

Clinical paper

Resuscitation feedback and targeted education improves quality of pre-hospital resuscitation in Scotland[☆]

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ABSTRACT

Background: Out-of-hospital cardiac arrest (OHCA) is a leading cause of mortality and serious neurological morbidity in Europe. Recent studies have demonstrated the adverse physiological consequences of poor resuscitation technique and have shown that quality of cardiopulmonary resuscitation (CPR) is a critical determinant of outcome from OHCA. Telemetry of the defibrillator transthoracic impedance (TTI) trace can objectively measure quality of pre-hospital resuscitation. This study aims to analyse the impact of targeted resuscitation feedback and training on quality of pre-hospital resuscitation.

Methods: Prospective, single centre, cohort study over 13 months (1st December 2009–31st December 2010). Baseline pre-hospital resuscitation data was gathered over a 3-month period. Modems ($n=40$) were fitted to defibrillators on ambulance vehicles. Following a resuscitation attempt, the event was sent via telemetry and the TTI trace analysed. Outcome measures were time spent performing chest compressions, compression rate, the interval required to deliver a defibrillator shock and use of automatic or manual cardiac rhythm analysis. Targeted resuscitation classes were introduced and all ambulance crews received feedback following a resuscitation attempt. Pre-hospital resuscitation quality pre and post intervention were compared.

Results: 111 resuscitation traces were analysed. Mean hands-on-chest time improved significantly following feedback and targeted resuscitation training (73.0% vs 79.3%, $p=0.007$). There was no significant change in compression rate during the study period. There was a significant reduction in median time-to-shock interval from 20.25 s (IQR 15.50–25.50 s) to 13.45 s (IQR 2.25–22.00 s) ($p=0.006$). Automatic rhythm recognition fell from 50% to 28.6% ($p=0.03$) following intervention.

Conclusion: Telemetry and analysis of the TTI trace following OHCA allows objective evaluation of the quality of pre-hospital resuscitation. Targeted resuscitation training and ambulance feedback improves the quality of pre-hospital resuscitation. Further studies are required to establish possible survival benefit from this technique.

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1. Background

Out-of-hospital cardiac arrest (OHCA) is a leading cause of mortality and serious neurological morbidity in Europe.¹ The incidence of OHCA is 40–60 per 100,000 population every year with survival to discharge rates being variable.^{1,2} Survival from OHCA is dependent on the “chain of survival” and quality of pre-hospital resuscitation is important to achieve return-of-spontaneous circulation (ROSC).

Cardiopulmonary resuscitation (CPR) is vital to maintain cerebral and cardiac perfusion until ROSC can be achieved. The importance of bystander CPR before arrival of emergency medical services has already been widely established. Chest compressions aim to provide some perfusion to vital organs, including the brain and heart, during cardiac arrest, prolonging the time before irreversible ischaemic damage occurs.³ Periods during which chest compressions are not performed result in poor blood flow to vital organs, making successful defibrillation less likely.⁴ Recent studies have demonstrated the adverse physiological consequences of poor resuscitation technique and have shown that quality of CPR is a critical determinant of outcome from OHCA.^{5,6} Time spent performing chest compressions, compression rate and compression depth are all important measures of CPR quality.⁷ Recent evidence suggests an increased hands-on-chest time is associated

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with favourable outcome from OHCA.^{3,6} Endotracheal intubation, establishing intravenous access and patient extrication all interrupt chest compressions.⁸ Neither endotracheal intubation nor administration of resuscitation drugs have been definitively shown to improve survival from OHCA in humans and both can distract from performing continuous chest compressions.^{9,10}

