# Paediatric early warning scores are predictors of adverse outcome in the pre-hospital setting

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**Title: Paediatric Early Warning Scores are predictors of adverse outcome in the pre-hospital setting: a national cohort study**

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**Abstract**

**Introduction**

Physiological deterioration often precedes clinical deterioration as patients develop critical illness. Use of a specific Paediatric Early Warning Score (PEWS), based on basic physiological measurements, may help identify children prior to their clinical deterioration. NHS Scotland has adopted a single national PEWS – PEWS (Scotland). We aim to look at the utility of PEWS (Scotland) in unselected paediatric ambulance patients.

**Methods**

A retrospective cohort of all ambulance patients aged under 16 years conveyed to hospital in Scotland between 2011 and 2015. Patients were matched to their 30 day mortality and ICU admission using data linkage.

**Results**

Full results were available for 21,202 children and young people (CYP). On multivariate logistic regression, PEWS (Scotland) was an independent predictor of the primary outcome (ICU admission within 48 hours or death within 30 days) with an odds ratio of 1.403 (95%CI 1.349 to 1.460, $p<0.001$). Area Under Receiving Operator Curve (AUROC) for aggregated PEWS was 0.797 (95% CI 0.759 to 0.836 ,$p<0.001$). The optimal PEWS using Youlden's Index was 5.

**Discussion**

These data show PEWS (Scotland) to be a useful tool in a pre-hospital setting. A single set of physiological observations undertaken prior to arrival at hospital can identify a group of children at higher risk of an adverse in-hospital outcome. Paediatric care is becoming more specialised and focussed on a smaller number of centres. In this context, use of PEWS in the pre-hospital phase may allow changes to paediatric pre-hospital pathways to improve both admission to ICU and child mortality rates.

## Introduction

Each year approximately 350 to 450 infants, children and young people (CYP) die in Scotland. Similar to figures across the UK, the majority of deaths occur in children under one year of age, with the second largest number of deaths occurring in the 15 to 18 year old age group [1].Child mortality rates fare particularly poorly in the UK compared to the rest of Europe and the UK has the greatest "excess mortality" of any country in western Europe. A recent report by Healthcare Quality Improvement Partnership (HQIP) Clinical Outcome Review Programme (CORP): Child Health, confirmed there are also variations between the 4 home nations with Scotland having the greatest "excess mortality" from injuries over the age of 10 years with 146 additional deaths compared to England. It is important, therefore that measures are taken to improve recognition and management of the seriously ill or injured child across the health service [2].

NHS Scotland is committed to improving the outcome of Child and Maternal Health as evidenced by their inclusion in the Scottish Patient Safety Programme. An important element in improving the care of any deteriorating patient is early identification and early intervention, both of which have been shown to improve outcomes [3,4]. This has been followed through with a commitment from the Scottish Patient Safety Programme to make the development and implementation of a single national Paediatric Early Warning Score (PEWS Scotland) a priority [5].

Physiological deterioration often precedes clinical deterioration as patients develop critical illness [6, 7]. Recognition of this has led to the development of Early Warning Scoring (EWS) systems, which have allowed earlier identification of physiological deterioration[8-10]. By assigning numerical values to various physiological parameters, a composite score can be assigned to a patient, allowing early identification of those at risk of critical illness. EWS were initially established to assist in the management of adult patients in the general ward setting [11,12]. More recently, studies have looked at the use of EWS in the Emergency Department (ED) [13-15]. These studies have shown some success at identifying patients at

risk of adverse outcome such as ICU admission or death, however this has not been without controversy [16]. Notwithstanding this, the use of a standard National adult EWS (NEWS) across the NHS in the United Kingdom has been recommended to improve patient care [17]. Due to the standardised approach to the assessment of the critically ill adult, NEWS has become a common language to communicate illness severity across the patient journey [18]. The use of multiple different scoring systems which happened prior to NEWS implementation in the adult population, has the potential to result in staff across the patient care continuum speaking at cross purposes, with warning signs being missed, and ultimately patient care being compromised.

