THE IMPACT OF A PRE-HOSPITAL CRITICAL CARE TEAM ON SURVIVAL FROM OUT-OF-HOSPITAL CARDIAC ARREST

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ABSTRACT

Aim

To assess the impact of a pre-hospital critical care team (CCT) on survival from out-of-hospital cardiac arrest (OHCA).

Methods

We undertook a retrospective observational study, comparing OHCA patients attended by advanced life support (ALS) paramedics with OHCA patients attended by ALS paramedics and a CCT between April 2011 and April 2013 in a single ambulance service in Southwest England. We used multiple logistic regression to control for an anticipated imbalance of prognostic factors between the groups. The primary outcome was survival to hospital discharge. All data were collected independently of the research.

Results

1851 cases of OHCA were included in the analysis, of which 1686 received ALS paramedic treatment and 165 were attended by both ALS paramedics and a CCT. Unadjusted rates of survival to hospital discharge were significantly higher in the CCT group, compared to the ALS paramedic group (15.8% and 6.5%, respectively, $p < 0.001$). After adjustment using multiple logistic regression, the effect of CCT treatment was no longer statistically significant (OR 1.54, 95% CI 0.89 to 2.67, $p = 0.13$). Subgroup analysis of OHCA with first monitored rhythm of ventricular fibrillation or pulseless ventricular tachycardia showed similar results.

Conclusion

Pre-hospital critical care for OHCA was not associated with significantly improved rates of survival to hospital discharge. These results are in keeping with previously published studies. Further research with a larger sample size is required to determine whether CCTs can improve outcome in OHCA.

INTRODUCTION

Sudden death due to out-of-hospital cardiac arrest (OHCA) is a major health problem, with an estimated 275,000 cardiac arrests in Europe each year.[1] Survival rates of between 5% and 38% have been reported, and have been linked to differences in pre-hospital treatment.[1,2] Optimising care for patients suffering OHCA through early recognition and improved pre-hospital provider response times has been the focus of many emergency medical systems (EMS) over the last two decades.[2,3] A range of different interventions have been studied,[4,5] but only chest compressions[6,7] and defibrillation[2,8] have been shown to consistently improve survival from OHCA. There is some evidence that advanced life support (ALS), which includes interventions such as tracheal intubation and intravenous drug administration, can improve outcomes further.[9,10] ALS is now the standard of pre-hospital care for OHCA in most advanced EMS.[3] In addition to ALS providers, many EMS have also established targeted dispatch of physicians and/or specialised critical care paramedics to OHCA; a concept referred to as pre-hospital critical care.[11,12]

Pre-hospital critical care for OHCA

The mechanisms by which outcomes might be improved through the presence of pre-hospital critical care practitioners include ALS-interventions undertaken more efficiently, supplementation of ALS-protocols with enhanced experience and clinical judgment and an advanced level of post-arrest treatment, including transport to the most appropriate destination hospital.[13] There is little research addressing the concept of pre-hospital critical care in general, and in the context of OHCA specifically. We recently published a systematic review on the impact of paramedic-delivered pre-hospital critical care which did not identify any studies relating to OHCA.[14] A systematic review by Botker from 2009 examined the effect of physician-delivered pre-hospital critical care on OHCA outcomes and found a benefit, ‘based on limited evidence’.[15] Small sample size,[16] comparison of pre-hospital critical care with very limited basic life support[17] and study designs which did not control for significant confounding factors[17-20] make the application and generalisation of these findings problematic.

Olasveengen et al acknowledged this lack of evidence regarding pre-hospital critical care for OHCA.[21] In 2009, these authors compared survival rates from OHCA with pre-hospital physician care (n=232) and with paramedic ALS care (n=741) in Norway. Data were collected prospectively and no significant difference in outcomes was found.

