Original Article

Impact of a physician – critical care practitioner pre-hospital service in Wales on trauma survival: a retrospective analysis of linked registry data

J. Lyons,[1] B. J. Gabbe,[2,3] D. Rawlinson,[4,5] D. Lockey,[6] R. J. Fry,[7] A. Akbari[8] and R. A. Lyons[9]

1 Research Officer and Data Scientist (Health Data Research UK), 3 Honorary Professor, 5 Honorary Clinical Research Fellow, 7 Senior Lecturer in GIS and Health Geographies, 8 Senior Research Manager and Data Scientist (Health Data Research UK), 9 Clinical Professor of Public Health Medicine (Health Data Research UK), Swansea University, Swansea, UK.
2 Head of the Pre-hospital, Emergency and Trauma Research Unit, School of Public Health and Preventive Medicine at Monash University, Melbourne, Australia.
4 Clinical Informatics and Research Manager, 6 National Director, Emergency Medical Retrieval and Transfer Service (EMRTS) Cymru, Wales, UK.

Summary

The Emergency Medical Retrieval and Transfer Service for Wales launched in 2015. This service delivers senior pre-hospital doctors and advanced critical care practitioners to the scene of time-critical life- and limb-threatening incidents to provide advanced decision-making and pre-hospital clinical care. The impact of the service on 30-day mortality was evaluated retrospectively using a data linkage system. The study included patients who sustained moderate-to-severe blunt traumatic injuries (injury severity score ≥ 9) between 27 April 2015 and 30 November 2018. The association between pre-hospital management by the Emergency Medical Retrieval and Transfer Service and 30-day mortality was assessed using multivariable logistic regression. In total, data from 4035 patients were analysed, of which 412 (10%) were treated by the Emergency Medical Retrieval and Transfer Service. A greater proportion of patients treated by the Emergency Medical Retrieval and Transfer Service had an injury severity score ≥ 16 and Glasgow coma scale ≤ 12 (288 (70%) vs. 1435 (40%) and 126 (31%) vs. 325 (9%), respectively). The unadjusted 30-day mortality rate was 11.7% for patients managed by the Emergency Medical Retrieval and Transfer Service compared with 9.6% for patients managed by standard pre-hospital care services. However, after adjustment for differences in case-mix, the 30-day mortality rate for patients treated by the Emergency Medical Retrieval and Transfer Service was 37% lower (adjusted odds ratio 0.63 (95%CI 0.41–0.97); p = 0.037). The introduction of an emergency medical retrieval service was associated with a reduction in 30-day mortality for patients with blunt traumatic injury.

Reducing the time from injury to definitive care is perceived to be associated with improved health outcomes [1]. Organisation and enhanced models of trauma care, pre-hospital critical care and patient transport have been shown to improve equity of access to time-critical care provision and reduce mortality and duration of hospital stay

of patients with traumatic injuries [2–5]. However, some studies have shown no significant change in mortality for patients with traumatic injuries transported by helicopter or attended by physician-led pre-hospital critical care teams [6, 7]. These studies have predominantly involved transport modality comparisons of helicopter vs. ground emergency medical services or have only investigated in-hospital death rates due to a lack of access to data linkage systems. Changes in the organisation of care are more difficult to evaluate than therapeutic developments, due to differences pertaining to care provision, such as access to services, which may contribute to the inconsistencies in study findings.

It has been argued that all new healthcare services should have their performance, impact and population benefit evaluated [8, 9]. Helicopter Emergency Medical Services (HEMS) are relatively expensive to operate, and given the limited number of high-quality service evaluations undertaken, the impact of any new service introduced should be evaluated. However, the evaluation of such services rarely fits a randomised trial design and requires the ability to control for confounders such as the presence of comorbid disease or injury severity.

In April 2015, the Emergency Medical Retrieval and Transfer Service (EMRTS) launched as a pre-hospital critical care service in partnership with the established Wales Air Ambulance. This new service was funded by the Welsh Government and aimed to deliver senior doctors and critical care practitioners to provide advanced decision-making and pre-hospital care to time-critical life- and limb-threatening incidents. The service also supports time-critical inter-hospital transfers across Wales. Examples of the criteria for dispatching the EMRTS are shown in Table 1. The EMRTS provides critical care interventions outside standard ambulance practice such as the administration of blood products and anaesthesia at the scene for both illness and injury (full details available in online Supporting Information Appendix S1). The EMRTS aims to reduce the time to definitive care by delivering interventions at the scene and transporting patients to appropriate receiving hospitals, as well as reducing geographical inequalities in care provision across Wales [10].