Children and young people have different physiological responses to illness and injury compared to adults. Paediatric Early Warning Scores (PEWS) have been developed in response to this to detect the early deterioration of the hospitalised child [19] . These studies have looked specifically at Paediatric Early Warning Score (PEWS) in the Emergency Department (ED) and whether this can be useful in predicting outcomes such as need for admission to hospital and significant illness [20,21]. These studies have shown PEWS to be specific but not sensitive for these outcomes in ED. Whilst need for admission is an important outcome for ED patients, need for critical care and mortality are arguably more important outcomes. In the paediatric population, using the outcome of critical care need and death are challenging due to the low incidence of these outcomes in the general paediatric population.

PEWS also has the potential to be used in prehospital care and ambulance services. Most ambulance services routinely collect the physiological data required to calculate a PEWS. An agreed PEWS score of greater than a specific level could be used as a trigger for ambulance service pre-alert of a receiving ED. However, controversy exists as to whether any EWS is valid in the prehospital environment although there are now some data that supports the validity of EWS in predicting adverse outcome in an adult population [22, 23]. As was initially seen with adult early warning scores, a plethora of paediatric scores and systems are in use within hospitals in the UK. The NHS within Scotland have agreed a

standardised single scoring system to be used in all hospitals within Scotland – PEWS (Scotland).

In summary, the identification of unwell children can be challenging, particularly as the proportion of paediatric patients with serious illness or injury is lower than that in a general adult population, and particularly in the prehospital environment where information can be less easily available than in the hospital environment. We wished to investigate the utility of PEWS (Scotland) at identifying children at risk of an adverse outcome in an unselected paediatric ambulance population.

**Study Objective:**

Is the PEWS (Scotland) a predictor of outcome in unselected out of hospital paediatric patients? Specifically, is PEWS (Scotland) a predictor of outcome, namely ICU admission within 48 hours or mortality within 30 days, for unselected paediatric patients transported by the Scottish Ambulance Service?

**Setting & Population**

All paediatric patients aged less than 16 years old on the date they are conveyed by the Scottish Ambulance Service (SAS) to hospital over a 5 year period from 2011 to 2015. The design was a retrospective cohort study.

**Methods**

**Data Definitions:**

The national PEWS (Scotland) contains seven physiological parameters (Appendix 1), each of which is assigned a value of between 0 and 3 inclusive as well as a score for being on supplemental oxygen or not (0 and 1 for supplemental oxygen).

For the purposes of the primary outcome, the first complete record of PEWS (Scotland) was used for analysis. The first complete record is defined as the first set of observations

taken by an attending ambulance crew where all eight parameters required for a PEWS (Scotland) score to be calculated were taken.

30 day mortality was defined as death within 30 days of SAS attendance to a patient, including all causes and those deaths occurring in the community. ICU admission was defined as admission to a level 3 (ICU) bed within 48 hours of SAS attendance to a patient.

**Data Collection / Data Linkage**

SAS Paramedic crews routinely collect patient observations in an electronic Patient Report Form (ePRF) on every patient encounter. This occurred for the duration of the study period.

The data from the time period required for the study was extracted from the SAS electronic patient report forms (ePRF), by an Information Services Manager within the SAS National Headquarters. It was then encrypted and sent via secure transfer to the research nurse. The data were then extracted into individual patient datasets, in order to be able to supply identifiers for data linkage. They were then anonymised, and the required variables necessary for linkage were transferred to Information Services Division (ISD) Scotland. ISD provides health information, health intelligence, statistical services and advice that support the NHS in progressing quality improvement in health and social care. Data were linked for mortality, hospital admission, total length of stay, ICU admission, length of stay in ICU and death in ICU, using the Unscheduled Care Datamart. The linked data were then sent back to the research nurse, where they were then matched to the full dataset. This dataset contained all physiological parameters for patients and these were used to calculate PEWS retrospectively.

**Linkage Process**: SAS incident numbers and Call Start Date were matched into a database held by ISD: the Unscheduled Care Datamart (UCD). Where this linking process produced a valid Community Health Index (CHI) or NHS number, further information on the inpatient admission/deaths associated with that SAS incident was extracted. The UCD is

a collaboration between Information Services Division, NHS 24 and the Scottish Ambulance Service (SAS). The UCD securely links data from NHS 24, the Scottish Ambulance Service, Out of Hours Primary Care services, Accident and Emergency services, Acute Hospital Admissions, Mental Health and Deaths to show patient journeys.