In summary, there is no existing evidence to support paramedic-delivered pre-hospital critical care for patients with OHCA, while for physician-delivered pre-hospital critical care studies have shown mixed results,[15] with the largest and most recent study failing to demonstrate any benefits.[21]

Currently, all EMS in the United Kingdom (UK) dispatch ALS trained paramedics to confirmed or suspected OHCA.[3] Pre-hospital critical care teams (CCTs) are utilised by some but not all UK EMS, and their availability varies significantly across regions.[11,22] This study examines the effect of pre-hospital critical care on survival from OHCA, when compared to ALS paramedics alone.

METHODS

We undertook a retrospective observational study, comparing OHCA patients attended by ALS paramedics to OHCA patients attended by both ALS paramedics and a CCT between April 2011 and April 2013. We used multiple logistic regression to control for an anticipated uneven distribution of prognostic factors between the CCT and the ALS paramedic groups. The primary outcome was survival to hospital discharge.

Great Western Ambulance Service (GWAS)

GWAS provided pre-hospital care for the counties of Wiltshire, Gloucestershire and Avon in Southwest England. GWAS covered an area of 3000 square miles with a population of approximately 2.4 million people. It operated 31 ambulance stations, two emergency operations centres and two air ambulances; the Great Western Air Ambulance and Wiltshire Air Ambulance. Between 2011 and 2012, GWAS responded to approximately 273,000 emergency calls. GWAS aimed to have an ALS paramedic respond to any confirmed or suspected OHCA within eight minutes of call registration. It used a combination of single-crewed rapid response vehicles and double-crewed ambulance vehicles. In February 2013 GWAS was acquired by South West Ambulance Service NHS Foundation Trust.

Great Western Air Ambulance (GWAA) Critical Care Team

In 2008, GWAS established a pre-hospital critical care team (CCT) provided by a pool of senior physicians and specially trained critical care paramedics (CCPs). The GWAA CCT attends all types of pre-hospital emergencies including medical, trauma and paediatric cases, alongside the usual ambulance response. The service is delivered using a combination of helicopter transport (provided by the Great Western Air Ambulance charity) and fast response road vehicles covering the GWAS territory.[23] To undertake pre-hospital work, pre-hospital physicians complete a training programme with specified competencies and mentored practice, coupled with theoretical and simulation training. CCPs are experienced paramedics who have completed a university-based theory and practical training course with mentoring and supervised experience, followed by the successful completion of a comprehensive qualifying assessment. Interventions for OHCA provided by the CCT in addition to ALS are induction and maintenance of anaesthesia, inotropic support, management of electrolyte disturbances and arrhythmias, complex invasive procedures in special circumstances (e.g. peri-mortem cesarean section) and transport to hospital by helicopter.[12] A detailed analysis of the competences of GWAS and GWAA pre-hospital providers has been published previously.[12] During the study period, the CCT was dispatched via a dedicated special operations desk manned by an experienced dispatcher. The dispatcher scans all incoming calls and weighs up the potential benefits of CCT dispatch together with the CCT. Frequently, the decision to dispatch is made when CPR instructions are given to the caller, or when the first ambulance resource on scene confirms OHCA. Factors such as the location, age of patient and whether the OHCA was witnessed influence the decision to activate the CCT.

Data collection

GWAS collected data on all OHCA patients routinely. Information for this electronic database was collected prospectively from ambulance records and included age and gender of the patient, location of OHCA, witnessed OHCA, bystander CPR, ambulance response time, first monitored rhythm, return of spontaneous circulation (ROSC) and the receiving hospital. Survival to hospital discharge is documented in the database through a process of mandatory reporting. Each case is identifiable through a patient care form (PCF) number. Independently of this database, the GWAA CCT keeps records of all cases attended, including the PCF number. We were therefore able to identify CCT cases on the GWAS database. We analysed the database between April 2011 and April 2013.

Inclusion and exclusion criteria

We examined adult (age 18 or older), non-traumatic OHCA, for which resuscitation was commenced or continued by a pre-hospital provider. Excluded were OHCA which occurred in the presence of EMS providers, patients with OHCA and return of spontaneous circulation prior to arrival of EMS and OHCA due to drug overdoses, trauma and drowning. Cases with incomplete documentation were also excluded.