The aim of this study was to evaluate the effect of the introduction of the EMRTS on 30-day mortality in patients who had suffered blunt traumatic injuries.

Methods

This study utilised anonymised and encrypted data sources held in the Secure Anonymised Information Linkage (SAIL) databank, a privacy-protecting trusted research environment [11, 12]. Formal ethical approval for this study was, therefore, not required. The independent information governance review panel approved the utilisation of the SAIL databank for this service evaluation, as did the joint study review committee of the Swansea Bay University Health Board. This study follows guidelines for the reporting of observational studies [13].

The study design was a natural experiment of the EMRTS response using 30-day mortality rates to assess the impact of the introduction of the service. Helicopter transport is not always available due to relatively frequent adverse weather conditions and restrictions on service operational hours; in these situations, fast-response cars are used as an alternative. Multivariable logistic regression was used to determine the odds ratio for 30-day mortality in patients with traumatic injuries who were managed by the EMRTS and standard pre-hospital emergency services. All

Table 1 Criteria for emergency medical retrieval and transfer service dispatch.

Immediate dispatch criteria	Interrogated dispatch criteria
• Serious road traffic collision • Patient unconscious • Major chest/head/pelvic injury • Airway compromise • Significant burns • Amputation above ankle or wrist • Fall from height (> 3 m or 1 storey) • Trapped in machinery • Animal incident • Aircraft/train/coach crash • Request from non-Welsh Ambulance Service Trust emergency service	• Major incident (standby/declared) • Vehicle or pedestrian road traffic collision • Industrial or agricultural accidents • Diving emergencies • Equestrian injuries • Coastal/beach incidents • 999 call originating from midwife-led maternity units • Crew request • Severe haemorrhage of any sort • Traumatic injuries including: hangings; burns/scalds; drowning; electrocutions; and spinal injury with paralysis • Medical emergencies including: myocardial infarction; cardiac arrest with return of spontaneous circulation • Patient agitated/combative • Access issues

patients were transferred to hospital units that participate in the UK's Trauma Audit and Research Network (TARN).

The SAIL databank contains routinely collected anonymised population-scale linkable health, demographic, administrative and environmental data at the individual and household level for the population of Wales. The SAIL databank has supported many different study designs including: large-scale community-based and condition-based observational studies; disease and injury surveillance; and a number of evaluations of natural experiments of service provision [14, 15]. This databank provides an infrastructure to create retrospective datasets from linking multiple data sources efficiently including baseline characteristic data (identifying Welsh residents for accurate follow-up), healthcare utilisation (attendance of EMRTS) and mortality outcome data.

Each data source included in this evaluation contained variables of interest to the research aim. The Welsh Demographic Service Dataset provides baseline characteristic data (age, sex, date of death), address history to identify Welsh residency for accurate censorship of individuals and the residential Lower-layer Super Output Area to identify patient socio-economic status, based on quintiles of the Welsh Index of Multiple Deprivation [16]. The EMRTS data provide information on all operational data since the service launched and was used to identify patients treated by the EMRTS (exposure variable), as well as the date of the trauma incident for appropriate follow-up. The TARN data provide information on trauma hospital admissions for Welsh residents or individuals treated in Welsh hospitals and contains numerous clinically significant variables for trauma outcomes including: injury severity score (ISS); Glasgow coma scale (GCS); pre-existing medical conditions score; and modified Charlson comorbidity index. These variables are used widely to quantify, categorise and compare injury severity and pre-injury health [17, 18]. The Office of National Statistics mortality data provide information surrounding the death of Welsh residents. The date of death variable was used to derive a dead/alive status variable at 30 days following the trauma incident.

Data linkage techniques were used to combine data sources, carry out data management and cleaning and create the study population. All individuals living in Wales at the time of injury (27 April 2015–30 November 2018), who sustained blunt trauma resulting in a moderate to severe injury (ISS ≥ 9) and who were admitted to a TARN-participating hospital were eligible for inclusion. Patients treated by the EMRTS were identified by fitting the inclusion criteria (Fig. 1) or by a record in TARN confirming EMRTS treatment. Patients who were not managed by the EMRTS and who met TARN inclusion criteria comprised the remainder of the study population (Fig. 1). Only individuals with an appropriate identity match to the Welsh Demographic Service Dataset were included to identify high-quality matching of personal identifiable data in creating the unique anonymised linkage field. The data cleaning methods applied are shown in Figure 2.