**Ethical approval**

Ethical approval was not sought for this study. Information Governance approval was sought through the Caldicott Guardian National Scrutiny Process for Scotland (ref 2015-23 VESPA), who approved the study design and the use of personal health data from multiple health boards in Scotland. Research & Development approval was also granted by NHS Greater Glasgow & Clyde Health Board (GN15AE477).

**Statistical Analysis**

Demographic variables are presented as mean ± standard deviation or quartiles or frequency and percentage as appropriate.

The odds ratios (with 95% confidence interval) are presented from a multivariable logistic regression models for the primary endpoint with age, gender and PEWS. The area under the Receiver Operating Characteristic (AUROC) curve and 95% confidence intervals were found. Youlden's index was used to determine the optimum threshold. The statistical analyses were performed using the statistical package SAS, version 9.4. All tests were applied with a 2-sided significance level of 5%.

**Exclusion Criteria:**

Patients in cardiac arrest on arrival of SAS crew

Incomplete data collection

Interhospital transfers

**Results**

Over the study period, a total of eligible 126,563 patients were attended by SAS. After exclusions, 21,202 children had fully matched data that were available for analysis. A breakdown of the reasons for exclusion is given in Figure 1.

Figure 1. Patient inclusion in the study

The demographics for the study group of 21,202 patients where all required PEWS (Scotland) data were available and the population of 102,993 patients with known outcome data are summarised in Table 1.

| | Full PEWS (Scotland) data available | Known outcome data | Comparison between full PEWS (Scotland) data available or not |
|---|---|---|---|
| Number of patients | 21,202 | 102,993 | |
| Mean Age (years) ± SD | 10.0 ± 4.6 | 5.8 ± 5.1 | p< 0.001 [1] |
| Gender:Male ( %) | 11,130 (53.8) | 58,108 (57.0) | p< 0.001 [2] |
| Admission to ICU within 48 hours (%) | 151 (0.7) | 1053 (1.0) | p< 0.001 [2] |
| Death within 30 days (%) | 26 (0.12) | 153 (0.15) | p = 0.317 [2] |
| Primary endpoint (%) | 176 (0.83) | 1178 (1.14) | p< 0.001 [2] |
| Median PEWS (Scotland) score (Q1, Q3) | 2 (1, 4) | n/a | |

[1] Two-sample t-test. [2] Fisher's exact test

Table 1. Demographics of study population

For the primary outcome of ICU admission within 48 hours and or death within 30 days, there were 102,993 patients with a known outcome. Of these 102,993 patients, 1053 (1.02%) were admitted to ICU within 48 hours and 153 (0.15%) died within 30 days.

1178/102993 (1.14%) had the primary outcome of ICU admission and or death within 30 days.

Within the study group where a first complete set of observations was made, the primary outcome measure of ICU admission and / or death within 30 days occurred in 176/21202 (0.83 %).

The mean PEWS (Scotland) score in the study group of 21,202 patients was 2.95, and the distribution of PEWS (Scotland) in this group is shown in Figure 2.

Multivariable logistic regression analysis showed that PEWS (Scotland) but neither age nor gender were independent predictors for the primary outcome– see Table 2.

| Effect | Odds Ratio | 95% CI and p value |
|---|---|---|
| **Gender Female vs Male** | 0.930 | ( 0.686 - 1.261) ; p = 0.639 |
| **PEWS (Scotland)** | 1.403 | ( 1.349 - 1.460) ; p = <0.001 |
| **Patient Age** | 1.003 | ( 0.972 - 1.035) ; p = 0.854 |

Table 2. Multivariable analysis of primary outcome

Using the PEWS (Scotland) composite score as the explanatory variable showed an area under the curve (AUC) for the primary outcome of 0.797 (95% CI 0.759 to 0.836, p<0.001). This is shown in Figure 3.

