G, Hostler D, Wang HE, Menegazzi JJ. A randomized, controlled comparison of cardiopulmonary resuscitation performed on the floor and on a moving ambulance stretcher. *Prehosp Emerg Care* 2006;10:68–70.

References (continued)

9. Bonnes JL, Brouwer MA, Navarese EP, et al. Manual cardiopulmonary resuscitation versus CPR including a mechanical chest compression device in out-of-hospital cardiac arrest: a comprehensive meta-analysis from randomized and observational studies. *Ann Emerg Med* 2016;67:349–60. e3.
10. Gates S, Quinn T, Deakin CD, Blair L, Couper K, Perkins GD. Mechanical chest compression for out of hospital cardiac arrest: systematic review and meta-analysis. *Resuscitation* 2015;94:91–7.
11. Tang L, Gu W-J, Wang F. Mechanical versus manual chest compressions for out-of-hospital cardiac arrest: a meta-analysis of randomized controlled trials. *Sci Rep* 2015;5:18415.
12. Stone CK, Thomas SH. Can correct closed-chest compressions be performed during prehospital transport? *Prehosp Dis Med* 1995;10(02):121–3.
13. Thomas SH, Stone CK, Bryan-Berge D. The ability to perform closed chest compressions in helicopters. *Am J Emerg Med* 1994;12:296–8.
14. Stapleton ER. Comparing CPR during ambulance transport. Manual vs. mechanical methods. *JEMS* 1991;16:63–4, 66, 68 passim.
15. Havel C, Schreiber W, Riedmuller E, et al. Quality of closed chest compression in ambulance vehicles, flying helicopters and at the scene. *Resuscitation* 2007;73:264–70.
16. Olasveengen TM, Wik L, Steen PA. Quality of cardiopulmonary resuscitation before and during transport in out-of-hospital cardiac arrest. *ibid.* 2008;76:185–90.
17. Perkins GD, Travers AH, Considine J. Part 3: adult basic life support and automated external defibrillation: 2015 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. *ibid.* 2015;95:e43–70.
18. Riegel B, Nafziger SD, McBurnie MA, et al. How well are cardiopulmonary resuscitation and automated external defibrillator skills retained over time? Results from the Public Access Defibrillation (PAD) Trial. *Acad Emerg Med* 2006;13:254–63.
19. Behrend T, Heineman J, Wu L, et al. Retention of cardiopulmonary resuscitation skills in medical students utilizing a high-fidelity patient simulator. *Med Student Res J* 2011;1:1–4.
20. Smith KK, Gilcreast D, Pierce K. Evaluation of staff's retention of ACLS and BLS skills. *Resuscitation* 2008;78:59–65.