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Clinical paper

Use of transoesophageal echocardiography in the pre-hospital setting to determine compression position in out of hospital cardiac arrest

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Abstract

Background: A proportion of patients due to anatomical variation do not receive chest compressions over the left ventricle. Transoesophageal echocardiography (TOE) has the potential to impact survival rates by identifying the area of maximal compression (AMC), potentially improving forward flow and systemic perfusion in cardiac arrest. There is a paucity of data regarding the use of TOE during out of hospital cardiac arrest (OHCA) in the pre-hospital setting, with most data coming from studies performed in hospital. We therefore set out to retrospectively review patients who had received TOE as part of their resuscitation care by a pre-hospital medical team.

Methods: A retrospective cohort study of OHCA patients treated by a specialist pre- hospital medical team who had received TOE as part of cardiac arrest management. Patients were identified over a 6-month period and their medical records reviewed. The primary outcome was to identify the proportion of patients in whom the AMC was not over the LV. The secondary outcomes were to describe the proportion of patients where information provided by the TOE clinically influenced patient management; to describe the temporal relationship between change in compression position and change in clinical findings including timing of ROSC or change in rhythm and to describe any associations between the AMC and physiological signs.

Results: Nineteen patients were identified who had received TOE as part of cardiac arrest management over a 6 month period. Intra-arrest TOE identified 17 (89%) patients in whom compressions were not being performed over the left ventricle. Improved echocardiography evidence of left ventricular compression occurred in 13/17 (76%) patients, resulting in return of spontaneous circulation in 6 patients and change in rhythm in 10 patients. TOE was able to change management or confirm diagnosis in 17/19 (89%) patients.

Conclusions: We present a retrospective cohort study of 19 patients who received pre- hospital intra-arrest TOE. Pre-hospital intra-arrest TOE is feasible and contributed significantly to optimising compression position to increase forward flow without interrupting chest compressions. Future studies are needed to correlate clinical findings with compression position as identified on TOE.

Keywords: Transoesophageal echocardiography, Advanced cardiopulmonary resuscitation, Out of Hospital Cardiac Arrest, Pre-hospital, Resuscitation

Introduction

Current cardiac arrest guidelines recognise the utility of point of care transthoracic echocardiography (TTE) during cardiac arrest to assist with the identification of reversible causes noting the potential for harm if chest compressions are interrupted and recommending that the use of TTE during resuscitation be carefully considered against the risk of interrupting chest compressions and ideally performed with compressions ongoing.[1,2] Common practical and physiological variables associated with cardiac arrest, including position of defibrillation pads, obesity and gastric distension, make it challenging to attain adequate acoustic windows when TTE is used. Furthermore, interruption of chest compressions invariably occurs, potentially delaying compressions for up to 21 seconds[3,4] and introducing the potential for harm as a result.[5]

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Resuscitation councils advise placement of the hands in the lower half of the sternum whilst recognising there is weak evidence to support this recommendation.[6] In theory, cardiopulmonary resuscitation (CPR) is thought to promote forward flow through one of two mechanisms, either through direct ventricular compression to simulate cardiac ejection and generate cardiac output, or via the thoracic pump mechanism which stimulates venous return.[7]

Radiological studies have demonstrated that in 46–80% patients, the left ventricle (LV) does not consistently sit in the "middle of the chest". In a proportion of patients, the left ventricular outflow tract (LVOT), aortic root or ascending aorta may be in that location.[8,9] For these patients, application of compressions runs the risk of obstructing the outflow tract of the heart, rendering CPR ineffective from the outset with significant limitations to forward flow. Multiple studies using cardiac ultrasound during cardiac arrest have demonstrated LVOT obstruction in greater than 40% of patients with standard compressions due to anatomical variation.[10,11]

The use of transoesophageal echocardiography (TOE) can overcome some of these problems with a superior acoustic window that is not subject to patient factors and provides continuous imaging without the requirement to repeatedly re-locate the acoustic window during a pulse check. Transoesophageal echocardiography has the potential to impact survival rates through its ability to identify the area of maximal compression (AMC), potentially improving forward flow and systemic perfusion in cardiac arrest. In addition to guiding compression placement, TOE has been demonstrated to find the cause of the arrest in 41% of patients[12] and can be used to confirm rhythm.

