A simple 5-point scoring system, NaURSE (Na\(^+\), Urea, Respiratory Rate and Shock Index in the Elderly), predicts in-hospital mortality in oldest old

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Abstract

Background: the mortality is high in acutely ill oldest old patients. Understanding the prognostic factors which influence mortality will help clinicians make appropriate management decisions.

Methods: we analysed prospective mortality audit data (November 2008 to January 2009) to identify variables associated with in-patient mortality in oldest old. We selected those with \(P < 0.10\) from univariate analysis and determined at which cut-point they served as the strongest predictor of mortality. Using these cut-off points, we constructed multivariate logistic regression models. A 5-point score was derived from cut-off points which were significantly associated with mortality tested in a smaller independent re-audit sample conducted in October 2011.

Results: a total of 405 patients (mean 93.5 ± 2.7 years) were included in the study. The mean length of stay was 18.5 ± 42.4 days and 13.8% died as in-patients. Variables (cut-off values) found to be significantly associated with in-patient mortality were admission sodium (>145 mmol/l), urea (≥ 14 mmol/l), respiratory rate (>20/min) and shock index (>1.0): creating a 5-point score (NaURSE: NaURS in the Elderly). The crude mortality rates were 9.5, 19.9, 34.4, 66.7, and 100% for scores 0, 1, 2, 3 and 4, respectively. Using the cut-off point of ≥ 2, the NaURSE score has a specificity of 87% (83.1–90.3) and sensitivity of 39% (28.5–50.0), with an AUC value of 0.69 (0.63–0.76). An external independent validation study (\(n = 121\)) showed similar results.

Conclusions: the NaURSE score may be particularly useful in identifying oldest old who are likely to die in that admission to guide appropriate care.

Keywords: prognostic score, mortality, oldest old, older people

Introduction

Current demographic trends suggest that in the future there will be a steady increase in the very elderly in Western societies [1]. This phenomenon is particularly seen in the oldest age group; the estimated population projections predict that in the UK there will be ~1 million people aged over 90 years of age by 2031 and will represent 1.6% of the population [2]. The number of centenarians is also increasing by 7% per annum [3]. Therefore, the oldest old are the fastest growing section of the population in the UK and other developed countries.

The oldest old often have significantly worse physical, cognitive and social functioning compared with the younger elderly. Few studies have prospectively evaluated predictors
of in-patient mortality in oldest old and previously described predictors of mortality include pressure sores, (relatively) older age, atrial fibrillation, malignant disease, admission for an acute infection, high disability level and poor physical and cognitive performance [4, 5].

We have previously reported that in the oldest old, usual predictors of outcomes such as age, higher number of co-morbidities and poor mobility were not predictive of in-patient mortality in acute hospital setting [6]. We have also previously reported that in frail patients from nursing homes (mostly elderly) who may share some characteristics of oldest old, acute illness markers are important predictors of mortality outcome [7].

We hypothesised that the acute illness markers may serve as indicators of in-patient mortality outcome in oldest old due to their narrow age range and similar levels of co-morbidity. This study aims to identify which readily available acute illness parameters are most useful in predicting the in-patient mortality outcome in oldest old admitted to hospital with an acute medical illness and also aims to develop and validate a simple scoring system that may guide the clinician in their management of oldest old in the acute setting.

Methods
This study used audit data from three UK centres: Norfolk and Norwich University Hospital (NNUH), Aberdeen Royal Infirmary (ARI) and Woodend Hospital, Aberdeen (WH). The NNUH had a catchment population of ~750,000 and the ARI and WH together had a catchment population of ~500,000. All the patients aged 90 years and over admitted to the acute medical assessment units (NNUH and ARI), or acute geriatrics wards (WH) in a 3-month period (November 2008 to January 2009) were included.

The audit entry criteria and patient-related sample characteristics have been previously reported [6]. Briefly, the data were recorded at two time points, at admission and at discharge, incorporating demographic data, presenting complaints, chronic co-morbidities, drug and social history; baseline clinical observations and standard biochemical investigations. The project was conducted as a comparative clinical audit to examine the mortality outcomes in extreme old age in English and Scottish centres. Therefore, LREC approval was not required. In line with Caldicott Principles and National Information Governance Board guidance only those who were directly involved with the clinical care had access to patient identifiable data. Anonymised, unidentifiable data were used for analysis and data were presented in an anonymised and aggregated fashion.