Sensitivity, specificity, positive predictive value and negative predictive value are shown in Table 3. The optimal value for PEWS using Youlden's index was 5.

| PEWS score | Frequency | Sensitivity | Specificity | Positive Predictive Value | Negative Predictive Value |
|---|---|---|---|---|---|
| **0** | 2740 | 1.000 | 0 | 0.0083 | . |
| **1** | 5235 | 0.960 | 0.130 | 0.009 | 0.997 |
| **2** | 3396 | 0.881 | 0.378 | 0.012 | 0.997 |
| **3** | 2686 | 0.841 | 0.539 | 0.015 | 0.998 |
| **4** | 2447 | 0.807 | 0.667 | 0.020 | 0.998 |
| **5** | 1516 | 0.710 | 0.783 | 0.027 | 0.997 |
| **6** | 985 | 0.619 | 0.854 | 0.034 | 0.996 |
| **7** | 809 | 0.540 | 0.900 | 0.043 | 0.996 |
| **8** | 487 | 0.432 | 0.938 | 0.055 | 0.995 |
| **9** | 306 | 0.364 | 0.960 | 0.071 | 0.994 |
| **10** | 212 | 0.278 | 0.974 | 0.082 | 0.994 |
| **11** | 161 | 0.199 | 0.983 | 0.091 | 0.993 |
| **12** | 111 | 0.136 | 0.991 | 0.108 | 0.993 |
| **13** | 48 | 0.085 | 0.995 | 0.135 | 0.992 |
| **14** | 27 | 0.051 | 0.997 | 0.143 | 0.992 |
| **15** | 23 | 0.045 | 0.999 | 0.222 | 0.992 |
| **16** | 8 | 0.011 | 0.999 | 0.154 | 0.992 |
| **17** | 4 | 0.000 | 0.99976 | 0.000 | 0.992 |
| **18** | 1 | 0.000 | 0.99995 | 0.000 | 0.992 |
| **19** | 0 | 0.000 | 1 | . | 0.008 |

Table 3. Sensitivity and specificity of PEWS (Scotland) by PEWS value

## Discussion

We believe this to be the first study to demonstrate that any PEWS recorded in paediatric ambulance patients can predict outcome; specifically ICU admission within 48 hours or death within 30 days for an unselected group of paediatric ambulance patients aged under 16 years. The study group are a national cohort with a robust follow up of 30 days.

Despite their widespread adoption[24] the utility of PEWS in inpatient settings for which they are designed, has long been debated[25] and is only just emerging in systematic reviews.[26-28] This controversy extends to PEWS in the ED[16,19-21,29] and they are still not incorporated into teaching on Advanced Paediatric Life Support Courses, due to insufficient evidence of benefit to patient outcome.[30] Despite evidence demonstrating the National Early Warning Score (NEWS) to be predictive of outcome in adults conveyed by ambulance,[22, 23] it has been suggested that prehospital PEWS may be a step too far[31].

If early warning scores are to live up to their name then identifying an ill child at the earliest point in their health care journey has the potential to lead to earlier intervention and improved outcomes. Demonstrating the utility of PEWS (Scotland) to identify patients at the time of ambulance conveyance is therefore a significant new contribution.

In the case of ambulance patients it can be postulated that PEWS (Scotland) may be of benefit in giving ambulance crews an objective measure on which to pre-alert a receiving ED to the arrival of an unwell paediatric patient. With the changing structure of receiving arrangements for paediatric patients, PEWS (Scotland) could allow for re-routing patients to appropriate receiving centres, when it is recognised that there is an increased risk of requiring active intervention including admission to intensive care, or the skills of a trauma team. Children have higher physiological reserve than adult patients and can often cope well in the early phases of illness or injury but then demonstrate a rapid decompensation, with measurable changes in physiological markers or PEWS. Reversing the decompensation in, for example sepsis, at this stage can be challenging and time critical.[32] In an attempt to maximise "early warning", the design of paediatric scoring systems take this compensation phase into account and are often criticised for being too sensitive and non specific at low scores, or too specific but not sensitive enough at higher scores.[19, 25] Using a PEWS in a group of patients or environment for which they were not designed can also cause issues with trade off of sensitivity and specificity.[19, 33, 34] As such each PEWS system has a recommended score to escalate care within that environment, with the assumption that specificity increases with increasing score.