Primary outcome measure was 30-day mortality (measured from the date of injury). This was chosen as most trauma deaths occur in the initial weeks following the trauma incident [19]. The Office of National Statistics mortality data and the Welsh Demographic Service Dataset were used to timestamp the date of death regardless of in-patient or hospital discharge deaths. The exposure of interest was treatment by the EMRTS (defined above). Covariates included: age; sex; ISS; tracheal intubation; GCS; socio-economic status; and comorbidity. Age was grouped into five cohorts (0–16, 17–24, 25–39, 40–64 and ≥ 65 years) [20] and ISS and GCS were split into three categories (9–15, 16–24 and ≥ 25 and 3–8, 9–12 and 13–15, respectively). These are established categories that have been used widely in research studies. Tracheal intubation status was defined using TARN data and included pre-hospital or in-hospital intubation. Socio-economic status categories were defined using the Welsh Index of Multiple Deprivation; this is linked to the Welsh Demographic Service Dataset to assign the area level deprivation to each study participant's residency at time of injury. Comorbidity was calculated by TARN using the pre-existing medical conditions score (see online Supporting Information Appendix S2) for each hospital admission. This is modified from the Charlson comorbidity index, with scores categorised into three groups (0, 1–5 and ≥ 6) to match TARN grouping (0, 1–5, 6–9 and ≥ 10) [20–22]. Individual patients with high PMC scores were combined into a single group (≥ 6) due to small numbers.

Chi-square tests were used to assess the association between EMRTS treatment status with categorical variables. Formal sampling or size calculations were not necessary for this study design. Univariate logistic regression was used to identify potential confounders of the association between EMRTS treatment status and mortality (see online Supporting Information Appendix S3). Multivariable logistic regression was used to determine the odds ratio for mortality, adjusting for potential confounders identified through the univariate analyses. Both the backwards elimination method, using the likelihood ratio test and a significance level of p-value < 0.05, and the Akaike information criterion method were used to determine the
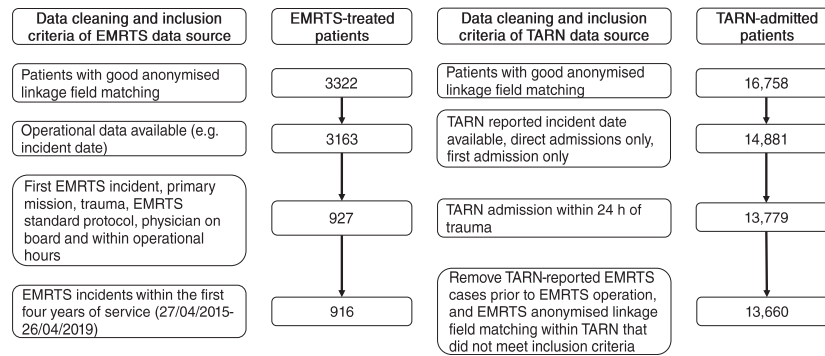
Figure 1 Inclusion criteria and data cleaning of Emergency Medical Retrieval and Transfer Service (EMRTS) and Trauma Audit and Research Network (TARN).
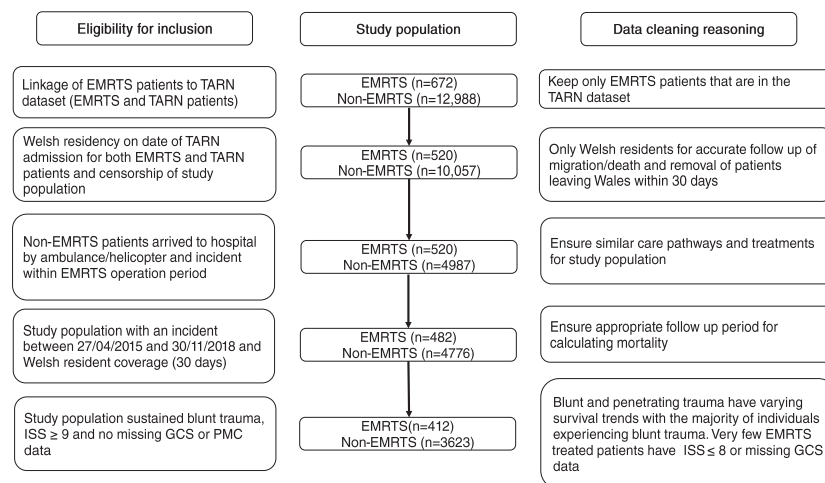

Figure 2 Inclusion criteria and data cleaning for the study population. EMRTS, Emergency Medical Retrieval and Transfer Service; TARN, Trauma Audit and Research Network; ISS, injury severity score; GCS, Glasgow coma scale; PMC, pre-existing medical conditions.

best fitting final model. Variance inflation faction was used to check for multicollinearity in the final model. Statistical analysis was carried out using R packages Survival, Stats, lmtest and MASS.