Most TOE data for cardiac arrest is from studies performed in hospital. There is a paucity of data regarding the use of TOE during out of hospital cardiac arrest. We therefore set out to retrospectively review patients who had received TOE as part of their resuscitation care, identify the proportion of patients where the area of maximal compression was not occurring over the left ventricle and assess any temporal physiological changes that occurred with TOE guided compression position.

Methods

Standard operating procedure

A medical cardiac arrest team as part of New South Wales Ambulance (NSWA) attends approximately 7–10 cardiac arrests per week and provides advanced cardiac resuscitation interventions including extracorporeal cardiopulmonary resuscitation (ECPR), invasive arterial line monitoring and transoesophageal echocardiography. The team is targeted towards cardiac arrest patients under the age of 70 years and thought to be a witnessed collapse in the greater Sydney area of New South Wales, Australia. If a patient is deemed ineligible for ECPR but suitable for continued resuscitation, advanced interventions and diagnostics including femoral arterial line access, resuscitative TOE and point of care testing to assist with paramedic advanced life support (ALS) management are performed.

Patient population

This was a retrospective cohort study using a convenience sample, selected among cases of OHCA patients attended by the medical cardiac arrest team when a TOE operator was available. Patients were identified over a 6-month period and their medical records reviewed. No data were available to inform a sample size calculation. Patients under the age of 18 or who were not in cardiac arrest when the TOE was performed or who received extracorporeal cardiopulmonary resuscitation (ECPR) were excluded, as were patients in cardiac arrest attended by the medical team without a credentialled TOE operator.

Resuscitative TOE image acquisition

Routine practice involves TOE probe insertion after endotracheal intubation and is performed by an experienced clinician with post graduate qualifications in TOE. Whilst there was no predefined protocol, all patients were treated by a single clinician in a similar fashion described below. A focused resuscitative TOE study is performed using the GE healthcare Venue Go^{TM} ultrasound machine. Resuscitative TOE is used to identify the area of maximal compression and enhance the delivery of chest compressions, to distinguish between low flow PEA and true PEA, asystole and fine VF and to attempt to identify the cause of the arrest. As such, the following standard views: mid-oesophageal long axis (ME LAX); mid-oesophageal two-chamber (ME 2C), mid-oesophageal four chamber (ME 4C) and transgastric short axis (TG SAX) are attained if possible. Time-stamped image loops are captured at baseline, and before and after any intervention. Additional views are obtained if clinically indicated. Based on the echocardiographic findings, the TOE clinician would instruct a change in compression position under TOE guidance. If change in compression position is required, the standard approach is to remove a mechanical CPR device if insitu and return to manual chest compressions until the optimal location for compressions is identified. If a change in compression position or management does occur, this is usually documented as an intervention in the patient's pre-hospital medical record as is standard practice when diagnostic imaging is used to guide an intervention in our service.

Assessment of the area of maximal compression

The primary use of TOE by the medical cardiac arrest team was to assess the AMC and optimise CPR. The AMC is defined as the area of the heart that is receiving the greatest anteroposterior compression (diameter shortening during compressions). This was routinely assessed by obtaining the ME LAX and ME 2 chamber view and by visual inspection. In addition to anteroposterior diameter shortening, other echocardiographic features of adequate LV compression were also assessed including: mitral and aortic valve opening during and the absence of compression of structures that were not the left and right ventricle.