Youlden's index in this study of PEWS (Scotland) demonstrates optimal sensitivity (0.71) and specificity (0.78) at a PEWS of 5. It is conceivable therefore that a PEWS (Scotland) of 5 could be recommended as the threshold for pre-alert or enhanced prehospital professional to professional advice. As the PEWS (Scotland) increases it becomes less sensitive but more specific so setting inflexible thresholds risks increasing proportions of patients with false negative scores. However, using a PEWS (Scotland) of 5 as the sole criteria to pre-alert receiving ED's could cause children with significant illness or injury to

be missed. Studies in ED suggest PEWS may be better at identifying medically unwell patients than surgically unwell/trauma,[19, 34] and that therefore suggests that PEWS (Scotland) can support, but not replace, triage. [33, 35]

All teaching on PEWS (Scotland) in hospital settings reiterates the importance of "staff or carer concerns" which are seen to "trump" a low score when present and contribute to the in-hospital PEWS (Scotland) system. As this study population is an unselected group transferred by ambulance it is likely that parent/ carer concern will be high, however it may be that the sensitivity of the score could be enhanced by the tacit knowledge input of the paramedic crew.[36] Further research in this area is ongoing in hospital settings and could enrich this study if replicated in the ambulance service.

A survey of paramedics has shown that NEWS is used to support but not replace or override their clinical knowledge and prehospital assessment tools.[37] This is consistent with teaching on PEWS to clinical staff caring for children in hospital.

**Limitations**

*Internal validity*

Despite identifying in excess of 100,000 patients with matched data, only 21% had a complete set of observations to calculate a PEWS. Whilst the outcomes for those with a PEWS (Scotland) appear representative for the whole sample it is not clear this would hold true for the PEWS (Scotland) score itself. During the development of PEWS (Scotland) concern has been raised by prehospital clinicians that a PEWS would be difficult to calculate. It is recognised that even in hospital a full set of observations may not be taken,[35] with blood pressure rarely performed in children,[38] capillary return poorly performed,[39] a temperature difficult to interpret in cases of exposure and there can be difficulties with monitor pickup in small infants with cool peripheries. PEWS may have better predictive values in acute medical illness compared with trauma.[19, 34] All of these factors may contribute to whether a full set of observations are recorded in the

prehospital environment. We propose that further work could be done to look at which observations are most commonly omitted, whether this changes with age and subgroup analysis of trauma versus acute illness.

*External validity*

This study has defined the primary outcome as admission to ICU within 48 hours or death within 30 days. These significant outcomes are thankfully rare in children and young people. PEWS (Scotland) has been shown to recognise these outcomes for children in hospital but this is the first evidence that it can in the prehospital environment as well. It could be hoped that critically ill children would be transferred to hospital by ambulance, and those less unwell present via other modes of transport. It is not known how many critically ill children self present but it is recognised that many children taken to hospital by ambulance are discharged home without hospital admission. As this population is an unselected ambulance cohort it is not clear how the results generalise to all unwell or injured children, and care should be taken if applying the results to other prehospital settings, for example GP practice, out of hours services or minor injuries units, where a higher proportion of lower acuity illness may be seen.

The PEWS (Scotland) was developed for inpatient units drawing on the combined expertise of front line clinical staff and clinical academics, a Delphi process and extensive testing. It was validated for in hospital use by Sue Chapman's group intheir comparative paper.[40] The optimal sensitivity and specificity as per Youlden's Index is also 5 for predicting death or ICU admission for paediatric inpatients included in that inpatient study population. This comparative study[40] demonstrates that some PEWS are better at predicting outcome than others. The PEWS (Scotland) had an AUROC of 0.81 which would place it 9$^{th}$ in the comparison table (unpublished data). It cannot be assumed that all PEWS would predict outcome in this, or any other, group of unselected ambulance patients. It was intended that PEWS (Scotland) would be validated for prehospital use in various settings once established in hospital practice. As a score of 5 shows optimal sensitivity

and specificity in both ambulance and inpatients, this permits a shared understanding of clinical staff throughout the patients' journey of what a score of 5 may mean.

Whilst any recognition system should be designed to identify those at highest risk of adverse outcome, many PEWS studies seek to use PEWS to predict hospital admission. It is not known if PEWS (Scotland) can be used to predict which patients transferred by ambulance require hospital admission. Should PEWS (Scotland) be used to support prehospital triage, recognition and decision making for patients requiring admission, appropriate validation should be undertaken to support safe transfer to an appropriate centre without either increasing secondary transfers or overloading major paediatric receiving units.

