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Rapid Emergency Medicine score: a new prognostic tool for in-hospital mortality in nonsurgical emergency department patients

T. OLSSON[1,2], A. TERENT[1] & L. LIND[1,3]
From the [1]*Department of Internal Medicine, University Hospital, Uppsala;* [2]*The Research and Development Unit, Jamtland County Council, Östersund; and* [3]*AstraZeneca R&D, Mölndal; Sweden*

Abstract. Olsson T, Terent A, Lind L (University Hospital, Uppsala; The Research and Development Unit, Jamtland County Council, Östersund; and AstraZeneca R&D, Mölndal; Sweden). Rapid Emergency Medicine score: a new prognostic tool for in-hospital mortality in nonsurgical emergency department patients. *J Intern Med* 2004; **255:** 579–587.

Objectives. To evaluate the predictive accuracy of the scoring system Rapid Acute Physiology score (RAPS) in nonsurgical patients attending the emergency department (ED) regarding in-hospital mortality and length of stay in hospital (LOS), and to investigate whether the predictive ability of RAPS could be improved by extending the system.
Design. Prospective cohort study.
Setting. An adult ED of a 1200-bed university hospital.
Subjects. A total of 12 006 nonsurgical patients presenting to the ED during 12 consecutive months.
Methods. For all entries to the ED, RAPS (including blood pressure, respiratory rate, pulse rate and Glasgow coma scale) was calculated. The RAPS system was extended by including the peripheral oxygen saturation and patient age (Rapid Emergency Medicine score, REMS) and this new score was calculated for each patient. The statistical associations between the two scoring systems and in-hospital mortality as well as LOS in hospital were examined.
Results. The REMS was superior to RAPS in predicting in-hospital mortality [area under receiver operating characteristic (ROC) curve 0.852 ± 0.014 SEM for REMS compared with 0.652 ± 0.019 for RAPS, $P < 0.05$]. An increase of 1-point in the 26-point REMS scale was associated with an OR of 1.40 for in-hospital death (95% CI: 1.36–1.45, $P < 0.0001$). Similar results were obtained in the major patient groups (chest pain, stroke, coma, dyspnoea and diabetes), in all age groups and in both sexes. The association between REMS and LOS was modest ($r = 0.47$, $P = 0.0001$).
Conclusions. The REMS was a powerful predictor of in-hospital mortality in patients attending the ED over a wide range of common nonsurgical disorders.

Keywords: cohort, emergency department, epidemiology, mortality prediction, scoring system.

Introduction

Several scoring systems for the assessment of the severity of illness have been presented during the last decades [1, 2]. They have mainly been directed to the critically ill, and their common purpose is to measure deviations in different physiological variables in order to provide an objective measurement of the severity of illness recognizable by physicians worldwide. The wide range of uses of predictive instruments has been described by Hyzy [3].

Several scoring systems have been applied to trauma patients [4–7], and Nguyen *et al.* recently described three scoring systems obtained at ED admission, but only for critically ill patients [8]. However, no scoring system has been specifically developed for all nonsurgical patients presenting to the emergency department (ED). A severity of disease classification in the Emergency room combined with an accurate description of the disease could prognostically stratify acutely ill patients and assist investigators comparing the success of new forms of therapy. This scoring index could also be used to evaluate the use of hospital resources and compare the efficacy of different EDs in a short as well as long-term perspective. The system could also have a potential as a triage instrument for nurses in the ED.

The severity of illness classification system acute physiology and chronic health evaluation (APACHE II), described by Knaus *et al.* [2] uses a point score based upon 12 routine physiological variables, together with age and previous health status for use in intensive care patients. APACHE II has been validated in both general [9–12] and surgical [13–17] intensive care patients. However, the APACHE II score includes several blood chemistry variables and is therefore not suitable for rapid scoring in the emergency room. The Mortality Probability Model II0 (MPM) published in 1985 [18], was based on data from ICUs in the USA. It was developed using logistic regression techniques to identify and weight the variables that were then included in the model. It has fewer parameters than APACHE II but still to many to be quick enough to use in the ED.

A multitude of other predictive models have been constructed for a variety of situations. Many are usually designed from and intended to be applied to specific patient populations such as Mortality in Emergency Department Sepsis (MEDS) score [19].