Results

Between 27 April 2015 and 30 November 2018, 4035 patients were identified in the databank for analysis. Of these, 412 (10%) were treated by the EMRTS. In general, patients treated by the EMRTS were more likely to be men and were younger than those receiving standard pre-hospital care (Table 2). A higher proportion of patients managed by the EMRTS were more severely injured as measured by ISS and GCS (Table 2). In terms of advanced interventions, 168 (41%) patients managed by the EMRTS underwent tracheal intubation compared with 304 (8%) patients receiving standard care. In patients who were

managed by the EMRTS, 36 (9%) received a pre-hospital red cell transfusion and 293 (71%) were transported by helicopter.

Unadjusted 30-day mortality rate was 11.7% for patients treated by the EMRTS and 9.6% for patients who received standard pre-hospital care (Table 1). The unadjusted odds ratio for 30-day mortality was higher for patients treated by the EMRTS (odds ratio 1.25, (95%CI 0.90–1.71)) (see online Supporting Information Appendix S3). After adjustment for differences in case-mix, patients treated by the EMRTS had a 37% lower chance of mortality compared with patients receiving standard care (adjusted odds ratio 0.63 (95%CI 0.41–0.97); p = 0.037) (Table 3). Requirement for tracheal intubation, increasing age, ISS, PMC and decreasing GCS were associated with a greater risk of mortality (Table 3). Sex and socio-economic status were not important predictors of mortality and were

Table 2 Comparison of patients with traumatic injuries treated in the pre-hospital setting by the Emergency Medical Retrieval and Transfer Service (EMRTS) and those receiving standard pre-hospital care. Values are number (proportion).

	Patients treated by the EMRTS n = 412	Patients receiving standard care n = 3623	p value
30-day mortality	48 (12%)	346 (10%)	0.174
Age; years			< 0.001
0–16	38 (9%)	102 (3%)	
17–24	41 (10%)	169 (5%)	
25–39	70 (17%)	320 (9%)	
40–64	163 (40%)	1071 (30%)	
≥ 65	100 (24%)	1961 (54%)	
Sex; male	302 (73%)	1826 (50%)	< 0.001
Injury severity score			< 0.001
9–15	124 (30%)	2188 (60%)	
16–24	104 (25%)	761 (21%)	
≥ 25	184 (45%)	674 (19%)	
Tracheal intubation	168 (41%)	304 (8%)	< 0.001
Socio-economic status			< 0.001
1	74 (18%)	799 (22%)	
2	91 (22%)	750 (21%)	
3	104 (25%)	716 (20%)	
4	94 (23%)	651 (18%)	
5	49 (12%)	707 (20%)	
Glasgow coma scale			< 0.001
3–8	88 (21%)	205 (6%)	
9–12	38 (9%)	120 (3%)	
13–15	286 (69%)	329 (91%)	
Pre-existing medical conditions (PMC) score			< 0.001
0	249 (60%)	1360 (38%)	
1–5	131 (32%)	1540 (43%)	
≥ 6	32 (8%)	723 (20%)	

Table 3 Multivariate logistic regression model results for 30-day mortality rates in patients with moderate to severe blunt traumatic injuries. Values are adjusted odds ratios (AOR) (95%CI).

	AOR (95%CI)	p value
EMRTS-treated		
No	REF	
Yes	0.63 (0.41–0.97)	0.037
Age; years		
0–16	REF	
17–24	0.71 (0.22–2.42)	0.575
25–39	0.86 (0.31–2.66)	0.777
40–64	1.63 (0.66–4.66)	0.320
≥ 65	8.30 (3.39–23.81)	< 0.001
Injury severity score		
9–15	REF	
16–24	1.47 (1.05–2.04)	0.024
≥ 25	3.69 (2.71–5.02)	< 0.001
Tracheal intubation		
No	REF	
Yes	2.05 (1.28–3.23)	0.002
Glasgow coma scale		
13–15	REF	
3–8	9.68 (5.96–16.02)	< 0.001
9–12	1.84 (1.08–3.05)	0.021
Pre-existing medical conditions (PMC) score		
0	REF	
1–5	1.28 (0.94–1.76)	0.127
≥ 6	2.68 (1.91–3.78)	< 0.001

excluded from the final model (see online Supporting Information Appendix S4).