Cardiac rhythm recognition is important during pre-hospital resuscitation. Rhythm recognition can be performed by trained healthcare professionals, including many ambulance crews, or automated cardiac rhythm recognition can be used. Automated rhythm analysis will often take longer than an experienced healthcare professional.^{11,12} The use of automated rhythm recognition can result in decreased hands-on-chest time. The interval between ceasing chest compressions and defibrillation (“time-to-shock”) is important. During OHCA resuscitation with a shockable rhythm, automated rhythm analysis can result in an increased time-to-shock interval. Increased time-to-shock intervals have been shown to decrease the chance of successful defibrillation.^{13,14} Use of defibrillators in manual mode by appropriately trained personnel leads to increased hands-on-chest time and shorter time-to-shock periods.¹²

International standards for monitoring of CPR quality and for uniform reporting of CPR variables are required.¹⁵ Performance of pre-hospital resuscitation by ambulance crews can be measured against current international resuscitation guidelines. Determining the quality of pre-hospital resuscitation performed by ambulance crews in the field is technically difficult but previous studies have reported poor compliance of ambulance crew performance with published guidelines, especially for recommended rate, depth and pauses in chest compressions.^{16,17}

Trans-thoracic impedance (TTI) measurement is a useful, validated tool to assess the quality of pre-hospital resuscitation by ambulance crews.¹⁸ Data on compression rate, hands on the chest time and time to defibrillation can be analysed. Sending the TTI data via telemetry allows instant data transmission post-resuscitation, can be achieved directly from the ambulance and allows remote data access.¹⁹

Ambulance crews receive initial training in performing CPR but receive variable training updates. In our region, ambulance crews receive CPR training approximately once per year. Individual ambulance crews in our region are likely to encounter few OHCA and skill retention can be problematic. CPR training should involve practical resuscitation training as well as theoretical knowledge updates.²⁰

Resuscitation feedback can be given in real-time or after the OHCA event. Post-event feedback allows individual ambulance crews to evaluate their performance. TTI analysis provides objective resuscitation feedback for ambulance crews as well as auditing quality of resuscitation in a region.

Collection of TTI data via telemetry from ambulance service defibrillators has not previously been performed in the UK. The aims of this study were to objectively assess the quality of pre-hospital resuscitation performed by City of Edinburgh ambulance crews over a 3-month period; introduce a monthly resuscitation class and post-event individual resuscitation feedback; and evaluate the impact of resuscitation training and feedback on quality of pre-hospital resuscitation.

2. Methods

2.1. Location

The study took place in Edinburgh City and the Lothians, an area of 259 km² with a population of approximately 500,000. The majority of OHCA occurring in the region are attended by ambulance

crews from Edinburgh City ambulance station and transported to Edinburgh Royal Infirmary.

2.2. Patients

All cases of non-traumatic OHCA in patients aged 16 years or over were included in the study. Ethical permission was sought and gained from the University of Edinburgh Ethics Committee.

2.3. Data collection and analysis

Data on all OHCA are collected in the Utstein format using ambulance electronic patient report forms.

Ambulance crews in Scotland currently use defibrillators capable of manual or advisory defibrillation (Lifepak 12, Physio Control, Redmond, WA). All frontline ambulance and response car defibrillators ($n = 40$) at Edinburgh City Ambulance station were fitted with general packet radio service (GPRS) modems, to allow telemetry transmission of the TTI defibrillator trace to a research computer. The modem case was sealed and did not require any operation by the ambulance crew. All ambulance crew members ($n = 137$) were informed of the installation and detailed instructions on how to transmit the TTI trace were placed on all defibrillators. Transmission of the TTI trace was very similar to sending 12-ECG traces via telemetry, which is familiar practice to ambulance crews. After a resuscitation attempt the attending ambulance crew **was encouraged to** transmit the TTI trace. Ambulance service records were matched by vehicle call sign to ascertain the proportion of all OHCA for which TTI traces were transmitted.

2.4. Data collection and storage

The TTI data packet was sent via GPRS and world-wide web to the LIFENET server (Physio Control, Redmond, WA). The LIFENET server then directed the data packet securely to a receiving computer or multiple receiving destinations. No data was held on the LIFENET server. The data packet was received onto the target computer for analysis. No patient-identifiable data was included in the transmission. Clinical data and individual ambulance crews were matched retrospectively to the date, time of transmission and the individual defibrillator using information obtained from the ambulance dispatch records and electronic patient record forms.