The Rapid Acute Physiology Score (RAPS) is an abbreviated version of APACHE II including the physiological variables pulse rate, blood pressure, respiratory rate and Glasgow coma scale (GCS). It has earlier been evaluated as a prehospital scoring system in a group of helicopter-transported patients [20].

The greatest advantage with the RAPS system as a prognostic tool in the ED would be the simplicity of the scoring procedure, since the four parameters can easily be collected even in the emergency situation. However, it would be of great value to improve the predictive accuracy of RAPS without making the system more complicated and less available. Body temperature and peripheral oxygen saturation are easy to obtain in the ED. Chronological age is a well-documented risk factor for death from acute illness independently of the severity of disease [8].

Two main questions were raised before the start of the study: first, could the abbreviated severity of disease classification system RAPS, created to be used in the prehospital setting, be useful in the ED to predict in-hospital mortality and hospital length of stay (LOS) in nonsurgical patients? Second, is it possible to modify RAPS to provide a more powerful scoring system for medical patients (Rapid Emergency Medicine score, REMS) to predict in-hospital mortality? To answer these questions data were collected in more than 12 000 nonsurgical ED patients attending the ED at our university hospital during 1 year.

Materials and methods

From October 1995 to November 1996 data were prospectively collected in 12 006 consecutive nonsurgical adult entries to the ED in the 1200-bed University Hospital of Uppsala, Sweden. If the reason for admission was cardiac arrest ($n = 52$) and the patients could not be resuscitated they were excluded, since these patients per definition would achieve a maximal score and thereby would skew the analyses. Patients with more than one parameter missing in the protocol were also excluded ($n = 203$). If only one parameter was missing ($n = 1393$), the data was later collected from the medical record. If this single parameter was not mentioned in the patients record ($n = 82$), it was regarded as normal.

The data included were gender, age, the main symptom presented at entrance, i.e. the reason for attending the ED, and six physiological measurements: blood pressure, pulse rate, GCS, respiratory rate, peripheral oxygen saturation and body temperature.

The nurse in charge of the patients applied the 6-point standard examination within 20 min following admission. The protocol was approved by the local ethics committee.

Measurements

The APACHE II uses a point score based upon values of 12 routine physiological measurements as well as age and previous health status [8]. The variables included in the APACHE II system are: body temperature, mean arterial pressure calculated from systolic and diastolic blood pressure, heart rate, oxygenation of arterial blood (PaO2), arterial pH, serum sodium, serum potassium, serum creatinine, hematocrite, white blood count and GCS. The maximal APACHE II score is 71.

The RAPS was developed by taking those elements of APACHE II easily obtained in the prehospital setting [20]. These variables were pulse rate, blood pressure, respiratory rate and GCS. The scoring procedure was identical to that of APACHE II except for GCS, which relative weight was reduced by two-thirds, compared with the APACHE II. The scoring range for each variable was 0–4 and the maximal score was 16 in the RAPS system.

Statistics

A multivariate logistic regression analysis was performed to identify independent predictors of in-hospital mortality. Based on that analysis REMS was defined. The prediction of in-hospital death by the RAPS and REMS systems was thereafter assessed by univariate logistic regression. The Spearman rank correlation method was used to determine the relationships between both scorings systems and LOS.

Validity was assessed by using the so-called split-sample technique [21]. The total sample was split into two equal parts and evaluated independently.

Discriminatory power for the scoring systems was assessed by using receiver operating characteristic (ROC) curves. The SEM and *P*-values for the ROC curves, as well as comparisons between them were calculated by the Hanley and McNeil methods [22, 23].

Calibration of the model is an evaluation of the extent to which the estimated probabilities of mortality of the model correspond to observed mortality rates. Calibration of REMS was evaluated with the Hosmer–Lemshow goodness-of-fit test [24, 25].

Statistical analyses were performed using the STAT-VIEW 5.0 package. Hosmer–Lemshow goodness-of-fit statistics was carried out using the Statistical Package for the Social Sciences (SPSS) for Windows. *P*-values below 0.05 were considered as significant.

Results

All six physiological measurements were available in 97.9% of the entries. Basic characteristics of these 11 751 patients constituting the cohort are given in Table 1.

