Patient risk profiling in acute medicine: the way forward?

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Summary

Background: The identification of high-risk patients could form a basis for targeted intervention following an emergency medical admission.

Methods: All emergency admissions to our institution over 12 years (2002–13) were included. An Illness Severity method based on admission laboratory parameters, previously developed between 2002 and 2007, was investigated for the 2008–13 cohort. We compared the area under the receiver operating characteristic (AUROC) to predict a 30-day in-hospital death between the original and validating cohorts using logistic multiple variable analyses. We defined six risk subgroups, based on admission laboratory data and examined the frequency of 30-day in-hospital mortality within these subgroups.

Results: About 66 933 admissions were recorded in 36 271 patients. Between 2002 and 2007, the 30-day in-hospital mortality was 11.3% but between 2008 and 2013 was 6.7% (\(P<0.001\)). This represented an absolute risk reduction (ARR) of 4.6%, a relative risk reduction (RRR) of 41.0%, and a number needed to treat of 21.6. The laboratory model was similarly predictive in both cohorts—for 2002–07, the AUROC was 0.82 (95% CI 0.81, 0.82) and for 2008–13 was 0.82 (95% CI 0.81, 0.83). Two high-risk subgroups were identified within each cohort; for 2002–07, these contained 15.0 and 30.2% of admitted patients but 95.5% of in-hospital deaths. For 2008–13, these two groups contained 15.7 and 31.0% of admitted patients but 97.0% of in-hospital deaths.

Conclusion: A previously described laboratory score method, based on admission biochemistry, identified patients at high risk for an in-hospital death. Risk profiling at admission is feasible for emergency medical admissions and could offer a means to outcome improvement.

Introduction

Acute medicine focuses on the immediate management of patients requiring emergency admission.\(^1\) The process of care delivery influences patient outcomes and as such care delivery in an acute medical admissions unit (AMAU) has been a priority of health care reform. Our institution established an AMAU in 2003 and has reported short- and long-term outcomes.\(^2\)\(^-\)\(^4\) The recent emphasis of care has been on getting senior decision makers in the form of consultant physicians engaged in active patient management both at an earlier stage of the admission and on a more continuous basis.\(^5\) Speciality ‘take’ has been advocated to improve outcomes,\(^6\) although comparable if not greater outcome improvements have not depended on such early triage.\(^4\)

Of course, the ultimate goal is to use available resources to improve clinical outcomes.
Developments such as the Medical Admission Unit have achieved considerable success. However, specific focus on prognostic variables at time of admission might offer the promise of further improvement. At admission, available parameters such as the haemodynamic status, presence of hypoxia, pyrexia and coma or altered mental status have been investigated as predictive outcome tools. Risk stratification methods have been suggested based on aggregate clinical scoring systems such as the Modified Early Warning Score (MEWS), the Rapid Acute Physiology Score (RAPS) or the Rapid Emergency Medicine Score (REMS). Mortality may be predicted based on the specific derangement of certain laboratory parameters at the time of emergency presentation; these include hypo- or hypernatraemia, hyperglycaemia, hypoalbuminemia and hyperpyrexia. Elevated serum urea had also been shown to be of prognostic significance. Broadly speaking, clinical outcomes for the entire population of hospital admissions can be predicted, using admission laboratory data. However, track and trigger systems to implement such principles have been disappointing when the translation of principle into practice has been tested.

We have described an improved prognostic method to predict clinical outcomes using physiological and laboratory data for emergency medical admissions. The aim of this study was 2-fold. First, to retrospectively confirm the utility of the laboratory predictive tool for the period (2008–13) after its initial development and validation. Second, to determine whether particular high-risk subgroups could be identified based on the laboratory data, that might permit focused intervention following an emergency medical admission.

Methods

Background

St. James Hospital (SJH) serves as a secondary care centre for emergency admissions for its local Dublin catchment area of 270,000 adults. After initial assessment, patients deemed to possibly require hospital admission are referred to one of nine teams operating a 24-h on-call roster. The ‘on-call’ system is covered by a ‘physician of the day’ and the corresponding ‘team’ (Registrar and Senior House Officers); with a post-call review round the following morning. Emergency medical patients were intended to be admitted from the Emergency Department to an AMAU opened in 2003.