Data acquisition

Standard monitoring is undertaken using the Zoll x series monitor (Zoll medical corporation, Tokyo, Japan), and includes: end tidal CO2 waveform capnography (mmHg), SpO2, ECG, invasive arterial blood pressure (mmHg). Monitoring is applied as per usual practice by the medical team and a monitor print out of this record is routinely attached to the patient's medical record at the end of the patient encounter, this records observations every two minutes. Key timings including time of collapse, dispatch of team, arrival of team and departure of team are routinely recorded on the case sheet.

A copy of the patient's case sheet, monitor print out and an electronic database entry are all stored on the NSWA Aeromedical database. All resuscitative TOE study loops are recorded and stored on machine hard drive with the TOE study loops exported and uploaded to be associated with the patient's medical record. All TOE loop recordings are time stamped. In addition, TOE loop acquisition and recording occurred before and after interventions such as re-positioning compression position or when pathology was identified. As part of standard medical documentation, the findings of the TOE are recorded in the patient's pre-hospital medical record with specific information pertaining to the area of maximal compression, any cardiac pathology identified, and any intervention performed as a result of the TOE findings.

The study has been approved by the SLHD research and ethics and governance office: X23-0150.

Data collection

Baseline demographic data that are routinely collected included: gender, age, presenting rhythm and witnessed arrest were identified from the patient's medical record. The following physiological variables were identified where available: invasive arterial pressure, continuous waveform capnography (ETCO2), rhythm, presence of brachial pulse, change in compression position and time of ROSC. Where available, physiological variables were identified and retrospectively correlated to three different time points during the resuscitation and TOE image acquisition by correlating the TOE image loops with the patient's monitored print out and case note documentation:

1. Baseline observations prior to the TOE being performed
2. At the time of TOE image acquisition
3. After a change to CPR delivery has occurred as determined by the medical record documentation

The TOE images were reviewed by a cardiac anaesthetist with over 10 years of TOE experience and they were asked to identify the area of maximal compression (AMC). Retrospective image interpretation was then correlated with the findings described during the active resuscitation. Disagreement was addressed by discussion and consensus.

Primary outcome

The proportion of patients in whom the AMC was not over the LV defined as either an absence of left ventricular compression, compression of the LVOT, aortic root or both as evidenced by transoesophageal echo findings.

Secondary objectives

1. To describe associations between the AMC and physiological signs including:
   a) the presence of a brachial pulse: as palpated 1–2 cm medial to the biceps tendon, 2–3 cm proximal to the cubital fossa
   b) the level of end-tidal carbon dioxide.
   c) the presence of a pulsatile invasive arterial waveform when sited.
   d) the presence of ROSC as evidenced by a palpable pulse and cessation of CPR.
   e) change in rhythm from non-shockable to shockable.
   f) Cardiopulmonary resuscitation induced consciousness or signs of life whilst CPR is ongoing.
2. To describe the temporal relationship between change in compression position and change in clinical findings including timing of ROSC or change in rhythm.
3. To describe the number of patients where information provided by the TOE clinically influenced patient management.
4. As part of an exploratory analysis, review the relationship between documented chest compression position and the TOE findings.

Data analysis

Due to lack of prior data no information was available on which to base a sample size calculation. Simple descriptive statistics were used. As data were non-parametric, they were described as median and interquartile ranges (IQR). Paired Wilcoxon signed rank test was used to evaluate differences in end tidal CO2 concentration before and after intervention. P values should be interpreted with extreme caution due to small sample sizes.

Results

Over a six-month period (April-October 2024), the medical cardiac arrest team were dispatched to 172 cases including 55 cardiac arrests. Of the 55 patients, four patients received pre-hospital ECPR and were excluded. In the remaining 51 patients, TOE was not performed due to a) provider not credentialed to perform TOE ($n = 8$) b) ongoing resuscitation attempts deemed to be futile ($n = 10$) c) Patients were either not in cardiac arrest ($n = 6$) or ROSC was achieved prior to the team's arrival ($n = 8$). Overall, a TOE study was performed in 19 patients (Fig. 1).