Table 1 Baseline characteristics and hospital course for the 11 751 patients presenting to the emergency department (ED)

Age	
Mean	61.9
SD	20.7
Minimum	15
Maximum	102
Median	67
Length of stay (days)	
Mean	3.2
SD	5.7
Minimum	0
Maximum	117
Median	1
Sex (female, %)	51.6
Hospitalized (%)	55.9
In-hospital mortality (%)	2.4
Mortality within 48 h (%)	1.0

Univariate logistic regression showed all six measured physiological parameters and age to be significant predictors of mortality. When multivariate analyses was performed, body temperature and blood pressure did not independently predict mortality, whilst the other four parameters did. However, blood pressure was not removed from the scoring system as it is incorporated in both APACHE II and RAPS. Oxygen saturation contributed to the predictive accuracy and age was the strongest predictor in the multiple logistic regression analysis (Table 2). The modified system REMS was therefore defined as the sums of coma, respiratory frequency, oxygen saturation, blood pressure and pulse rate (maximal score being 4 for all) and age (maximal score being 6; for details see Table 3).

The REMS was a powerful predictor of in-hospital mortality ($n = 285$) resulting in a likelihood ratio chi-square value of 487.3 ($P < 0.0001$) in the logistic regression model and an OR of 1.40 for each point increase (95% CI: 1.36–1.45). Similar results were obtained when REMS was applied to each of the major patient groups separately (chest pain, dyspnoea, stroke and diabetes) (Table 4).

The RAPS was also a significant predictor of in-hospital death with a likelihood ratio chi-square value of 261.2 ($P < 0.0001$) and an OR of 1.47 (95% CI: 1.41–1.54). Figure 1 shows the ROC curves for REMS and RAPS. RAPS exhibited weaknesses in the sensitivity and specificity of predicting death (0.652 ± 0.019 SEM), being below the areas for the most extensively evaluated scoring systems such as APACHE II which often have AUCs between

Table 2 Univariate and multiple logistic regression for all parameters in Rapid Acute Physiology score (RAPS) and for age, body temperature and oxygen saturation. Odds ratios for in-hospital mortality given for an increase of 1-point in the score

	Univariate analysis			Multivariate analysis		
Variable	Odds ratio	95% confidence interval (CI)	*P*-value	Odds ratio	95% CI	*P*-value
0–4 saturation	2.86	2.46–3.32	0.0001	1.70	1.36–2.11	0.0001
0–4 respiratory frequency	5.01	3.71–6.76	0.0001	1.93	1.37–2.72	0.0002
0–4 pulse frequency	2.51	2.10–2.99	0.0001	1.67	1.36–2.07	0.0002
0–4 body temperature	2.46	1.98–3.06	0.0001	0.91	0.62–1.32	0.0607
0–4 coma	2.74	2.36–3.19	0.0001	1.68	1.38–2.06	0.0001
0–4 blood pressure	1.63	1.39–1.91	0.0003	1.14	0.92–1.41	0.226
0–6 age	1.45	1.25–1.70	0.0001	1.34	1.10–1.63	0.004

Table 3 The scoring procedure for the parameters in the Rapid Acute Physiology score (RAPS), peripheral oxygen saturation, body temperature and for age

	High abnormal range				Low abnormal range				
Physiological variable	+4	+3	+2	+1	0	+1	+2	3+	+4
Body temperature	>40.9	39–40.9		38.5–38.9	36–38.4	34–35.9	32–33.9	30–31.9	<30
Mean arterial pressure	>159	130–159	110–129		70–109		50–69		<49
Heart rate	>179	140–179	110–139		70–109		55–69	40–54	<39
Respiratory rate	>49	35–49		25–34	12–24	10–11	6–9		<5
Peripheral oxygen saturation	<75	75–85		86–89	>89				
Glasgow coma scale	<5	5–7	8–10	11–13	>13				
Total sum of scoring points									

Points to age has been assigned as follows (age, points): <45, 0; 45–54, 2; 55–64, 3; 66–74, 5; >74, 6.