There was an underlying philosophy to this reorganization of Acute Medicine. First the concept of the ‘receiving ward’ where acutely ill medical patients could be stabilized, assessed and a treatment plan devised and implemented. The ‘safari ward’ round would be eliminated with all patients in the one location for between 3 and 5 days. This required 59 acute beds based on a daily intake of ~20 patients/day. All services would be brought to one location, with institutional focus and anticipated efficiencies of one location—rather than dispersal to various wards around the hospital, whether based on ‘the next available bed’ or ‘specialty take’ concepts. Second, the AMAU was colocated with the other important services for acutely ill medical patients—high dependency (HDU) and intensive care units (ICU) and diagnostic Imaging, to aid patient flow. Third, 66 nursing and allied health professionals were recruited; as they would only care for this one patient cohort, specific expertise could be expected to develop over time. Fourth, priority was to be accorded to this patient group for ward rounds, specialty consultations and diagnostic procedures. The operation and outcome of this development to date have been described elsewhere.

Data collection

For audit purposes, we employed an anonymous patient database assembling core information about each clinical episode from elements contained on the patient administration system, the national hospital in-patient enquiry (HIPE) scheme, the patient electronic record, the emergency room and laboratory systems. HIPE is a national database of coded discharge summaries from acute public hospitals in Ireland. Ireland used the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) for both diagnosis and procedure coding from 1990 to 2005 and ICD-10-CM since then.

Data held on the database includes the unique hospital number, admitting consultant, date of birth, gender, area of residence, principal and up to nine additional secondary diagnoses, principal and up to nine additional secondary procedures and admission and discharge dates. Additional information cross-linked and automatically uploaded to the database includes physiological, haematological and biochemical parameters. For this study, data were related to all emergency general medical patients admitted to SJH in the 12 years between 2002 and 2013.

Ninety percent of patients remained under the care of the admitting consultant for the duration of their admission. Approximately 9.9% of our patients stay >30 days with a median length of stay (LOS) of 54.8 days [interquartile ranges (IQR) 38.8, 97.2], the
majority for social rather than medical reasons. Consequently, the total LOS data represents a highly skewed distribution. To more reflect the bed day position due to medical rather than social reasons, we have employed a truncated end-point (30-day cut-off) for analysis.

Derangement of hemodynamic and physiological admission parameters has been utilized to derive and validate an Acute Illness Severity Score (AISS) to predict clinical outcomes.\textsuperscript{22,27,31} From modelling laboratory data collected at time of hospital admission, we developed a predictive algorithm based on serum sodium, potassium, urea, albumin, red cell distribution width and white blood cell count. The underlying principle is that as the profile deviates away from ‘normal homeostasis’ the risk increases; this non-linear relationship has been profiled and validated. Six groups were originally defined with a 30-day mortality risk increasing in an exponential fashion with cut-offs of 1, 2, 4, 8 and 16\%.\textsuperscript{31}

The Charlson Co-morbidity index provides an evaluation of co-morbidity, the presence of one or more additional disorders (or diseases) co-occurring with a primary disease or disorder.\textsuperscript{32} The Charlson Co-morbidity index predicts the 10-year mortality outcomes for patients who may have a range of Co-morbid conditions, such as heart disease, AIDS or cancer (a total of 22 conditions). Each condition is assigned a score of 1, 2, 3 or 6, depending on the mortality; scores are then summed into three classifying groups (Groups 0, 1 and 2).

We recently described a chronic disability score, derived from counts of discharge ICD9/ICD10 codes, that strongly correlated with mortality and LOS.\textsuperscript{33} Between 2002 and 2013 with 66 933 episodes in patients admitted as a medical emergency, only 11.3\% of such episodes had no disabling disease code.

Triage categories, based on the Manchester Triage System\textsuperscript{34} were Category 1 (resuscitation), Cat 2 (very urgent), Cat 3 (urgent), Cat 4 (standard) and Cat 5 (non-emergency).