Statistical analysis
Statistical analyses were performed using SPSS for Windows version 17.0 (SPSS, Inc., Chicago IL, USA). Means, odds ratios (OR) and their 95% confidence intervals (CI) are reported as appropriate. The variables to be included in this study were chosen on the existing literature on acute illness markers and outcomes [8–18]. Any patients with missing values for a criterion were excluded; therefore, the data analysis for this report was based on 405 patients. The 14 patients who were excluded were missing data at random and were not significantly different from those who were included.

The most important variables were identified from the dataset by comparing values for those who did and did not die in hospital, using Student t-tests, Mann–Whitney U tests and Chi-squared tests. A univariate logistic regression analysis for in-hospital mortality outcome using the variables that were identified from the first step was then undertaken. Any predictor variable with \( P < 0.10 \) from the univariate logistic regression was included in the next step, which involved backward stepwise multiple logistic regression with in-hospital mortality as the outcome. From these variables, we tested cut-off points in the data to determine whether there were points of significance in predicting mortality. We used quartile values or clinically meaningful cut-off points when values were non-normally distributed. We tested predictability of these individual cut-off points using univariate logistic regression analysis for the mortality outcome, using those that were significant at \( P < 0.05 \).

Binary outcome variables defined by the cut-offs that were significant in univariate analyses was tested using multivariate logistic regression analysis for the mortality outcome to determine which were significant according to the same criteria. From these analyses high sodium (Na), urea (U), respiratory rate (R) and shock index (SI) [19] were found to be significantly associated with in-patient death for this group of ≥90-year-old patients. We derived this new index (NaURSE) using these criteria and assessed its usefulness in the final analysis.

In October 2012, we conducted a prospective mortality re-audit of 121 consecutive ≥90 year olds admitted to the NNUH. We used the second audit data to assess the external validity of the scoring system.

Results
Table 1 shows the sample characteristics of the study population according to the total number studied, the number of those who died and total number of those discharged alive. Of 419 patients included in the audit, 405 patients were included in this study, the mean age 93.5 years (±2.7 years) of whom 58.2% were female. Fourteen patients were excluded due to random missing data and they did not differ from the included patients in terms of sample characteristics. Seventy-five (13.8%) died as an in-patient. Several variables were found to be significantly associated with in-patient mortality in univariate analysis. They were heart rate, respiratory rate, systolic BP, Glasgow Coma Score, \( O_2 \) saturations, haemoglobin (Hb), white cell count (WCC), C-reactive protein (CRP), albumin, urea, creatinine, sodium and being

Simple 5-point scoring system, NaURSE
Table 1. Sample characteristics in 405 patients ≥90 years old admitted with acute medical problem according to total number of study population, total number in those who died and total number in those discharge alive