Table 4 Odds ratios with 95% confidence intervals and *P*-values for in-hospital mortality resulting from an increase of 1-point in the REMS for different symptoms (i.e. reasons for attending the ED) are presented

Reasons for attending the ED	Odds ratio	95% CI	*P*-value	Subjects (*n*)	Mortality (*n*)
Chest pain	**1.47**	**1.36–1.60**	**0.0001**	**3234**	**59**
Stroke	**1.38**	**1.25–1.53**	**0.0001**	**831**	**46**
Coma	**1.34**	**1.16–1.56**	**0.0001**	**63**	**18**
Dyspnoea	**1.32**	**1.25–1.40**	**0.0001**	**1261**	**69**
General weakness	**1.20**	**1.08–1.32**	**0.0007**	**722**	**43**
Hyperglycaemia	**1.46**	**1.12–1.89**	**0.0048**	**324**	**8**
Asthma	**1.27**	**1.03–1.58**	**0.0261**	**290**	**5**
Fever	**1.31**	**1.03–1.67**	**0.0270**	**112**	**6**
Cough	1.30	0.99–1.70	0,0600	181	5
Arrhythmia	1.60	0.97–2.63	0.0649	419	3
Vertigo	1.29	0.85–1.90	0.260	729	2
Syncope	1.24	0.84–1.80	0.270	304	3
Epileptic seizures	1.06	0.73–1.54	0.750	245	2
Hypoglycaemia	1.00		0.999	22	2
Nausea, diarrhoea, pain in the leg etc.				3014	0
Total	**1.40**	**1.36–1.45**	**0.0001**	**11 751**	**285**

Number of subjects and number of deaths are given for each symptom. Subgroups with *P*-values below 0.05 are given in bold characters.
REMS, Rapid Emergency Medicine score; ED, emergency department; CI, confidence interval.

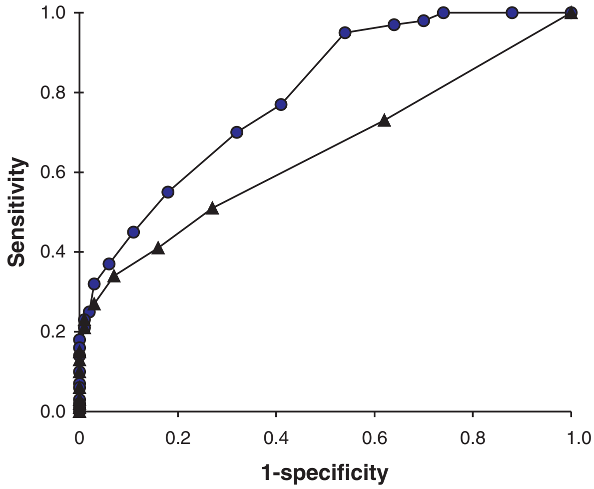

Fig. 1 Receiver operating characteristic (ROC) curves show graphically the predictive power for each test. Sensitivity is plotted on the vertical axis, whilst 1-specificity (equal to the false positive rate) is plotted on the horizontal axis. The area under the curve (AUC) determines the power of the test. Rapid Acute Physiology score (RAPS, ▲) exhibited weaknesses in the sensitivity and specificity of predicting death (0652 ± 0.019). The ROC curve for the Rapid Emergency Medicine score (REMS) system (●) was superior (area 0.852 ± 0.014) to the AUC for RAPS ($P < 0.05$).

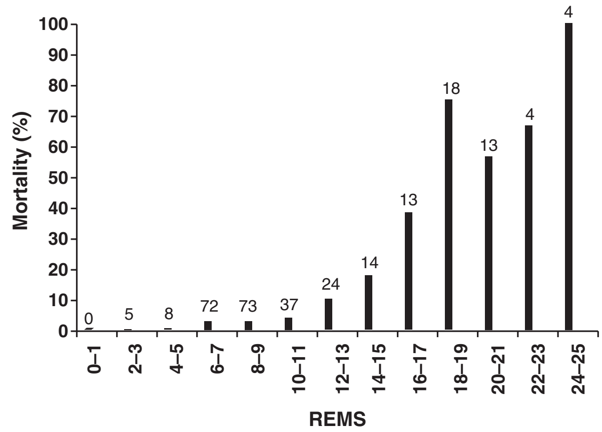

Fig. 2 In-hospital mortality in percentage and cases (n) for each Rapid Emergency Medicine score (REMS) point.