Outcomes

The primary outcome of survival to hospital discharge was routinely documented in the GWAS database, independently of this research.

Multiple logistic regression

The CCT dispatch process aims to maximise any potential benefit of the CCT and includes clinical decision making based on prognostic factors known at the time of dispatch. This process was expected to result in significant differences between the CCT and the ALS paramedic patient groups. We used multiple logistic regression with STATA-12 data analysis and statistical software (StataCorp LP, Texas) to adjust for these differences. Independent variables were based on previous research[21,24] and included patient age, location of OHCA, witnessed OHCA, bystander CPR, response time of first EMS provider and first monitored rhythm. We tested for interactions between these independent variables and included interactions which improved the model in the final logistic regression. To avoid over-fitting of the model, we aimed to have at least 20 events (survival to hospital discharge) per variable (n/20 rule).[25]

Statistical analysis

Demographic and clinical data are presented as medians or proportions. Differences between the two pre-defined groups were analysed using Fisher's exact test for categorical data and the Mann-Whitney test for continuous data, as appropriate. Multiple logistic regression with investigation of potential interactions between the independent variables was performed. We tested the effect of each interaction on the model, using the linear predicted value squared. Interactions which increased the p-value for the linear predicted value squared were included in the final model. Goodness-of-fit of the model was assessed using the pseudo R-square and the Hosmer and Lemeshow's goodness-of-fit test, which tests the model by comparing predicted and observed frequencies within the data.[26] P-values less than 0.05 were considered significant.

RESULTS

Resuscitation for OHCA was commenced or continued by GWAS pre-hospital providers in 2124 cases during the study period (OHCA without attempted resuscitation was not recorded in the database). After application of exclusion criteria and removal of cases with missing data, we were left with a sample of 1851 cases (see figure 1).

Of the 1851 OHCA patients included in the analysis, 1686 were treated by ALS paramedics and 165 were treated by both ALS paramedics and a CCT. Six ALS paramedic cases where the paramedics requested CCT backup (rather than primary CCT dispatch) remained in the ALS paramedic group for analysis, following an intention-to-treat principle. Survival to hospital discharge was significantly higher in the CCT group, compared to ALS paramedic treatment alone (15.8% and 6.5%, respectively, $p < 0.001$). As anticipated, the groups also differed significantly in a range of prognostic factors (Table 1).

We undertook a multiple logistic regression analysis to adjust for these differences between the groups. We tested for interactions between the included factors and found significant interactions between the age of the patient and the first monitored rhythm as well as the presence of bystander CPR and the first monitored rhythm. The inclusion of these two interactions improved the p-value of the linear predicted value squared from 0.05 to 0.34, suggesting a significant and satisfactory reduction in specification error. The pseudo R-square was 0.278 for the final model and the Hosmer and Lemeshow's goodness-of-fit test showed a chi2 (8) of 8.90 with a p-value of 0.35, both suggesting a good fit of the model. After adjusting for prognostic factors through multiple logistic regression analysis, CCT attendance was not associated with a statistically significant improvement in survival to hospital discharge (OR 1.54, (95% confidence interval 0.89 - 2.67, p=0.13); Table 2.

Of the 1851 cases included in this analysis, 519 (28.0%) had ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT) as the first monitored rhythm. A subgroup analysis of these cases with a 'shockable' first monitored rhythm showed unadjusted survival rates of 19.1% and 33.8% in the ALS-paramedic and CCT groups, respectively (p=0.01). Multiple logistic regression analysis resulted in a similar effect of CCTs on survival as for the complete sample, with OR 1.51, (95% confidence interval 0.82 - 2.78, p=0.19). See Tables 3 and 4 for further details.

Figure 2 shows median activation and response times in the CCT group. The CCT was dispatched to the scene via helicopter in 78 cases and via rapid response vehicle in 87 cases.