Discussion

After adjustment for differences in case-mix, we found a 37% reduction in the adjusted odds ratio for 30-day mortality in patients with blunt traumatic injuries who were treated by EMRTS compared with standard pre-hospital care pathways.

It is important to evaluate new healthcare services to measure performance, impact and population benefit,

particularly when interventions cannot be allocated randomly and where there is a limited supporting evidence base. There is conflicting evidence regarding the benefits of HEMS and physician-led pre-hospital critical care teams, with some studies showing improved survival [4, 8] whilst others no difference [6, 7]. Previous literature has evaluated HEMS in other countries with different operating procedures as well as using varying methodologies, including cohort transport modality comparisons of helicopter vs. ground emergency medical services.

Improved survival with HEMS can be over-estimated due to over-triaging of less severe trauma cases [23]. However, in this study, we excluded minor injuries (ISS < 9) and adjusted for case-mix differences in evaluating the association between EMRTS treatment and mortality. As the EMRTS was implemented for life- or limb-threatening conditions, and in general should only treat more severely injured patients, the exclusion of minor injuries was appropriate.

There are a number of strengths to this study. The use of population-scale data linkage allowed for the creation of a population-level retrospective cohort, reducing systematic, recall and loss of follow-up bias. The SAIL databank facilitated access to baseline characteristic and mortality data sources which allowed the identification of all individuals living in Wales at time of injury, near complete follow-up across multi-sourced healthcare data and the ability to capture deaths accurately, whether in hospital or after discharge/hospital transfer. Identification of Welsh residency allowed for consistency of care pathways between the two comparator groups. The use of TARN data allowed access to important trauma profile characteristics and covariates that influence trauma survival such as ISS, GCS, pre-existing medical conditions and tracheal intubation status for both patient cohorts.

This study focused on blunt traumatic injuries only. Blunt trauma mechanism of injuries includes falls, vehicle incidents/collisions, blast, blows and crush injuries. Blunt and penetrating injuries have differing care needs and survival pathways and, therefore, it is important to study these injury mechanisms independently [24]. However, it would be beneficial to review the impact of EMRTS on penetrating mechanisms of injury as EMRTS case numbers increase.

A number of limitations exist. First, the study population was based on individuals admitted to a TARN-participating hospital. Submission of data to TARN is voluntary and, therefore, data are not representative of all trauma cases or complete from all trauma-receiving hospitals; this could lead to potential case selection bias. Second, pre-hospital deaths from injury were excluded from the analysis. Our design required that all study participants who survived to hospital admission be captured by TARN to enable access to injury severity measurement and other important trauma survival confounders. We cannot comment on injuries that resulted in deaths at the scene. Finally, we did not include the impact of treatment at a major trauma centre in the analysis. The EMRTS provides enhanced decision-making to definitive care, including whether to transport patients to a major trauma centre. The effect of treatment at particular sites and centres has been excluded from the analysis to prevent multicollinearity with EMRTS management.

In conclusion, after adjustment for key differences in case-mix, the pre-hospital management of patients by the EMRTS following a moderate to severe blunt traumatic injury resulted in a significant reduction in 30-day mortality. This study was not designed to determine which elements of the care provided by the EMRTS were responsible for this improvement in clinical outcome. However, the proportion of patients with low GCS, high ISS and who underwent tracheal intubation was significantly higher in the cohort managed by the EMRTS. It may be that the performance of time-critical interventions on scene, coupled with rapid transit to definitive care could be explanatory factors for the improvement in mortality. Further studies should consider incorporating penetrating injuries to assess all trauma presentations in Wales.

Acknowledgements

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Supporting Information

Additional supporting information may be found online via the journal website.

Appendix S1. Critical care interventions provided by the Emergency Medical Retrieval and Transfer Service.

Appendix S2. Comorbidity conditions included by the Trauma Audit and Research Network in calculating the pre-existing medical conditions score.

Appendix S3. Univariate logistic regression model results for 30-day mortality rates in patients with moderate to severe blunt traumatic injuries.

Appendix S4. Multivariate logistic regression full effects model results for 30-day mortality rates in patients with moderate to severe blunt traumatic injuries.

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