Analysis was performed using proprietary software, CODE-STAT 8.0 (Lifepak 12, Physio Control, Redmond, WA). Traces were reviewed by the research team to identify errors in the automatic annotation and periods of ROSC. Following annotation, the software was used to calculate hands-on-chest time, compression rate and time-to-shock intervals. It was also noted whether cardiac rhythm recognition was performed automatically or by the crew.

2.5. Study period

The study ran for 13 months (1st December 2009–31st December 2010). The first three months (December 2009–March 2010) was used to **capture baseline resuscitation data without introducing new training or feedback**. Post-resuscitation feedback and monthly resuscitation training was introduced in March 2010. Ambulance crews were invited to a one-day resuscitation symposium where several lectures on resuscitation were given by senior clinicians. **Attendance at the symposium was voluntary**. Further information was emailed to all ambulance crews at Edinburgh City ambulance station and displayed on notice boards. Ambulance crews were encouraged to transmit TTI traces after a resuscitation event and attend resuscitation classes **on a voluntary basis**.

The intervention phase took place over the following ten months (March–December 2010). After each OHCA for which a TTI trace was

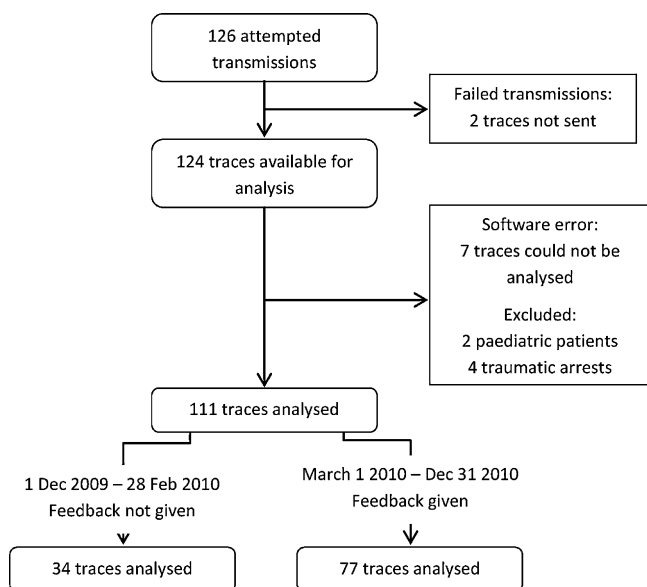


Fig. 1. Summary of data collection and analysis.

received, a resuscitation report was generated, printed and sent to the individual attending ambulance crew. This report contained a graphical representation of the resuscitation attempt and summary statistics including hands-on-chest time and compression rate. A letter from the research team accompanied the report containing targeted feedback and advice on how to improve resuscitation practice. In addition, monthly resuscitation classes were provided for crews to discuss cases and review their TTI traces with senior clinicians and paramedic colleagues. These classes included 'hands-on' refresher training in advanced life support skills.

2.6. Statistical analysis

Data were entered into proprietary software (Excel 2007, Microsoft Corp, Redmond, WA) and statistical analysis performed using specific software (Prism 5, GraphPad, La Jolla, CA). The Shapiro–Wilk test was used to assess the normality of the data. The means of normally distributed continuous data were compared using a two-tailed *t*-test, and a Mann–Whitney *U* test was used to compare non-parametric data. Fisher's exact test was used to compare the method of cardiac rhythm recognition. Categorical variables were compared using Chi square with Yates' correction. Statistical significance was taken as a *p*-value of <0.05.