## Statistical methods

Emergency medical admissions were divided into two cohorts based on year of admission, 2002–07 and 2008–13, and comparisons were made between the two groups.

Descriptive statistics were calculated for background demographic data, including means/standard deviations (SD), medians/IQR or percentages. Comparisons between categorical variables and mortality were made using chi-square tests. We compared the area under the receiver operating characteristic (AUROC) for the previously derived AISS for our two cohorts.\textsuperscript{22}

Adjusted odds ratios (OR) and 95\% confidence intervals (CI) or incidence rate ratios (IRR) were calculated for those predictors that significantly entered the model ($P < 0.10$). Statistical significance at $P < 0.05$ was assumed throughout. Stata v.13.1 (Stata Corporation, College Station, Texas) statistical software was used for analysis.

## Results

### Patient demographics

A total of 66 933 episodes were recorded in 36 271 unique patients admitted as medical emergencies between 2002 and 2013. These episodes represented all emergency medical admissions admitted under the ‘on-call’ physician, including patients admitted directly into the AMAU, medical wards, ICU or HDU, respectively, who had completed the clinical episode or who had suffered an in-hospital death, within 30 days of admission. The proportion of males and females was 48.4 and 51.6\% respectively. The median (IQR) LOS was 4.5 (1.8, 9.0) days. The median (IQR) age was 58.2 (37.7, 75.8) years, with the upper 10\% boundary at 84.5 years. The major disease categories (MDC) by episode were respiratory (21.5\%), cardiovascular (16.8\%), neurological (18.8\%), gastrointestinal (10.4\%), hepatobiliary (5.1\%) and renal (4.5\%).

### Comparison of cohorts between 2002 and 2007 and 2008–13 (Tables 1 and 2)

Comparing the 15 965 patients of 2002–07 with the 20 305 patient cohort of 2008–13 showed similar a gender balance. The mean age increased from 57.6 years (IQR 36.5, 75.6) to 58.8 years (IQR 38.7, 76.0) ($P < 0.001$). LOS fell slightly—4.6 days (IQR 1.8, 9.3) vs. 4.4 days (IQR 1.8, 8.8) ($P < 0.001$). There was a large increase in urgent patients (Manchester Triage Category 2) seen in the Emergency Department (28.6\% vs. 48.5\% $P < 0.001$). The frequency of patients with 2–4 points of Chronic Disabling Score increased; 2 points 27.4 vs. 28.0\%, 3 points 16.2 vs. 20.1\% and 4 points 9.6 vs. 12.5\% ($P < 0.01$). Sepsis screens (blood culture requests) increased, however positive blood culture rates fell (4.1 vs. 3.2\%; $P < 0.01$). Charlson Index increased in Category 1 (25.6 vs. 19.7\%) but decreased in Category 2 (21.0 vs. 26.1\%) ($P < 0.001$). Overall the pattern was consistent with an ageing population with increased Emergency Department urgency and more Chronic Disabling Disease but similar Charlson Co-Morbidity.
Thirty-day in-hospital mortality in the two cohorts (Figures 1 and 2; Table 3)

Between 2002 and 2007, the 30-day per patient in-hospital mortality averaged 11.3% and in the subsequent period from 2008 to 2013 had fallen to 6.7% ($P < 0.001$). This represented an absolute risk reduction (ARR) of 4.6% and a relative risk reduction (RRR) of 41.0%, with a number needed to treat (NNT) of 21.6. The AISS model for a 30-day in-hospital death performed similarly in both cohorts; for 2002–07, the AUROC was 0.82 (95% CI 0.81, 0.82) and for 2008–13 was 0.82 (95% CI 0.81, 0.83). This prediction was mirrored closely by the actual data on outcomes (Figures 1 and 2).