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total, ( n = 405 )</th>
<th>Those who died ( n = 75 ) (18.5%)</th>
<th>Those alive ( n = 330 ) (81.5%)</th>
<th>( P )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (SD)</td>
<td>93.5 (2.7)</td>
<td>93.4 (2.68)</td>
<td>93.5 (2.89)</td>
<td>0.802</td>
</tr>
<tr>
<td>Sex, ( % )</td>
<td>Male 135 (33.3)</td>
<td>30 (40)</td>
<td>105 (31.8)</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>Female 270 (66.7)</td>
<td>45 (60)</td>
<td>225 (68.2)</td>
<td></td>
</tr>
<tr>
<td>Type of residence, ( % )</td>
<td>Home 220 (54.3)</td>
<td>38 (50.7)</td>
<td>182 (55.2)</td>
<td>0.981</td>
</tr>
<tr>
<td></td>
<td>Residential home 66 (16.3)</td>
<td>12 (16)</td>
<td>54 (16.4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nursing home 52 (12.8)</td>
<td>17 (22.6)</td>
<td>35 (10.6)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shelter 64 (15.8)</td>
<td>8 (10.7)</td>
<td>56 (16.9)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other 3 (0.8)</td>
<td>0</td>
<td>3 (0.9)</td>
<td></td>
</tr>
<tr>
<td>Type of admission, ( % )</td>
<td>A&amp;E 214 (52.9)</td>
<td>41 (54.7)</td>
<td>173 (52.3)</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>GP 189 (46.7)</td>
<td>33 (44)</td>
<td>156 (47.1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clinic 1 (0.2)</td>
<td>0</td>
<td>1 (0.3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other 1 (0.2)</td>
<td>0</td>
<td>1 (0.3)</td>
<td></td>
</tr>
<tr>
<td>Number of chronic conditions, mean (SD)</td>
<td>2.54 (1.45)</td>
<td>4.95 (2.67)</td>
<td>5.27 (3.3)</td>
<td>0.161</td>
</tr>
<tr>
<td>Number of medications, mean (SD)</td>
<td>5.21 (3.19)</td>
<td>2.35 (1.52)</td>
<td>2.58 (1.43)</td>
<td>0.720</td>
</tr>
<tr>
<td>Vital signs, mean (SD)</td>
<td>Temperature 36.4 (0.9)</td>
<td>36.4 (1.16)</td>
<td>36.4 (0.87)</td>
<td>0.545</td>
</tr>
<tr>
<td></td>
<td>Heart rate 88 (22)</td>
<td>92.7 (27.1)</td>
<td>86.9 (21.6)</td>
<td>0.047</td>
</tr>
<tr>
<td></td>
<td>Respiratory rate 20.4 (6.5)</td>
<td>22.2 (7.5)</td>
<td>19.9 (6.26)</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td>Systolic BP 139.7 (32)</td>
<td>130.2 (29.6)</td>
<td>141.8 (32.5)</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>Diastolic BP 76.4 (18)</td>
<td>75.1 (17.4)</td>
<td>76.7 (18.9)</td>
<td>0.489</td>
</tr>
<tr>
<td></td>
<td>GCS 14.3 (1.9)</td>
<td>13.7 (2.82)</td>
<td>14.5 (1.61)</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>( O_2 ) sats 95.3 (5.3)</td>
<td>93.9 (5.1)</td>
<td>95.6 (5.3)</td>
<td>0.015</td>
</tr>
<tr>
<td>Haematology and biochemistry results, mean (SD)</td>
<td>Hb 12.5 (5.4)</td>
<td>13.7 (11.7)</td>
<td>12.3 (2.1)</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td>WCC 11.2 (6.2)</td>
<td>13.5 (9.5)</td>
<td>10.6 (5.1)</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>CRP 64.7 (81)</td>
<td>100.1 (102.6)</td>
<td>56.7 (74.1)</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Albumin 35.7 (5.9)</td>
<td>33.8 (5.1)</td>
<td>36.2 (5.9)</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>Urea 12.2 (8.4)</td>
<td>16.2 (12.4)</td>
<td>11.3 (6.8)</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Creatinine 123.4 (69)</td>
<td>149.1 (112.9)</td>
<td>117.5 (54.3)</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Sodium 138.5 (5.8)</td>
<td>141.0 (8)</td>
<td>138.0 (5.1)</td>
<td>0.000</td>
</tr>
</tbody>
</table>

\( ^a \)Continuous data show mean, standard deviation and \( P \)-value using independent \( t \)-test.

\( ^b \)Categorical data show number and percentage and \( P \)-value using Pearson’s Chi-square.

\( ^c \)Non-parametric data using the Mann–Whitney \( U \) test.

admitted from a nursing home. At the multivariate level, only SI (heart rate/systolic blood pressure) [19], respiratory rate, WCC, CRP, albumin, urea and sodium were independent predictors (data not shown).

The best cut-off values for those variables that proved significant after logistic regression against the outcome of their relationship with in-patient mortality were albumin >35 g/l, CRP >100 mg/l, respiratory rate >20/min, SI >1.0, sodium >145 mmol/l, urea >14 mmol/l and WCC >20 \times 10^9 /l (Supplementary data available in *Age and Ageing* online, Table S1).

Table 2 shows the independently significant acute illness markers after multivariate logistic regression. Sodium >145, urea >14, respiratory rate >20 and SI >1.0 were found to be significant in terms of predicting in-patient mortality. Determining whether patients’ score for each of these cut-off point criterion gives a person a score out of 4.

Table 3 shows the sensitivity and specificity of the various NaURSE score categories. The specificity rises from 54.4% for score >0 to 100% for score >3; whereas the sensitivity goes from 74.7% for score >0 to 2.7% for score >3. The area under the ROC curve was 0.691.

We used additional prospective audit data, not used for formulating the scoring system, to externally validate the score. This population consisted of a similar age group of patients, \( n = 121 \) and their mean age was 92.6 years (SD 2.85). Eighty-nine (73.6%) of the study population were female. Eighteen (14.9%) patients in this re-audit died as in-patients. Supplementary data available in *Age and Ageing* online, Figure S1 show the crude mortality rates (95% CI) for patients according to each NaURSE score category for both derivation and validation cohorts.

**Discussion**

The results of this study suggest that a scoring system based on one point for each for admission sodium of >145 mmol/l, urea >14 mmol/l, respiratory rate >20/min and SI >1.0 predicts in-patient mortality in patients aged 90 or over acutely.
admitted to hospital. Each point increase in score results in an exponential steep rise in the in-patient mortality rate in both derivation and validation samples. Our findings improve understanding of prognostic factors in the oldest old admitted with an acute medical problem.