Patient demographics of all arrests attended by the medical team and broken down by those where TOE was completed are reported in Table 1. The median age of all patients ($n = 55$) was 54 years, 34 patients (70%) were male, 21 (41%) patients had an initial shockable rhythm, 6 (11%) patients were not in cardiac arrest and 22 (43%) patients were in a non-shockable rhythm with no signs of life on attendance of the first crew (Table 1).

Of the 19 patients who received TOE guided resuscitation; twelve were male (63%), with median age of 55 years old (interquartile range [IQR] 48–65) and an estimated median weight of 90 kg (IQR 73–90). The presenting rhythm was ventricular fibrillation (VF) in twelve patients, four patients had asystole and three patients had pulseless electrical activity (Table 1). All patients had mechanical CPR devices being utilised at the time of medical team arrival. The defined standard views used for resuscitative TOE in this setting were able to be attained 100% of the time. On the arrival of the medical team, nine of the patients with VF had degenerated into a non-shockable rhythm. The presence of a brachial pulse on arrival of the medical team was documented in 17/19 patients (89%) (Table 2). The median time to TOE image acquisition from time of collapse was 38 min (IQR 30–45). The median time from team arrival to initiation of TOE study was eleven mins (1–28 mins). All compressions being performed prior to the commencement of TOE were as per Australian Resuscitation council guidelines.

Post hoc analysis of intra-arrest TOE identified 17 (89%) patients in whom compressions were not being performed over the left ventricle (Fig. 2). In nine patient's chest compression occurred directly over the left ventricular outflow tract or the aortic root, in three patients only the right ventricle was compressed, and in three patients there was ineffective LV compression. One patient had no LV compression due to chest wall rigidity; this was not improved despite changing the area of maximal compression (AMC). Initial compressions being performed over the LV occurred in 2 patients and no changes to the AMC were made. There was 100% agree-

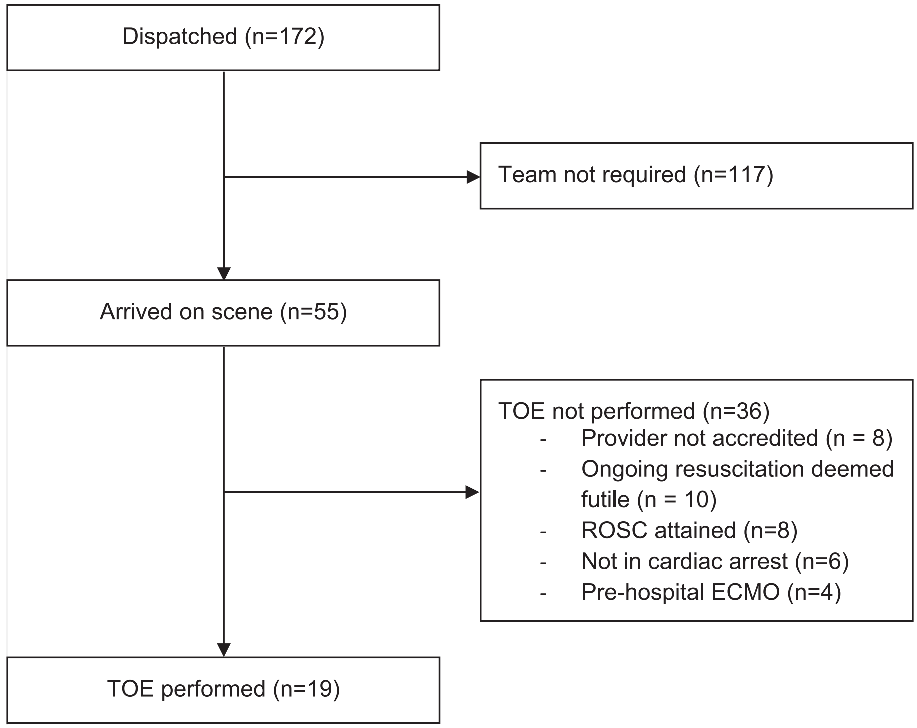

Fig. 1 – Study enrolment.