Table 1 Cohort characteristics of emergency medical admissions (2002–13)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>2002–07</th>
<th>2008–13</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N$</td>
<td></td>
<td>15 965</td>
<td>20 305</td>
<td>0.92</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>7730 (48.4%)</td>
<td>9821 (48.4%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>8235 (51.6%)</td>
<td>10 484 (51.6%)</td>
<td></td>
</tr>
<tr>
<td>Outcome</td>
<td>Alive</td>
<td>14 160 (88.7%)</td>
<td>18 948 (93.3%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Died</td>
<td>1805 (11.3%)</td>
<td>1357 (6.7%)</td>
<td></td>
</tr>
<tr>
<td>Age (years: IQR)</td>
<td></td>
<td>57.6 (36.5, 75.6)</td>
<td>58.8 (38.7, 76.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LOS (days: IQR)</td>
<td></td>
<td>4.6 (1.8, 9.3)</td>
<td>4.4 (1.8, 8.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Manchester Triage</td>
<td>3</td>
<td>11 102 (69.5%)</td>
<td>9999 (49.2%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4571 (28.6%)</td>
<td>9851 (48.5%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>292 (1.8%)</td>
<td>455 (2.2%)</td>
<td></td>
</tr>
<tr>
<td>Sepsis status</td>
<td>None</td>
<td>11 792 (73.9%)</td>
<td>15 406 (75.9%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Negative</td>
<td>3518 (22.0%)</td>
<td>4241 (20.9%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Positive</td>
<td>655 (4.1%)</td>
<td>658 (3.2%)</td>
<td></td>
</tr>
<tr>
<td>Charlson index</td>
<td>0</td>
<td>8644 (54.1%)</td>
<td>10 844 (53.4%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>3153 (19.7%)</td>
<td>5190 (25.6%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4168 (26.1%)</td>
<td>4271 (21.0%)</td>
<td></td>
</tr>
</tbody>
</table>

Manchester triage 30-day in-hospital mortality rates were 5.5, 11.6, and 43.8% for triage groups 3+, 2 and 1, respectively. Charlson Co-morbidity groups 0, 1 and 2 had 30-day in-hospital mortality rates of 2.9, 8.8 and 22.0%, respectively.

Table 2 Chronic disabling disease and acute illness severity by time period

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>2002–07</th>
<th>2008–13</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age distribution</td>
<td>&lt;40</td>
<td>4651 (29.1%)</td>
<td>5397 (26.6%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>40–</td>
<td>3781 (23.7%)</td>
<td>5128 (25.3%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>60–</td>
<td>3387 (21.2%)</td>
<td>4335 (21.4%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>75–</td>
<td>2775 (17.4%)</td>
<td>3462 (17.1%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>85+</td>
<td>1366 (8.6%)</td>
<td>1981 (9.8%)</td>
<td></td>
</tr>
<tr>
<td>Disabling score</td>
<td>0</td>
<td>2746 (17.2%)</td>
<td>2576 (12.7%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>4722 (29.6%)</td>
<td>5431 (26.7%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4375 (27.4%)</td>
<td>5678 (28.0%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2590 (16.2%)</td>
<td>4085 (20.1%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1532 (9.6%)</td>
<td>2535 (12.5%)</td>
<td></td>
</tr>
<tr>
<td>Acute illness severity</td>
<td>1</td>
<td>634 (4.6%)</td>
<td>941 (5.1%)</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1458 (10.7%)</td>
<td>1952 (10.6%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2115 (15.5%)</td>
<td>2783 (15.1%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2264 (16.5%)</td>
<td>3289 (17.8%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>2396 (17.5%)</td>
<td>3187 (17.3%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>4816 (35.2%)</td>
<td>6290 (34.1%)</td>
<td></td>
</tr>
</tbody>
</table>

