Association of out of hospital paediatric early warning score with need for hospital admission in a Scottish emergency ambulance population

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Assessing Pre-hospital PEWS as a predictor of the need for hospital admission in an Scottish emergency ambulance population

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Abstract

Objective

Physiological derangement, as measured by Paediatric Early Warning Score is used to identify children with critical illness at an early point to identify and intervene in children at risk. PEWS has shown some utility as a track and trigger system in hospital and also as a predictor of adverse outcome both in and out of hospital. This study examines the relationship between pre-hospital observations, aggregated into an eight point Paediatric Early Warning Score (PEWS Scotland), and hospital admission.

Methods

A retrospective analysis of all patients aged <16 transported to hospital by the Scottish Ambulance Service between 2011 and 2015. Data were matched to outcome data regarding hospital admission or discharge, and length of stay.

Results

Full data were available for 21,202 paediatric patients, of whom 6,340 (29.9%) were admitted to hospital. Pre-hospital PEWS Scotland was associated with an odds ratio for admission of 1.189 (95% CI 1.176-1.202;p<0.001). The Area Under Receiver Operating Curve (AUROC) of 0.617 (95% CI 0.608-0.625; p<0.001), suggests poorly predictive ability for hospital admission. There was no association between pre-hospital PEWS Scotland and length of hospital stay

Discussion

These data show that a single pre-hospital PEWS Scotland is a poor predictor of hospital admission for unselected patients in a pre-hospital population. The decision to admit a child to hospital is not solely based on physiological derangement of vital signs, and hence physiological based scoring systems such as PEWS Scotland cannot be used as the sole criteria for hospital admission, from an undifferentiated pre-hospital population.

Keywords: child health; emergency medical services; critical illness; ambulances; patient safety

Annually, 350-450 children die in Scotland [1]. Through confidential enquiries, potentially preventable factors contributing to mortality can be identified and used to inform policy makers and clinicians. The confidential enquiry into paediatric deaths in 2006 reported the failure to identify the severity of illness in children as a recurrent factor in paediatric deaths. This was most pronounced at the first point of contact with medical services and offers an opportunity to improve the early recognition and response to unwell children [2].

Early Warning Systems (EWS) were initially developed to recognise physiological deterioration early in order to facilitate identification of those at risk of critical illness and trigger clinical review [3,4]. These systems were created in order to track adult ward patients and have since been extrapolated to the Emergency Department [5,6]. There is now a standard National EWS for adult patients in NHS UK [7].

Paediatric early warning scores (PEWS) combine a series of physiological parameters in order to create a 'score' to track a patient's clinical course in hospital and recognise deteriorating patients. These parameters are age adjusted and weighted according to how far they deviate from normal range. There is a national PEWS in place in Scotland (PEWS Scotland), which is used for hospital inpatients. PEWS is an established tool in the UK hospital setting [8]. A cluster, randomised controlled trial into the effect of PEWS versus usual care across twenty one hospitals found no effect on mortality but was associated with earlier ICU admission [9]. The study of PEWS is challenging as the outcome measurements of mortality and critical illness thankfully, have a low incidence in children, as such any detection of a statistically significant effect is difficult. However, there are published studies showing potential for the use of PEWS in the emergency department as a predictor of hospital admission [10 – 12].

PEWS also has the potential to be used in pre-hospital care and by ambulance services. Most ambulance services routinely collect the physiological data required to calculate a PEWS. Our previous study showed that a single elevated PEWS Scotland when a patient is assessed by ambulance staff is associated with a higher risk of adverse outcome (ICU admission or death within 30days) [13]. There is also potential to simplify the process with the use of an abbreviated, or quick PEWS (qPEWS). which we have also shown to be associated with a higher risk of an adverse outcome [14].

Subsequently, there is interest at looking at a further progression of this work and whether any EWS is a potentially useful tool in predicting hospital admission. A review of the literature reveals seven studies specifically looking at PEWS as a method of predicting hospital admission. Two studies calculated the AUROC for predicting ward admission: one study in Thailand calculated an AUROC of 0.71 (95%CI: 0.66–0.75) [15] and another study an AUROC 0.690 [16] defining it as a fair or poor test.

Generally studies found that increasing the cut off for PEWS score increased sensitivity for admission but decreased specificity, as shown in table one. One study found that a PEWS ≥3 resulted in an odds ratio of admission 4.1 p<0.001 [12], with a separate study reporting that a single point increase in PEWS increased the odds of admission 54% relative to the odds of discharge (odds ratio 1.54; 95% CI, 1.32-1.81) [17]. An evaluation of ten different PEWS in the ED found an AUROC for hospital admission ranging between 0.56 (95% CI 0.55-0.62) and 0.68 (95% CI 0.66-0.69) for the scores [10].

These studies show there is no clear consensus regarding a cut off for PEWS which indicates hospital admission, but that higher PEWS scores are associated with an increased likelihood of hospital admission. The issue is further complicated by the heterogeneous nature of the PEWS components and weightings.