3. Results

During the study period Edinburgh City ambulance crews attended 289 OHCA. A total of 126 defibrillator traces were sent via telemetry. 2 traces were unable to be sent due to technical error, presumed lack of modem signal. Of the 124 traces successfully transmitted, 7 traces were unable to be analysed due to incomplete TTI data and 6 traces were excluded (2 paediatric OHCA and 4 OHCA of traumatic origin). 111 defibrillator traces were included in the study from 282 OHCA meeting inclusion criteria, resulting in an overall transmission capture rate of 39%. This is shown in Fig. 1. 34 TTI traces were transmitted in the pre-intervention study period and 77 in the post-intervention. A summary of the defibrillator traces received with respective demographic data is shown in Table 1.

Table 1

Demographics of OHCA patients for whom a trans-thoracic impedance trace was sent via telemetry. ROSC: return of spontaneous circulation.

	Pre-intervention (%)	Post-intervention (%)	Significance (<i>p</i>)
Number of traces analysed	34	77	
Sex			
Male	14 (41.2)	51 (66.2)	0.024
Female	14 (41.2)	21 (27.3)	0.22
Unknown	6 (17.6)	5 (6.5)	0.14
Age (mean ± SD)	67 ± 17	64 ± 17	0.34
Initial rhythm			
VF/VT	13 (38.2)	26 (33.8)	0.81
PEA	6 (17.6)	20 (26.0)	0.48
Asystole	15 (44.1)	31 (40.3)	0.86
ROSC pre-hospital	11 (32.4)	31 (40.3)	0.56
Survived to hospital discharge	4 (11.8)	9 (11.7)	0.90

Of the 137 ambulance crew members working in Edinburgh City ambulance station, 94 (69%) attended the symposium or at least one training session. Some personnel attended more than one session.

3.1. Hands-on-chest time

Mean hands-on-chest time improved significantly following the implementation of feedback: (73.0% [95% CI 68.6–77.3] vs 79.3% [95% CI 76.9–81.8], *p* = 0.007). The frequency distribution of hands-on-chest time in the pre- and post-intervention periods is shown in Fig. 2.

3.2. Compression rate

The mean compression rate was found to be higher than recommended in the 2005 European Resuscitation Council guidelines during the initial data collection phase (124.5/min, 95% CI 117.4–131.6). There was a trend towards slower compression rate following introduction of feedback (124.5/min [95% CI 117.4–131.6] vs 121.3 [95% CI 117.3–125.4], *p* = 0.41). Graphs showing frequency distribution of compression rates can be seen in Fig. 3.

3.3. Cardiac rhythm recognition

Use of automatic rhythm recognition was performed during 17 (50%) resuscitation attempts during the baseline data collection period and 22 (28.6%) resuscitation attempts following intervention (*p* = 0.040).

3.4. Time-to-shock

At least one shock was delivered in 56 (50.5%) of the 111 cases where the TTI trace was analysed. There was a significant reduction in median time-to-shock when pre-feedback and post-feedback periods were compared (20.25 s [IQR 15.5–25.5] vs 13.5 s [IQR 2.2–22.0], *p* = 0.006). Graphs showing frequency distribution of time-to-shock can be seen in Fig. 4. Automatic rhythm recognition fell from 50% to 28.6% (*p* = 0.03) following intervention.

4. Discussion

This study has described the impact of using a telemetry network to evaluate quality of pre-hospital resuscitation and the impact of resuscitation feedback and training. We found establishing a telemetry network to be an effective, time-efficient means

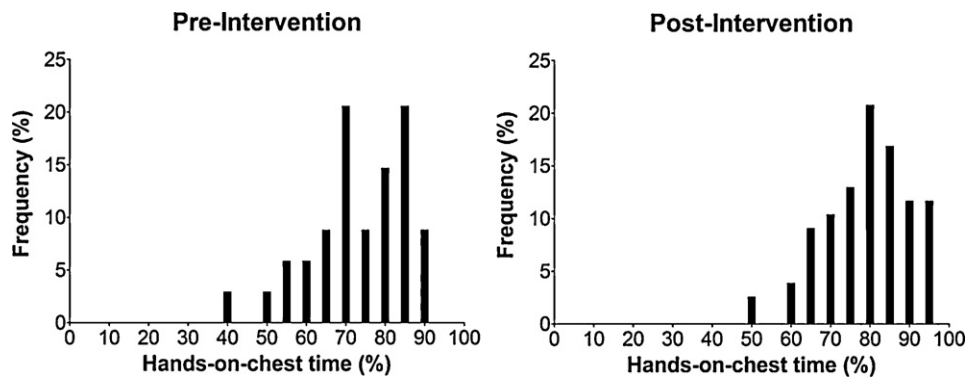


Fig. 2. Frequency histograms showing the distribution of hands-on-chest time before and after introduction of targeted feedback and resuscitation.