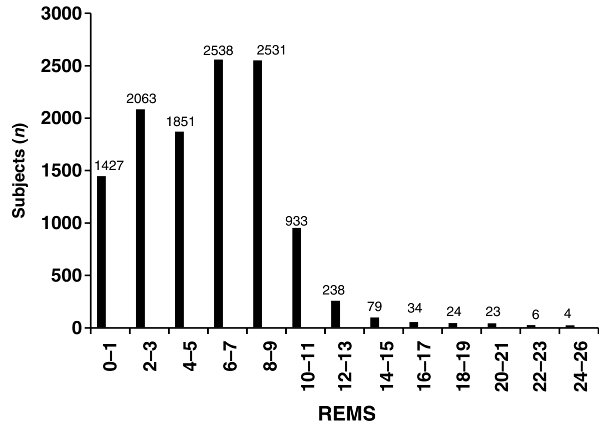

Fig. 3 Frequency distribution for Rapid Emergency Medicine score (REMS).

Table 5 Mean values with SD for age, length of stay (LOS) in hospital and scoring sums for survivors and for those who died during there hospital stay

	Survived (n = 11 466)	Dead (n = 285)	P-value
Age	61.5 ± 20.7	80.2 ± 10.6	<0.0001
LOS	3.2 ± 5.6	6.5 ± 8.3	<0.0001
REMS	5.5 ± 3.4	10.5 ± 4.9	<0.0001
RAPS	1.8 ± 1.7	4.0 ± 3.9	<0.0001

REMS, Rapid Emergency Medicine score; RAPS, Rapid Acute Physiology score.

0.8 and 0.9 in different settings [8]. The ROC curve for the REMS system had an acceptable area (0.852 ± 0.014) and showed a superior discriminating power compared with RAPS ($P < 0.001$).

The differences regarding scores, age and LOS between those who survived and those who died during their hospital stay are shown in Table 5.

Two clear-cut off points could be defined in the REMS (Fig. 2). First, all patients presenting with REMS < 3 survived. Secondly, at 24- and 25-points all the patients died. On the latter level there were only four cases (Figs 2–3). The mortality and frequency distribution are also presented for each RAPS point (Figs 4–5).

The REMS seemed to be a robust system giving similar ORs in different age groups, grouped as in the APACHE age score, although REMS was not evaluated in the youngest subgroup because of a very low mortality (Table 6).

There were almost identical ORs for REMS between men and women:1.40 (95% CI: 1.34–1.47) for men and 1.41 (1.34–1.47) for women.

The REMS was validated by the so-called split-sample method. The ORs and their 95% confidence intervals for the two parts of the population were almost identical and are presented in Table 7. Also area under curve (AUCs) and goodness-of-fit tests were comparable between the two groups.

The calibration of REMS was poor. The Hosmer–Lemeshow goodness-of-fit statistic was performed

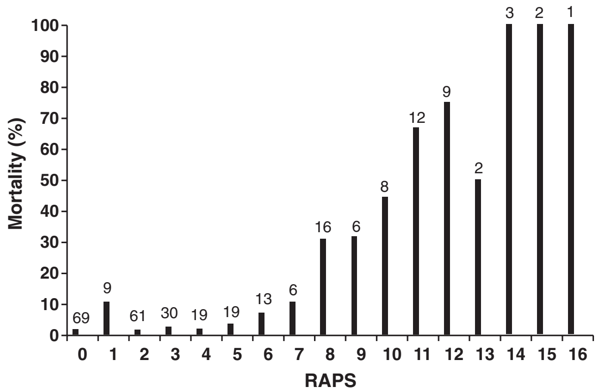

Fig. 4 In-hospital mortality in percentage and cases (n) for each Rapid Acute Physiology score (RAPS) point.