We were unable to identify any studies which focus on pre-hospital PEWS and likelihood of hospital admission. Adult National Early Warning Scores (NEWS) have been validated in the pre-hospital environment and high NEWS scores are associated with poorer clinical outcomes (measured by ICU admission or death) [19]. An observational study of 790 adult patients looking at early warning scores in the Emergency Department, found a statistically significant linear correlation between increasing scores and hospital admission [20].

In summary, available evidence suggests that a higher PEWS in the Emergency department is associated with hospital admission. Therefore in our study, we examined whether pre-hospital PEWS Scotland is predictive of the need for hospital admission in children and young people being transported by ambulance.

Study Objective:

Is PEWS Scotland a predictor of hospital admission or length of stay for paediatric patients transported by the Scottish Ambulance Service?

Methods

The methods were outlined in our original paper [13] .Briefly, we studied all children (< 16 years) conveyed by the Scottish Ambulance Service to hospital from 2011 to 2015. We did not study children in cardiac arrest or children transferred between hospitals. We assigned risk scores of 3 and 1 for each (of seven) physiological variables if they deviated outside their 99%CI and 95%CI, respectively, adjusted for five age categories: Glasgow coma score; heart rate; systolic blood pressure; respiratory rate; pulse oxygen saturation; temperature; time to capillary reperfusion. We assigned a score of 1 if supplemental oxygen was given. We analysed the association of scores with a primary outcome of inpatient hospital admission, identified by linking records with the Community Health Index or NHS number. We used the physiological values recorded from the first instance that all eight variables were recorded. We did not impute missing values.

Statistical Analysis:

We used SAS® software for all analyses (version 9.4, SAS Institute Inc.; Cary, NC, USA). Categorical data are reported as percentages. Odds ratios, their 95% confidence intervals and p-values for each endpoint are estimated using logistic regression. The PEWS group and gender are considered independent variables and age as a continuous covariate. Receiver operating characteristic (ROC) curves plotting sensitivity (true positives) against 1-specificity (false positives) are used to measure the accuracy of predicting outcomes. Differences among areas under the ROC are compared using DeLong's test. Results are considered significant at a $p<0.05$ threshold (two tailed).

Results

Over the study period, 126,563 patients were conveyed by the Scottish Ambulance Service, of whom 21,202 had at least one full set of eight observations required to calculate PEWS Scotland. Regarding the final outcome of hospital admission, 102,993 had a known outcome, of whom 34,655 were admitted (33.65%). Within the study group of patients with a complete set of pre-hospital observations, 6,340 of 21,202 (29.9%) were admitted to hospital. See Figure 1. There was a statistically significant difference in the rate of hospital admission between these groups ($p<0.001$).

For those patients with missing data, these are summarised in Table 1

Demographics

On univariate analysis, pre-hospital PEWS and age are independent predictors of the outcome of hospital admission, but gender is not as shown in figure 2 and Table 2.

Further analysis of PEWS shows AUROC of 0.617 (95% CI 0.6081 - 0.6249; p<0.001), suggesting poor predictive ability of hospital admission. Gender does not significantly alter this (p=0.322) whereas addition of age increase the AUROC to 0.630 (p<0.001). See Figure 3.

Analysis of sensitivity and specifcity shows a PEWS of 4 to have optimal Youden Index, in the whole cohort. At this threshold the sensitivity is 46% and specificity is 72% to predict hospital admission. This value varies with age – see Table 3.

There was no correlation between pre-hospital PEWS and length of stay in hospital (r=0.092) (95% CI 0.068 - 0.117). A scatterplot of length of stay against PEWS is shown in Figure 4.

Discussion

This study finds that pre-hospital PEWS Scotland in an undifferentiated population of paediatric ambulance patients in Scotland is a poor predictor of hospital admission. Although age improves this statistically, it remains a poor predictor. There are no other studies identified which study pre-hospital PEWS in the paediatric population as a predictor of hospital admission. In comparison, a retrospective analysis of adult ambulance NEWS in England found that patients with a NEWS classified as 'low risk' were more likely to be discharged, with a positive association between increasing NEWS and disposition (discharged, ward admission, ICU admission, death in ED, p<0.001) [21]. PEWS in the Emergency Department has been more extensively studied, with mixed outcomes. It is confounded by the wide variety of PEWS systems studied and the heterogeneity of the presenting problems in the paediatric population. In 2016, Lillitos [14] examined 1,921 children presenting to the ED and found an AUROC for predicting hospitalisation of 0.690, not dissimilar to the 0.617 found in our study. As the cut off PEWS threshold increases, sensitivity decreases and specificity increases, with this study reporting an optimum cut off of ≥3 for a specificity of 93% and sensitivity of 32% . When examining 10 different PEWS systems in a prospective cohort of 17,943 children, Seiger reported AUROC ranging between 0.56-0.68 for predicting hospital admission [10]. Bradman has performed two studies into the use of PEWS in the emergency department. One looked at 424 patients and found that higher PEWS scores were associated with a higher likelihood of admission, again with a low sensitivity [9]. In 2014, Bradman compared triage nurse, PEWS and paediatric risk assessment score on predicting admission

and reported that PEWS ≥4 had a 15% sensitivity and 98% specificity for admission. Triage nurses were found to have a higher predictive accuracy than the other measures studied [11].