Table 1 – Demographics for all cardiac arrest patients treated by the medical cardiac arrest team.

	TOE (N = 19)	No TOE (N = 32)	P value	All arrests excluding ECPR (N = 51)
Age (median: IQR)	55 (47–65)	55 (50–64)	0.817	54 (44–68)
Gender (male) (n:%)	12 (63%)	22 (69%)	0.813	34 (68%)
Initial Shockable rhythm (n:%)	12 (63%)	12 (38%)	0.138	24 (47%)
Initial non-shockable rhythm: PEA no SOL/Asystole (n:%)	7 (37%)	20 (62%)	0.138	27 (53%)
PEA with SOL	0	1	0.606	1 (0.1%)
Witnessed collapse (n:%)	15 (79%)	17 (53%)	0.065	32 (63%)
Bystander CPR (n:%)	19 (100%)	32 (100%)		51 (100%)

PEA: Pulseless electrical activity, SOL: signs of life, TOE: transoesophageal echocardiography.
*incomplete data set.

ment when identifying the area of maximal compression between the interpretation of the TOE images during active resuscitation and the post hoc interpretation by a second, experienced TOE operator.

The final compression position was documented and recorded in the patients notes in all cases. Transoesophageal echo guided compression optimization shifted the AMC on the surface of the chest wall generally towards the left of sternum and towards the apex. The repositioning resulted in reporting of adequate echocardiography evidence of LV compression in 13/17 (76%) patients. These were visual estimations only. Three additional patients still had inadequate LV compression despite adjustment. Median time taken to adjust AMC was 3 min (IQR 2–4 min).

Return of spontaneous circulation (ROSC) was achieved in seven patients. In six of those patients, ROSC occurred after compression position change. Change of rhythm occurred in ten patients when the compression position was guided with TOE, rhythm changes included VF to ROSC (n = 2) after defibrillation, asystole into a low flow PEA (n = 2), asystole into ROSC (n = 5), asystole into VT (n = 1). Four patients were identified as being in a low flow state (ventricular contraction on TOE with no palpable blood pressure) and two patients had a large embolus identified in the main pulmonary artery, two patients monitored in VF but were in cardiac standstill on echo imaging. Seventeen patients were identified where TOE assisted in improving the compression position (n = 13) or distinguishing low flow PEA from cardiac standstill (n = 4) and redirected treatment. Invasive arterial blood pressure monitoring only occurred in 8 out of 19 patients and therefore no analysis was undertaken looking at this physiological variable.

Discussion

To our knowledge, this is the largest study of patients with out of hospital cardiac arrest receiving pre-hospital transoesophageal echocardiography reported in the literature. Management changes as a result of TOE findings occurred in 89% of patients where the compression position was not over the LV or the TOE was able to differentiate between a low flow state and cardiac standstill.

Table 2 – Break down of compression position as seen during intra-arrest TOE.

N = 19	AMC over the LV		AMC over the aortic root/LVOT		AMC over the RV only		Compression depth not adequate		Compression position change: AMC over LV	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
N (%) patients	4 (21%)		9 (47%)		3 (16%)		3 (16%)		16 (16%)	
Presence brachial pulse	1 (5%)	2 (10%)	1 (5%)	7 (37%)	1 (5%)	3 (16%)	0	3 (16%)	3 (16%)	14 (77%)
Median ETCO2	27 (24–33)	33 (25–58)	54 (45–80)	44 (40–60)	50 (28–90)	54 (52–60)	25 (23–46)	40 (35–43)	46 (28–69)	48 (39–60)
P value *	0.79		0.40		1.00		0.25		0.98	
Rhythm change	n/a		n/a		n/a		n/a		10 (53%)	
ROSC at any time	n/a		n/a		n/a		n/a		7 (37%)	

Pre = clinical findings prior to compression position change.
Post = clinical findings after compression position change.
AMC = area of maximal compression
LVOT: left ventricular outflow tract.
LV = left ventricle.
RV = Right ventricle.
n/a = ROSC or rhythm change did not occur in the absence of compression position change and is therefore only reported in the final column.
* P value for median end tidal CO_2.