DISCUSSION

Patients with OHCA who received treatment from the CCT had a significantly higher chance of survival to hospital discharge compared to those receiving ALS paramedic care only (15.8% and 6.5% respectively, p<0.001). However, CCT dispatch aims to maximise potential benefit from CCT treatment, and OHCA cases in the CCT group had significantly better prognostic factors. After adjusting for this imbalance between the CCT and ALS paramedic groups, the effect of CCT treatment was no longer statistically significant (OR 1.54, 95% confidence interval 0.89 - 2.67, p=0.13).

Despite a current lack of scientific evidence to support pre-hospital critical care for OHCA, it is the standard of care in many European countries and increasingly common in the UK.[11,13,17] While it is intuitive that a higher level of pre-hospital care will improve outcomes, the findings of this and previous studies[21] warrant a detailed discussion of how exactly CCTs might benefit patients with OHCA, to guide further research and EMS configurations.

Potential benefits from CCTs can occur at different stages of cardiac arrest, the first of which is the initial resuscitation phase. Both physicians (when compared to paramedics) and more experienced ALS paramedics have been shown to undertake better initial resuscitation, with mixed effects on survival to hospital discharge.[10,21] However in our study the impact of the CCT on the initial resuscitation phase appears small. Figure 3 shows that on average ALS paramedics arrived at the scene of an OHCA 6 minutes after the initial call was made, whilst the CCT was only dispatched 6 minutes after the initial call and then required an average of another 14 minutes to arrive at scene. This contrasts with the majority of publications comparing physician and ALS paramedic care. Dickinson et al demonstrated rates of survival to hospital discharge of 5% for ALS-paramedics, which increased to 44% (p<0.009) if 'experienced emergency physicians' were present on the responding ambulance vehicle.[16] While the study groups were well matched, with an incidence of VF of about 50%, there were only nine cases in the physician group. A retrospective database analysis by Soo et al showed that the odds of survival to hospital discharge after OHCA were better when a physician assisted ALS paramedics on scene.[19] However, the assisting physicians were not dispatched by EMS but happened to witness the OHCA in a public place. Olasveengen et al compared physician and ALS-paramedic staffed ambulances for OHCA, both with median response times of 9 minutes, and found no difference in survival to hospital discharge (OR 1.35; 95% CI 0.71 - 2.60).[21]

While it would be intuitive to assume that the early presence of a CCT at the scene of OHCA is beneficial, there are practical barriers to achieving this. The median response time of 6min for the first EMS resource in this study is achieved through a pre-alert system, in which one or multiple vehicles are mobilised at the moment of receiving the 999-call. This model results in a high number of EMS vehicles being stood down, once more clinical information is gathered.[27] Dispatching the CCT in a similar manner, especially when helicopter-based, would increase costs significantly and would make the CCT unavailable for other incidents of critical illness or trauma occurring around the same time. The issue of optimising helicopter-based CCT dispatch is well recognised, and a priority for further pre-hospital research.[28]

The next stage at which pre-hospital critical care might improve outcomes from OHCA follows the initial resuscitation phase. If the standard ALS algorithm has not resulted in a return of spontaneous circulation (ROSC) by the time the CCT reaches the scene, the CCT can provide additional therapies in special circumstances such as drug overdose, electrolyte disturbances or traumatic cardiac arrest.[12] However we excluded cases known to be of non-cardiac aetiology, since these causes of OHCA are infrequent and represent very specific groups of patients that might influence survival rates disproportionately.[29] If ROSC has been achieved after OHCA of cardiac aetiology, the CCT can provide advanced cardiovascular support as well as pre-hospital anaesthesia in agitated patients.[30] A CCT may also be able to transport a patient to the most appropriate destination hospital, providing safe transfer over long distances to a centre where coronary angiography and a concentration of expertise is available; factors that have been shown to be associated with improved survival following OHCA.[31,32] In fact, of the patients transported to hospital by the CCT, 82% were transported to the regional cardiac centre, compared to 20% in the ALS paramedic group (data not shown). It is entirely possible that the destination hospital, rather than the CCT team per se, is responsible for an improved patient outcome, however we were unable to test this hypothesis in our study. A likely scenario is that any overall benefit of CCT care is the cumulative effect of early pre-hospital critical care interventions and the highest standard of in-hospital treatment.