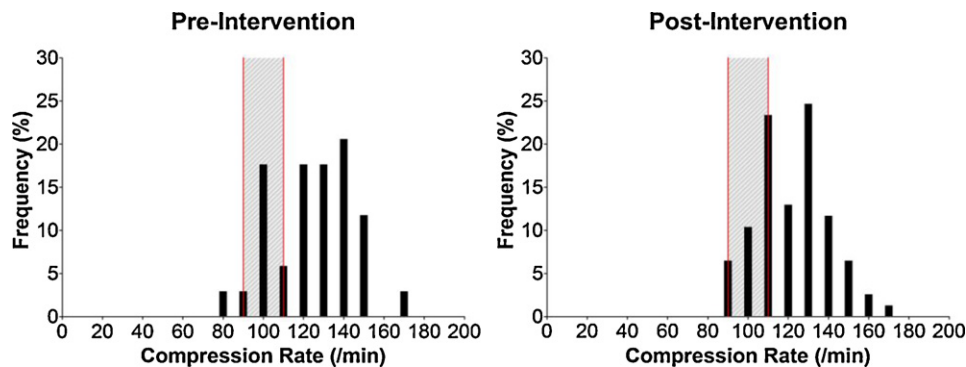


Fig. 3. Frequency histograms showing the distribution of compression rates around the ideal of 90–110/min (shaded area) before and after introduction of targeted feedback and resuscitation.

of accurately and objectively assessing quality of pre-hospital resuscitation across a wide geographical area. Using GPRS technology to transmit TTI traces proved to be a reliable, rapid means of transmitting data to a remote computer for analysis. Targeted resuscitation training and post-event feedback improved the quality of pre-hospital resuscitation during the study period. Hands-on-chest time, time-to-shock and use of manual rhythm analysis all improved significantly following the implementation of feedback and training. A non-significant improvement was seen in compression rate following intervention.

Previous studies have highlighted the need to collect resuscitation data and monitor the quality of CPR performed by ambulance

crews²¹ but few studies have described the methodology for collecting such data and evaluated the impact of post-event resuscitation reporting and targeted resuscitation training. The value of resuscitation feedback and training has been demonstrated for in-hospital cardiac arrest.²² We found targeted resuscitation training and post-event reporting to have a positive impact on quality of resuscitation. Previous studies²⁰ have highlighted the need for regular resuscitation training but there is some discrepancy in the efficacy of real-time and post-event feedback for resuscitation.^{23–25} We would suggest the training structure, experience and competence of ambulance crews varies greatly on a national level and the impact of feedback and training is likely to vary across