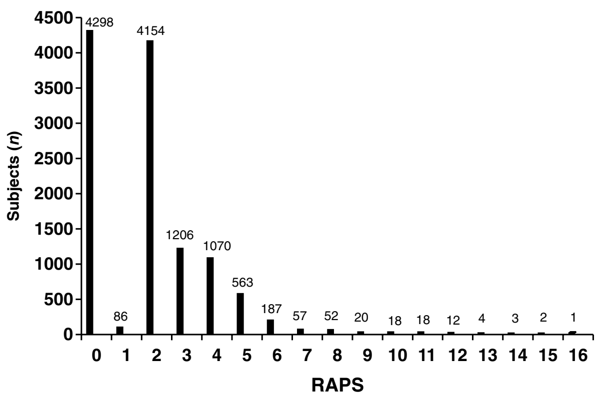

Fig. 5 Frequency distribution for Rapid Acute Physiology score (RAPS).

with deciles of risk and was found to have low degree of fit with chi-square 62, d.f. = 7 ($P < 0.0001$) (Table 8). There was a modest correlation between REMS and LOS. Spearman's rank coefficient $r_s = 0.47$, $P < 0.0001$), and a rather poor correlation between RAPS and LOS ($r_s = 0.22$, $P = 0.0001$) (see Fig. 6).

Discussion

The present study showed that RAPS developed for the prehospital setting was a predictor of in-hospital death in nonsurgical patients admitted to the ED. Moreover, the addition of peripheral oxygen saturation and age to the RAPS system, resulting in REMS, improved the predictive ability considerably. REMS is equally powerful in the major patient groups, such as chest pain, coma, stroke, diabetes or dyspnoea. The REMS system offers rapid and easily performed scoring procedure with parameters accessible in the ED and is independent of later treatment.

The association between LOS in hospital and REMS, on the other hand was of modest order. One possible explanation may be that LOS reflects not only the acute severity of illness, but also general morbidity and cognitive function in the elderly patients. Thus, the ability of REMS to predict the LOS in hospital is limited.

As peripheral oxygen saturation is measured in almost every patient in the ED, it would be very easy to expand the RAPS system by adding this parameter. As age was the strongest predictor of mortality in the multiple regression model, it seemed natural to incorporate that variable weighted as originally described in the APACHE II [8]. Blood pressure, another APACHE II parameter, did not independently predict mortality in the present study. In the original APACHE II work, however, BP was measured invasively and in most subjects continuously. In the present study, precision may have been lost by calculating mean blood pressure from a single noninvasively measured systolic and diastolic blood pressure.

Table 6 Odds ratios for each Rapid Emergency Medicine score (REMS) point increase, number of subjects and number of deaths for different age groups

Subgroups of the population	Odds ratio	95% CI	*P*-value	Subjects (*n*)	Mortality *n* (%)
Age (years)					
<45	–	–	–	2699	2 (0.07)
45–54	1.60	1.38–1.86	0.0001	1476	7 (0.47)
55–64	1.27	1.05–1.53	0.015	1298	16 (1.2)
65–74	1.43	1.29–1.58	0.0001	2012	38 (1.9)
>74	1.23	1.18–1.28	0.0001	4265	222 (5.2)
Total	1.40	1.36–1.45	0.0001	11751	285 (2.4)

Table 7 Validation of the Rapid Emergency Medicine score (REMS) with split-sample technique. Odds ratios for each point increase, area under receiver operating curve (AUC) and goodness-of-fit (GOF) with chi-square values in both the sample sets

REMS in population	Odds ratio	Confidence interval (CI)	Likelihood ratio	*P*-value	AUC	GOF	Number of cases	Number of dead
1	1.40	1.34–1.46	261	<0.0001	0.832 ± 0.016	35.3, d.f. = 7	5876	145
2	1.41	1.34–1.48	226	<0.0001	0.862 ± 0.018	31.7, d.f. = 7	5875	140

Table 8 Calibration of the Rapid Emergency Medicine score (REMS) with the Hosmer–Lemshow goodness-of-fit test [22] comparing the observed mortality with the expected mortality within deciles of risk

Deciles of risk	Observed alive	Expected alive	Observed dead	Expected dead	Total
1	1406	1403	0	3	1406
2	1531	1526	0	5	1531
3	1224	1224	8	8	1232
4	1167	1160	5	12	1172
5	1492	1524	53	21	1545
6	974	974	19	19	993
7	1660	1658	44	46	1704
8	1382	1371	50	61	1432
9	630	626	106	110	736