The frequency by patient and chronic disabling Score of 0, 1, 2, 3 or 4+ points was 14.7, 28.0, 27.7, 18.4 and 11.2%; their overall respective 30-day in-hospital mortality rates were 1.2, 4.0, 7.7, 13.4, and 25.4% respectively. The frequency of acute illness severity groups 1, 2, 3, 4, 5 and 6 was 4.3, 9.4, 13.5, 15.3, 15.4 and 30.6%; their respective 30-day in-hospital mortality rates were 0.13, 0.12, 0.63, 1.4, 4.7% and 23.9%, respectively.
patients presenting to and admitted from the Emergency Department does not offer an explanation as to why there should have been a mortality fall of such magnitude. The mortality differences for acute illness severity risk categories IV, V and VI were striking; between 2002 and 2007 their respective 30-day in-hospital mortality rates were 2.6, 7.1 and 30.5% [total deaths: 1700/7776 (17.9%)], compared with 0.6, 2.9 and 18.7% [total deaths: 1293/11 473 (10.1%)]. A risk profile constructed at hospital entry based on the laboratory score, shows that the top two risk groups (V and VI) for the period 2002–07 contained 15.0 and 30.2% of the admitted patients and together were responsible for 95.5% of in-hospital deaths; for the period 2008–13, these two groups contained 15.7 and 31.0% of the admitted patients and together were responsible for 97.0% of in-hospital deaths. Concentrating on the top risk group (VI) would encompass 85.6 and 89.8% of deaths for the respective periods.

**Multivariable model of 30-day in-hospital mortality (Table 3)**

We assessed the overall risk of 30-day in-hospital death, comparing the patient cohort of 2002–07 with those admitted between 2008 and 2013; the unadjusted OR showed a highly significant ($P < 0.001$) reduction in mortality over time, OR 0.56 (95% CI 0.52, 0.60). We then adjusted the univariate estimate of time related difference by other outcome variables that have been shown to be predictive of mortality in our cohort—AISS, Manchester Triage Category, Chronic Debilitating and Charlson Co-Morbidity Scores and MDCs in the respiratory, cardiovascular or neurological domains. The fully adjusted OR was 0.41 (95% CI 0.37, 0.45). The inference is that the risk profile of the 2008–13 cohort exceeded that of the 2002–07 cohort, resulting in an even greater estimate of the mortality reduction over time.

**Discussion**

Our study demonstrates that the AISS is an effective means of identifying high risk patients at the time of medical admission. Previous investigators have sought to identify high-risk patients for focused intervention; the Medical Emergency Team—an early intervention team alerted with abnormal physiological variables and with a standardized team approach was investigated to reduce the high morbidity and mortality associated with the seriously ill. Efforts have been made to predict patients at high-risk to be admitted as a medicinal emergency. A systematic review of 36 eligible papers (with 25 distinct physiological systems) noted little evidence of reliability, validity and utility; sensitivity was poor. This score has a number of advantages over alternative scoring systems. The chief of these is that it is readily and easily available at the time of medical admission. All of the data included in the current score is available on the laboratory reporting system so is not dependent on fallible factors such as access to old paper medical records or a full detailed history from a patient who may not be able to give such. Risk stratification methods which are based on aggregate clinical scoring systems such as the MEWS, the RAPS and the REMS, have
the intrinsic disadvantage that they are reactive rather than anticipatory systems, the patient must be deteriorating sufficiently to affect the included physiologic parameters to prompt intervention. While these scores are designed to promote early intervention, for some patients even this initial delay in intervention may adversely affect outcomes. The early hours of an admission are a crucial time for any patient and facilitating intervention at this time offers the possibility to improve outcomes.

Our study has a number of strengths. We have evaluated two large patient cohorts increasing the precision of our model. Our results are consistent between the two separate cohorts demonstrating the reliability of the model for predicting an in-hospital death. We would argue that a further advantage is the simplicity of the model and ease of collection of the variables, facilitating use in clinical practice.

Like any study ours also has limitations. Our institution is a large university teaching hospital, serving a deprived urban area.39 Our proposed model will require external validation particularly in smaller and rural hospitals before use in those settings. Our study and model will accurately predicting those who are likely to suffer negative outcomes following admission does not prove that intervention will improve outcomes. While it would be logical that those with the highest mortality are the most likely to benefit, not all adverse outcomes may be preventable even with optimal management. However, we have previously demonstrated significant positive influences of a variety of factors including an AMAU setting and consultant experience and volumes on outcomes following an acute medical admission and therefore improved outcomes are possible.4,40–42

In conclusion, the AISS accurately identifies patients at high risk for in-hospital death. Risk profiling at admission is feasible for emergency medical admissions and could offer a means to investigating a targeted approach in outcome improvement.

Acknowledgements

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Conflict of interest: None declared.
References