The CCT responded to the OHCA patient by helicopter or car, depending upon the distance, time of day and prevailing weather conditions. A helicopter can improve the range, and therefore efficiency, of a CCT, but the effect of patient transfer by helicopter over relatively short distances in urban and semi-rural settings in unknown.[33] In our study almost all patients attended by the CCT were conveyed to hospital by conventional land ambulance, suggesting that air transport of patients is not a factor that influences outcome in our setting.

Although we were unable to show a statistically significant improvement in survival to hospital discharge in this study, an OR of 1.54 (p=0.13) does not rule out the possibility of a clinically significant benefit. The lack of statistical significance is potentially due to a type 2 error, since the sample size was restricted by a change in routine data collection that prevented continuation beyond April 2013. Assuming an average survival to hospital discharge of 7.0% in the ALS paramedic group, with an OR of improved survival of 1.54 for CCT attendance, it would require a total sample of approximately 6000 cases to reach a power of 80% for the detection of a 3.5% absolute increase in survival. A survival benefit of 3.5% would be highly clinically significant, but would need to be balanced against the cost of CCT dispatch to OHCA, and the potential negative impact on other patients with critical illness and injury who could benefit from the same resource. It would also be helpful to understand the mechanism by which any survival benefit occurs, to inform future policy and service configuration decisions. In view of this, a larger study is warranted to further examine the potential benefits of pre-hospital critical care in OHCA.

Limitations

This is a retrospective cohort study using an EMS database in which data were collected for the purpose of quality control rather than research. Retrospective observational studies are subject to confounding, and the statistical techniques employed cannot eliminate this possibility entirely. Some OHCA patients may not have been registered on the database, and this could have influenced our results. Sample size was limited by practical issues and the study is therefore underpowered. The outcome of survival to hospital discharge is relatively robust, but is less patient-centred than long-term neurological recovery. However, survival to discharge is commonly used in pre-hospital studies of OHCA, and survivors frequently achieve a good neurological recovery.[34]

CONCLUSION

Pre-hospital critical care teams are dispatched to patients who have suffered OHCA with increasing frequency, despite a lack of evidence to support this practice. In this retrospective observational study the attendance of a CCT was not associated with significantly improved survival to hospital discharge, however the odds ratio was 1.54 (p=0.13) with the possibility of a type 2 error. Further research, including a larger sample size, is required to determine whether CCTs can improve outcome in OHCA, and the possible mechanisms by which this may be achieved.

CONFLICT OF INTEREST

Jonathan Benger and Johannes von Vopelius-Feldt work with the Great Western Air Ambulance. The authors did not receive any funding for this work.

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LEGENDS TO FIGURES AND TABLES

In order of appearance in the text:

Figure 1. Flow-chart of out-of-hospital cardiac arrest cohort (inclusion and exclusion criteria)

Table 1. Demographics and survival to hospital discharge of ALS-paramedic and CCT groups

* statistically significant result ($p < 0.05$)

Table 2. Multiple logistic regression of factors associated with survival to hospital discharge after OHCA

* statistically significant result ($p < 0.05$)

Table 3. Demographics and survival to hospital discharge of ALS-paramedic and CCT groups, in cases where the first monitored rhythm was ventricular fibrillation or pulseless ventricular tachycardia

* statistically significant result ($p < 0.05$)

Table 4. Multiple logistic regression of factors associated with survival to hospital discharge after OHCA with first monitored rhythm of ventricular fibrillation or pulseless ventricular tachycardia

* statistically significant result ($p < 0.05$)

Figure 2. Activation times and response times in the critical care team (CCT) group

* Ambulance response time 6min (interquartile range 5min)

** 999 call to CCT allocation time 6min (interquartile range 7min)

*** CCT allocation to arrival at scene time 14min (interquartile range 8min)