Acute illness markers such as urea and respiratory rate and blood pressure have been shown to be part of clinically useful scores [20]. Other acute illness markers that have been found to be both readily available and useful in determining prognosis for patient groups are SI [8], temperature [21], high and low levels of sodium [9], high WCC [21], high CRP [22], albumin [23] and Hb [24].

Our results reinforce the evidence with regard to the usefulness of all of the parameters individually as predictors of mortality in a variety of patient populations. Sodium levels (both hyponatraemia and hypernatraemia) have been identified as prognostic indicators of mortality in acutely unwell patients and it has been recognised that any disturbance of sodium regulation predicts mortality in the frail elderly population [9]. Hyponatraemia has been identified as a significant predictor of mortality in patients with heart failure [10], whereas hypernatraemia has been identified as a significant predictor of in-patient mortality especially in older patients and those with febrile illness or cerebro-vascular deficit [11]. This study relates to admission values in the oldest old patients, thus high sodium levels identify those most acutely unwell and frail, who are those most likely to die during that admission.

High levels of urea have been associated with mortality in patients with COPD [12], heart failure [13], terminal cancer [14], acute coronary syndrome [15], ischaemic colitis [16], acute pancreatitis [17], pneumonia [25] and *Clostridium difficile* colitis [26]. This study reinforces current evidence about high levels of urea being associated with poor outcome. There is variety of definitions of ‘high levels’ of urea, however, and this study’s cut-off point of ≥14 mmol/l reflects the older and chronicity of the population studied.

Similar to other studies, the high respiratory rate was found to be associated with in-patient mortality. This parameter has especially been noted for patients with pneumonia [10] and patients with terminal cancer [14]. Indeed, the CURB-65 score uses increased respiratory rate and raised urea for predicting severity of community acquired pneumonia. The levels identified in the literature vary from 24/min [25], to ≥25/min [10] to over 30/min [27]. However, this paper found a lower level—of over 20/min—to be predictive of mortality. This reflects the fact that the patients here are not exclusively respiratory patients (19% had pneumonia [6]).

SI, defined as the ratio of heart rate to systolic blood pressure, ≥1.0 has been found to be an accurate predictor of 30-day mortality in patients with community acquired pneumonia [8] and acute pulmonary embolus [18]. Other studies have found low blood pressure and fast heart rate are predictive of mortality in patients over 80 with acute coronary syndrome [28]. Low blood pressure is a predictor of mortality in severe pneumonia [29] and tachycardia is a predictor of mortality in terminal cancer patients [14].

The current literature, therefore, confirms that these are good acute markers for mortality in hospital patients. Bringing them together in this particular patient-group gives clearest indication of the particular prognostic clinical markers in the oldest old patients admitted for any cause into an acute hospital. However, it is interesting to note that other variables are not significant markers of in-patient mortality in this study: age, sex, place of residence, comorbidities, premorbid function and mobility did not prove to be significant; neither were laboratory tests such as WCC or Hb. This may relate to the homogeneity of the group and homogeneity of their presentation in acute medical centres [29]. Further possibilities for this could be blunting of inflammatory response to acute illnesses and infection in this age group. The published literature investigating ageing physiopathology reports a low-grade inflammatory process in older people. This concept is probably related to antigenic stress throughout life that may have caused exhaustion of immunological cells, thus decreasing the capacity of the immunological system to respond to antigens [30].

This study had a relatively large sample of patients and the data were collected prospectively. Variables analysed were easily gathered, standard observations and biochemical and physiological markers which reflect acuteness of the illness condition for patients in hospital. We used objective data collected on standardised collection forms by fully qualified specialist trained investigators. This study also draws on external validation data to confirm its findings. One of the key strengths of this study was that the data came from three

**Table 2. Multivariate analysis of acute illness markers in predicting in-patient mortality in study population**

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR</th>
<th>CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shock index &gt;1.0</td>
<td>2.65</td>
<td>1.20–5.86</td>
<td>0.016</td>
</tr>
<tr>
<td>Respiratory rate &gt;20</td>
<td>1.88</td>
<td>1.08–3.27</td>
<td>0.027</td>
</tr>
<tr>
<td>WCC &gt;20</td>
<td>1.79</td>
<td>0.76–4.21</td>
<td>0.183</td>
</tr>
<tr>
<td>CRP &gt;100</td>
<td>1.48</td>
<td>0.75–2.93</td>
<td>0.258</td>
</tr>
<tr>
<td>Albumin &gt;35</td>
<td>1.08</td>
<td>0.59–1.97</td>
<td>0.812</td>
</tr>
<tr>
<td>Urea ≥14</td>
<td>1.93</td>
<td>1.06–3.48</td>
<td>0.031</td>
</tr>
<tr>
<td>Sodium &gt;145</td>
<td>3.37</td>
<td>1.45–7.74</td>
<td>0.005</td>
</tr>
</tbody>
</table>