Lastly, as a single PEWS has been adopted through all paediatric units in Scotland this study supports the use of this scoring system in children transferred by ambulance. Whilst many teams continue to work on identifying the best PEWS for use in hospital, it is recommended that we continue to move towards a UK standardised score, both in hospital and prehospital as is seen in NEWS.

**Conclusion**

These data show PEWS (Scotland) to be a useful tool in a pre-hospital setting. A single set of physiological observations undertaken prior to arrival at hospital can identify a group of children at higher risk of an adverse in-hospital outcome. Paediatric care is becoming more specialised and focussed on a smaller number of centres. In this context, use of PEWS in the pre-hospital phase may allow changes to paediatric pre-hospital pathways to improve both admission to ICU and child mortality rates.

**Competing interests**

All authors have completed the ICMJE uniform disclosure form at http://www.icmje.org/coi_disclosure.pdf and declare:

LC – former National Clinical Lead for paediatric workstrand of Maternity and Children's Quality Improvement Collaborative, Scottish Patient Safety Programme and responsible for implementation of national PEWS (Scotland)

All other authors - no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years , no other relationships or activities that could appear to have influenced the submitted work.

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**Contributorship**

AC conceived the study and obtained research funding. AC, KR, ES, DS, LC and PK designed the protocol. ES undertook collection of data and undertook the data linkage process. HS provided statistical advice on study design and analysed the data. AC, KR, LC, DS and HS were responsible for data analysis and interpretation. AC drafted the manuscript, and all authors contributed substantially to its revision. AC takes responsibility for the paper as a whole.

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**Appendix 1. PEWS (Scotland)**

**Respiratory Rate**

| Age | 3 | 1 | 0 | 1 | 3 |
|---|---|---|---|---|---|
| 0-11m | <20 | 20-29 | 30-49 | 50-69 | >70 |
| 12-24m | <20 | 20-24 | 25-39 | 40-59 | >60 |
| 2-4y | <15 | 15-19 | 20-34 | 35-49 | >50 |
| 5-11y | <15 | 15-19 | 20-29 | 30-39 | >40 |
| >12 | <10 | 10-14 | 15-24 | 25-34 | >35 |

**Oxygen Saturations ($SpO_2$)**

| Age | 3 | 1 | 0 |
|---|---|---|---|
| all ages | <92 | 93-94 | >94 |

**$O_2$ Delivery**

| Age | 0 | 1 |
|---|---|---|
| all ages | Air | $O_2$ |

**Temperature**

| Age | 3 | 1 | 0 | 1 |
|---|---|---|---|---|
| all ages | <35 | 35-35.9 | 36-37.9 | >38 |

**Systolic BP**

| Age | 3 | 1 | 0 | 1 | 3 |
|---|---|---|---|---|---|
| 0-11m | <60 | 60-69 | 70-99 | 100-109 | >110 |
| 12-24m | <60 | 60-69 | 70-99 | 100-109 | >110 |
| 2-4y | <70 | 70-79 | 80-99 | 100-119 | >120 |
| 5-11y | <80 | 80-89 | 90-109 | 110-129 | >130 |
| >12 | <90 | 90-99 | 100-119 | 120-139 | >140 |

**Heart Rate**

| Age | 3 | 1 | 0 | 1 | 3 |
|---|---|---|---|---|---|
| 0-11m | <100 | 100-109 | 110-159 | 160-169 | >170 |
| 12-24m | <80 | 80-99 | 100-149 | 150-159 | >160 |
| 2-4y | <70 | 70-89 | 90-139 | 140-149 | >150 |
| 5-11y | <60 | 60-79 | 80-129 | 130-139 | >140 |
| >12 | <50 | 50-70 | 70-109 | 110-129 | >130 |

**Capillary Return**

| Age | 0 | 1 | 3 |
|---|---|---|---|
| All ages | <2 seconds | 2-4 seconds | >4 seconds |

**Conscious Level**

| Age | 0 | 3 |
|---|---|---|
| All ages | Alert | V/P/U |