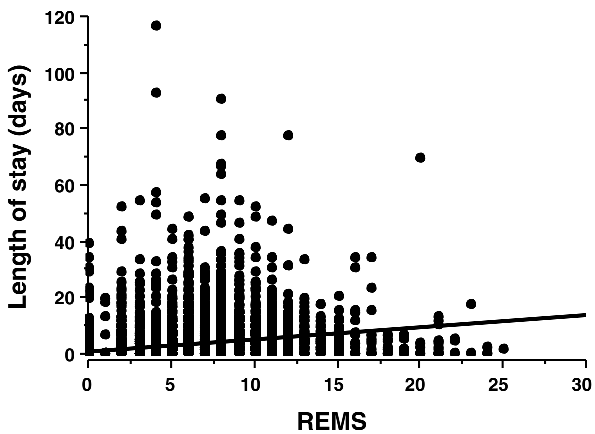

Fig. 6 The linear correlation between Rapid Emergency Medicine score (REMS) and length of stay.

The strength of the present work is a prospective design of the study with a large sample of patients collected in a consecutive way. The in-hospital mortality in the total sample was low (2.4%), but this was compensated for with the size of the data set (11 751 subjects). Furthermore, all three major demands to be considered when constructing a new severity of disease classification system were fulfilled.

First, the validity was evaluated by the split-sample technique [21] (a portion of the group from which the data were originally collected, but from which data were not used to develop the model). This method has reached standard level and, as such, is generally accepted by the medical community. Secondly, the discriminatory ability was assessed and presented in ROC curves and these were compared using an established method. Thirdly, the calibration of the scoring system, i.e. the evaluation of the extent to which the estimated probabilities of mortality of the model correspond to observed mortality rates, was calculated with the Hosmer–Lemeshow goodness-of-fit test [24]. Most of the widely used scoring systems created for the ICU setting are evaluated by this method.

Thus, the established methodology in this field [26] was strictly followed in the process of developing the REMS.

The discrimination and validity were satisfactory for the REMS, but the calibration of the model was poor. Poor fit along with good discriminative ability have been previously reported in several studies for APACHE II and other intensive care scoring systems [27–29]. Several explanations are proposed for this outcome of the Hosmer–Lemeshow goodness-of-fit test. Zhu *et al.* [30] claimed that large data sets would give significance even with small differences. Given the size of our study population, it may therefore not be surprising that the goodness-of-fit test was significant. Another answer could be variation of the data quality. Teres and Lemeshow could show great variation of data quality despite low inter-rater variability [31]. In our study, no check up for the inter-rater variability was performed. The length of hospital stay can also influence the observed mortality. One study comparing LOS and in-hospital as well as 30-day mortality, revealed higher hospital mortality in a region with longer LOS but identical 30-day mortality [32]. Knaus and coworkers included LOS as a variable in their estimation of probability of hospital death and showed a higher mortality in hospitals with a longer average LOS [33].

Another limitation in the present work was that the data only represents patients from a nonsurgical ED in a university teaching hospital. We must therefore be cautious in generalizing the results presented here to a nonuniversity or to a surgical ED. The data are now 7–8 years old. Changes in structure and process within EDs may generate different results if the study were repeated now. The methodology employed to determine validity was a split-sample technique. There is a scope for further validation using a more recent cohort of admissions.

One major advantage with REMS is its usefulness across different nonsurgical patient groups. Disease-specific scoring systems already exist, such as those designed for acute coronary syndromes [34, 35], stroke [36] and asthma [37], but most of these specific systems require collection of data not being easily available in the ED.

Further research will determine if REMS also could be useful as a severity of disease classification system for surgical patients in the ED. Specified trauma scores are used [4–7], but other surgical patients exist, such as those with acute abdominal disorders.

The standard procedure in many hospitals to date is that the nurse-in-charge triage the patients regarding symptoms, e.g. patients with chest pain are prioritized before those who are dizzy. A combined system with symptoms and REMS could be of value in this work providing both the nurse and the physician with a better and more reliable tool for triage in the ED. Specific cut-off points in the score might define those who are critically ill and have to be taken care of immediately.

Turner *et al*. claimed that scoring patients later in their illness allows better predictability and decision-making for individual patients [38]. To achieve maximum benefit from severity of illness scores these should be repeated on successive days following admission. REMS is particularly well-suited for this purpose and could have the potential of being a system of continuous monitoring of patients during transport, in the ED and later in the hospital to follow the status of the patients.

In conclusion, the present study revealed REMS as a powerful predictor of in-hospital mortality in patients attending the ED over a wide range of common nonsurgical disorders.