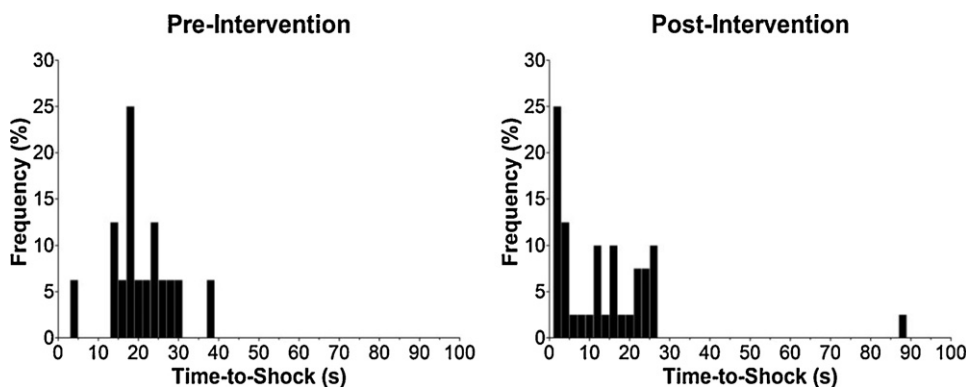


Fig. 4. Frequency histogram showing the distribution of time from cessation of chest compressions to delivery of a shock. The single outlier in the post-intervention group receiving a shock after 88 s was due to an unrecognised re-arrest during extrication.

different ambulance services. Individual ambulance crews becoming involved in OHCA data collection and resuscitation training is likely to have a positive impact in terms of motivation and willingness to attend non-compulsory resuscitation training sessions, raise awareness of OHCA and perform to a higher standard when faced with a patient requiring resuscitation.

Similar to previous studies,^{17,26} we found compression rate to be higher than recommended guidelines. Previous studies²⁷ have indicated the value of metronomes in lowering compression rates and we suggest that this type of approach may improve resuscitation in our context. Currently, Scottish Ambulance Service defibrillators default to automatic mode. This setting encourages personnel who are not confident in rhythm recognition to rely on automatic analysis, but increases time-to-shock delays. Regular resuscitating training, including practical simulation with cardiac rhythm analysis may improve confidence in cardiac rhythm recognition, increasing use of manual defibrillator mode.

A back-to-basics approach to resuscitation is required. Resuscitation practice has introduced several interventions, including advanced airways, intravenous cannulation and drug administration, which have not been proven to improve outcome from OHCA and may distract from time spent performing chest compressions and ensuring defibrillator shocks are delivered with the minimum of interruption. A study which evaluated a resuscitation protocol involving an increased period of chest compressions and delayed endotracheal intubation showed an improved survival-to-discharge rate.²⁸ Subjective analysis of several of the OHCA cases in this study revealed significant proportion of non-compression time in favour of establishing intravenous access and performing endotracheal intubation. Education in this area is likely to show the significant improvement in quality of pre-hospital resuscitation we have demonstrated.

This study has several limitations. Analysis of TTI traces is reliant on the trace being transmitted by the attending ambulance crew. A limitation of this study is our inability to be certain that we have identified all OHCA cases that were attended by the modern-equipped ambulances during the study period. We have attempted to ensure we accurately matched all OHCA cases with the attending vehicle but we cannot be certain defibrillators were not moved between vehicles. Nonetheless, we accurately identified all cases for which a defibrillator trace was received. In this study, the overall transmission rate was lower than would be ideally be desired. We encouraged ambulance crews to transmit defibrillator data at every opportunity; however, crews with poorer resuscitation performance may have been less likely to transmit their defibrillator traces for scrutiny, introducing bias. Future work should aim for automatic defibrillator trace transmission, without the need for ambulance crew input. The reason for the uneven sex distribution in the pre-intervention period is not known. We were unable to match defibrillator downloads to individual ambulance crew members and analyse whether individual performance improved as a result of feedback and training. Future work should attempt to individualise defibrillator downloads which would give a more accurate measure of the intervention effect. The overall number of OHCA cases included in this study is relatively small and further, large studies are required.

Further research is warranted to incorporate objective quality of pre-hospital resuscitation data into cardiac arrest registries and to assess the impact of targeted resuscitation training and post-event feedback on outcome following OHCA.

5. Conclusion

Evaluating quality of pre-hospital resuscitation practice is important to assure quality control and to improve outcome from

OHCA. TTI analysis is an accurate means of calculating the hands-on-chest time, compression rate and delay-to-shock time. TTI data sent via telemetry is straightforward, efficient and allows resuscitation data to be captured and analysed from a large geographical area. Targeted resuscitation training and ambulance feedback improves the quality of pre-hospital resuscitation. Further studies are required to establish possible survival benefit from this technique.

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Conflict of interest statement

None.

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