We also found no association between PEWS Scotland in the paediatric ambulance population and hospital length of stay. A study of 761 children in Oslo reported that children with a PEWS ≥3 had an average stay of three days in comparison to those with a PEWS 0-2 who had an two day average length of stay ($p<0.001$). This study took observations in the ward or emergency department rather than the pre-hospital setting. In addition, all the patients had been referred by a general practitioner which limits comparability with UK studies [22]. In a small, single centre study of 73 children with bronchiolitis, PEWS correlates with length of stay ($r=0.43$, CI 0.22-0.60), and children with a PEWS >5 have a statistically significantly longer hospital stay ($p<0.001$) [23].

Even in a cohort of patients arriving at hospital by ambulance, just under 30% require hospital admission. This overall figure hides a variation in admission rates across the paediatric age group, with hospital admission more common in younger children. These findings highlight multiple factors, apart from illness and physiological upset that influence hospital admission in children and young people. Bradman found that of paediatric patients presenting to their ED in Australia over a one week period in May 2010, 80% were discharged, although no information was given regarding how the patient arrived in the department [11], which is reflected by the national data which provides a 72% discharge rate [24]. Data from Addenbrookes hospital in the UK reports an 88% discharge rate over a 12 month period in 2013 [25]. An analysis of 887 emergency paediatric admissions to five Yorkshire hospitals showed that the majority of patients admitted had a minor illness and 61% stayed one night at most. Younger children are more likely to be admitted, with 25% of admissions representing children under 6 months of age [26]. Around half of the same cohort completed questionnaires with parents providing feedback on their perceived need for admission. Themes were that admission provided observation and reassurance in a safe environment [27]. The population in this study is an unselected group transferred by ambulance, where it is likely that parental/carer concern is high. It is likely that the decision to admit children from the Emergency Department is influenced by factors other than illness severity alone.

Our study has some limitations. The initial dataset for this study included 126,563 patients, but only 21,202 had a complete set of observations and known outcome data. This suggests that the sample of data analysed may not represent that sample of patients transported by the Scottish Ambulance Service. As detailed within Fig 1, there are a number of reasons for non inclusion in the study. The largest group not included are those with missing data. In order to be included within the study a patient had to have all eight PEWS components recorded contaemparaneously in the pre-hospital

environment. As pseudoanonymised data, the dataset only includes age ands gender information therefore it is difficult to make detailed comparison between the sample and population and any potential differences.

In addition, as this population represents only the children transported by ambulance, it is not easy to generalise to the wider population of children presenting to the Emergency Department, or to other pre-hospital settings. Although it is impossible to tell the PEWS of the children with incomplete data sets, studies in the Emergency Department suggest that children with traumatic injuries are more likely to have incomplete vital sign documentation.

In addition, there are potential limitations to the use of PEWS Scotland and other PEWS in the pre-hospital environment. Factors such as the temperature and capillary refill will be affected by the environment [28], and the impact of distress on paediatric observations. Seiger's study into PEWS documentation in the Emergency Department found that oxygen saturation and blood pressure were the vital signs most likely to be omitted [10]. Our previous study [14] showed that an abbreviated PEWS score (qPEWS) performed as well as a full PEWS in predicting adverse outcome in the pre-hospital environment and the use of qPEWS may be a focus for future research in the pre-hospital environment. One study [16], which was a single centre urban study undertaken in winter in a mixed adult and paediatric ED undertook a subgroup analysis. They found that PEWS is a good predictor of significant respiratory illness, of which there were a large proportion of in their study. Similarly, Chaiyakulsil [15] examined 1,136 paediatric medical patients over one month in a tertiary centre in Japan, and whether their PEWS in the Emergency Department predicted disposition. They reported an AUROC of 0.71 (95% CI 0.66-0.75), suggesting the ED PEWS may be a better predictor of admission in subgroups of paediatric emergency presentations . In our study we did not analyse predictive value based on presenting complaint and this may be an area for future research.

Overall, while PEWS Scotland is a useful indicator of severity of illness and potential adverse outcome in the pre-hospital paediatric population, our data show that it is not specific or sensitive enough to be used in isolation around the need for hospital admission.

Competing interest statement- "All authors have completed the Unified Competing Interest form (available on request from the corresponding author) and declare: no support from any

organisation for the submitted work [or describe if any]; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years [or describe if any], no other relationships or activities that could appear to have influenced the submitted work [or describe if any]

Contribution: AC conceived the concept for the project. ES & HS undertook data management and analysis. AC, KB,HS,ES,LC & KR all contributed to multiple drafts of the manuscript. KR is the guarantor for the manuscript.

Transparency declaration - KR affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

The Caldicott Guardian National Scrutiny Process for Scotland approved this study, as did the Greater Glasgow and Clyde NHS Board for research and development. We did not seek ethical approval.

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