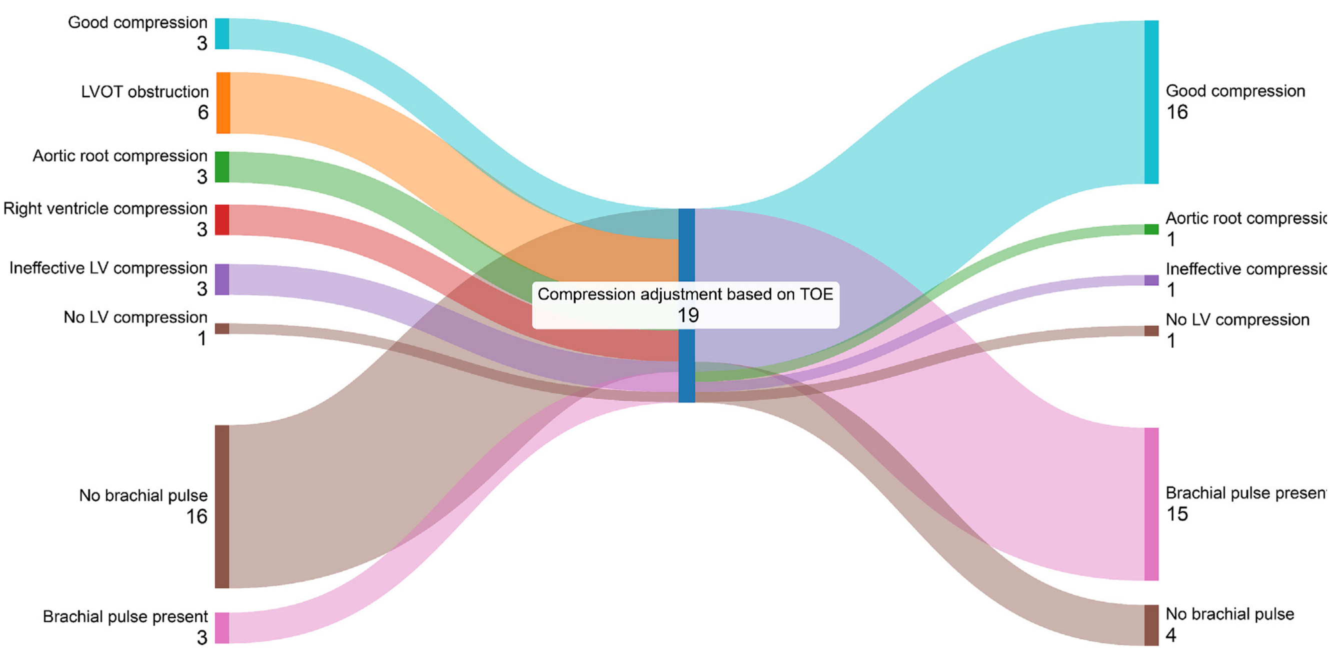

Fig. 2 – Pre and post compression repositioning. Sankey diagram demonstrating patient characteristics (chest compression quality and presence/absence of brachial pulse) before TOE (left), whether chest compression changed based on intra-arrest TOE image acquisition, and effect on chest compression and brachial pulse thereafter.