**Table 3. Specificity and sensitivity of NaURSE score values in study population**

<table>
<thead>
<tr>
<th>Score</th>
<th>Specificity (%)</th>
<th>95% CI</th>
<th>Sensitivity (%)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derivation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;0</td>
<td>54.4</td>
<td>49.0–59.6</td>
<td>74.7</td>
<td>63.8–83.1</td>
</tr>
<tr>
<td>&gt;1</td>
<td>87.0</td>
<td>83.1–90.2</td>
<td>38.7</td>
<td>28.5–50.0</td>
</tr>
<tr>
<td>&gt;2</td>
<td>99.0</td>
<td>97.3–99.7</td>
<td>10.7</td>
<td>5.5–19.7</td>
</tr>
<tr>
<td>&gt;3</td>
<td>100.0</td>
<td>98.6–100.0</td>
<td>2.7</td>
<td>0.7–9.2</td>
</tr>
<tr>
<td>Validation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;0</td>
<td>47.6</td>
<td>38.2–57.1</td>
<td>94.4</td>
<td>74.2–99.0</td>
</tr>
<tr>
<td>&gt;1</td>
<td>89.6</td>
<td>82.4–94.1</td>
<td>46.7</td>
<td>24.8–69.9</td>
</tr>
<tr>
<td>&gt;2</td>
<td>99.0</td>
<td>94.7–99.8</td>
<td>5.6</td>
<td>1.0–25.8</td>
</tr>
<tr>
<td>&gt;3</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
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</tr>
</tbody>
</table>

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different sites, suggesting that the score could be used in different centres.

Potential limitations of the study are that these variables could change during a patient’s admission. We standardised our approach to ensure that the first set of observations and blood results on admission were used. Furthermore, the different centres might have different standards of care, however, analysis of mortality outcomes between centres demonstrated no significant difference between the centres ($P = 0.98$) [6]. Another important limitation is that the score has not been tested against clinical intuition. However, predicting mortality in this group is difficult and the score is therefore likely to be helpful, but a further study is needed.

The NaURSE score provides comparative specificity for predicting in-patient mortality, reflecting the exponential increase in crude mortality as the score increases. However, the score’s sensitivity is relatively weaker. This reflects a variety of factors. Some patients have secondary events after admission in hospital—such as aspiration pneumonia post-stroke—and the population is, by definition both frail and highly varied. Nevertheless, the highly specific nature of this score serves as a useful guide for a clinician first meeting a patient from this population as to particular patients at particularly high risk of mortality, allowing her to determine immediate care—whether aggressive or palliative—from the outset. The AUC score of 0.69 is modest. However, when taken in context with our cohort of patients who are aged over 90 years and who have a higher mortality rate compared with younger patients based solely on age, our score has proved to be good at predicting in-patient mortality in the acute setting among the population with high-risk mortality.

In conclusion, we found that a simple point score using easily available clinical and biochemical markers at the time of hospital admission is useful in predicting in-patients mortality in a population of hospital patients aged $\geq 90$ years. This clinical score will help decision-making for clinicians. It may also be useful in informing patients and family members about the likely prognosis. The usefulness of this score should be tested in larger samples in various acute healthcare settings in the future.

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**Key points**

- Prospective mortality audit data analysed to identify variables associated with in-patient mortality in oldest old.
- A simple point score predicts in-patient mortality in oldest old.
- Sodium ($>145$ mmol/l), urea ($\geq 14$ mmol/l), respiratory rate ($>20$/min) and shock index ($>1.0$) are included in the score.

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**Authors’ contributions**

The authors wish it to be known that, in their opinion, the first two authors should be regarded as joint first authors. A.W. and A.K. and all co-authors had full access to all of the anonymised data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. A.W.: study design, interpretation, writing and manuscript preparation. A.C.K.: study design, interpretation, writing and manuscript preparation. J.S.: supervision of data analysis and manuscript preparation. P.M.: data preparation and manuscript preparation. Y.P.: audit design, manuscript preparation and editing. Authors C.J.L., C.B. and R.L.S.: audit design, data collection and manuscript preparation. J.F.P.: manuscript preparation and editing.

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**Conflicts of interest**

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**Supplementary data**

Supplementary data mentioned in the text is available to subscribers in *Age and Ageing* online.

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**References**