The application of TOE in the pre-hospital setting provides the opportunity to guide compression position in real time and maximise stroke volume in the early stages of cardiac arrest whilst maintaining high quality chest compressions. Echocardiographic findings of adequate CPR include LV compression and absence of LVOT/aortic root compression.[13] The ME LAX and the ME 4 chamber view are the most valuable for determining both compression effectiveness and the area of maximal compression.[14]

Our findings are consistent with previous publications describing the use of intra-arrest TOE in the hospital setting. In a prospective observational study of 34 patients receiving TOE during cardiac arrest the AMC was reported to be located over the aorta in 59% of patients and the LVOT in 41% patients.[10] This is further supported by the work of Teran et al (2024) reporting data from a multicentre registry of 916 patients, 278 OHCA patients received intra-arrest TOE, only 28% of OHCA patients had the initial AMC over the left ventricle with chest compression position modified in 25% of OHCA patients.[15]

The efficacy of intra-arrest TOE in optimising chest compressions has been demonstrated in several studies[13] with an association between TOE determined AMC and ROSC.[11,13,16] Of note we identified, 7 out of 16 patients achieved ROSC once compressions were positioned over the LV. In addition, small studies have demonstrated an association between LVOT compression and reduced ROSC rate.[13,16] Swine models have demonstrated the impact on haemodynamic variables when compressions are performed over the left ventricle. Compressions over the LV were associated with a higher ROSC rate and an increase in haemodynamic variables with an increase in end tidal CO2, mean arterial blood pressure and cerebral blood velocity.[17]

Given the nature of this study, it was not possible to study any association between physiological variables and compression position. Future prospective studies with comparator groups (ideally randomised) are required. However, we have demonstrated that pre-hospital TOE is feasible and can be successfully integrated into pre-hospital cardiac arrest workflow, in a time frame where the intervention may impact on outcome. Understanding the clinical indicators of effective forward flow will enable pre-hospital clinicians to more effectively deliver CPR irrespective of the use of TOE. This includes examining an association between brachial pulse, ETCO2, colour, rhythm and Sp02 trace with effective LV compression. To our knowledge, there are limited human studies which have correlated haemodynamic clinical findings with the area of maximal compression during CPR. For this reason, we are planning to conduct a prospective observational study to further explore the efficacy of pre-hospital TOE in OHCA.

Limitations

This was a retrospective cohort study of patients in whom data was collected and reviewed retrospectively and as such, the results potentially affected by recall bias, missing data and the accuracy of record keeping. In addition, as with all observational research, the study is subject to misclassification and confounding bias. Resuscitative TOE studies were performed and interpreted by a single experienced cardiac anaesthetist, which is consistent with routine clinical practice however reduces the external validity of the study and since no blinded assessment of the TOE loops was performed, the interpretation of these loops could be subjective and influenced by the operators expectation, potentially overestimating the effect with regards to compression position change. Moreover, the extent of the compression position change was not formally measured, rather it was a visual estimation which was documented in the patient's medical record. The presence of a brachial pulse post change in compression position is likely impacted by differential misclassification bias as it was not practical to blind the team to TOE findings.

It is hoped that the results of this preliminary observational study and the associations that have been identified, will inform and assist with the design of larger, prospective studies utilising resuscitative TOE for OHCA in the pre-hospital setting. Furthermore, resuscitative TOE was performed by a single clinician with significant experience in TOE however, this makes the findings less generalisable to the larger pre-hospital medical team workforce and the scalability of such an intervention. A direction of future research should include the training of TOE-naïve clinicians to assess compression effectiveness in the OHCA population.

Conclusion

We present a retrospective cohort study of 19 patients who received pre-hospital intra-arrest TOE. Pre-hospital intra-arrest TOE contributed significantly to optimising compression position to increase forward flow without interrupting chest compressions. Future studies are needed to correlate clinical findings with compression position as identified on TOE.

CRediT authorship contribution statement

Natalie Kruit: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ian Ferguson:** Writing – review & editing, Methodology. **Jan Dieleman:** Writing – review & editing, Methodology. **Brian Burns:** Writing – review & editing. **Nicolas Shearer:** Data curation. **David Tian:** Formal analysis, Data curation. **Mark Dennis:** Writing – review & editing, Methodology.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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