Conflict of interest statement

No conflict of interest was declared.

References

1 Clark C. The issues. *Emerg Med, Congressional Q Res* 1996; **6:** 3–9.

2 Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. *Crit Care Med* 1985; **13:** 818–29.

3 Hyzy RC. ICU scoring and clinical decision-making. *Chest* 1995; **107:** 1482–83.

4 Boyd CR, Tolson MA, Copes WS. Evaluating trauma care: the TRISS method. *J Trauma* 1987; **27:** 370–8.

5 Champion HR, Copes WS, Sacco WJ *et al.* A new characterization of injury severity. *J Trauma* 1990; **30:** 539–45.

6 Champion HR, Sacco WJ, Copes WS, Gann DS, Gennarelli TA, Flanagan ME. A revision of the trauma score. *J Trauma* 1989; **29:** 623–9.

7 Baker SP, O'Neill B, Haddon W Jr, Long WB. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma* 1974; **14:** 187–89.

8 Nguyen HB, Rivers EP, Havstad S *et al.* Critical care in the emergency department: a physiologic assessment and outcome evaluation. *Acad Emerg Med* 2000; **7:** 1354–61.

9 Porath A, Eldar N, Harman-Bohem I, Gurman G. Evaluation of the APACHE II scoring system in an Israeli intensive care unit. *Isr J Med Sci* 1994; **30:** 514–20.

10 Wilairatana P, Noan NS, Chinprasat S, Prodeengam K, Kityaporn D. Scoring systems for preciting outcomes of critically ill patients in northeastern Thailand. *Southeast Asian J Trop Med Public Health* 1995; **26:** 66–72.

11 Rowan KM, Kerr JH, Major E, Mcpherson K, Short A, Vessey MP. Intensive Care Society's Acute physiology And Chronic Health Evaluation (APACHE II) study in Britain and Ireland: a prospective, multicenter, cohort study comparing two methods for predicting outcome for adult intensive care patients. *Crit Care Med* 1994; **22:** 1385–91.

12 Wong DT, Crofts SL, Gomez M, McGuire GP, Byrick RJ. Evaluation of predictive ability of APACHE II system and hospital outcome in Canadian intensive care unit patients. *Crit Care Med* 1995; **23:** 1177–83.

13 Giangiuliani G, Mancini A, Gui D. Validation of a severity of illness score (APACHEII) in a surgical intensive care unit. *Intensive Care Med* 1989; **15:** 519–22.

14 Bohnen JMA, Mustard RA, Oxholm SE, Schouten BD. APACHE II score and abdominal sepsis. A prospective study. *Arch Surg* 1988; **123:** 225–9.

15 Poenaru D, Christou NV. Clinical outcome of seriously ill surgical patients with intra-abdominal infection depends on both physiologic (APACHE II score) and immunologic (DHT score) alterations. *Ann Surg* 1991; **213:** 130–6.

16 Bosscha K, Reijnders K, Hulstaert PF, Algra A, van der Werken C. Prognostic scoring systems to predict outcome in peritonitis and intra-abdominal sepsis. *Br J Surg* 1997; **84:** 1532–4.

17 Berger MM, Marazzi A, Freeman J, Chiolero R. Evaluation of the consistency of Acute Physiology And Chronic Health

Evaluation (APACHE II) scoring in a surgical intensive care unit. *Crit Care Med* 1992; **20:** 1681–7.
18 Lemeshow S, Teres D, Klar J, Avrunin JS, Gehlbach SH, Rapoport J. Mortality Probability Models (MPMII) based on an international cohort of intensive care unit patients. *JAMA* 1993; **270:** 2478–86.
19 Shapiro NI, Wolfe RE, Moore RB, Smith E, Burdick E, Bates DW. Mortality in Emergency Department Sepsis (MEDS) score: a prospectively derived and validated clinical prediction rule. *Crit Care Med* 2003; **31:** 670–5.
20 Rhee K, Fisher C, Willitis N. The Rapid Acute Physiology score. *Am J Emerg Med* 1987; **5:** 278–86.
21 Efron B. Bootstrap methods: another look at the jackknife. *Ann Stat* 1979; **7:** 1–26.
22 Hanley J, McNeil B. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology* 1982; **143:** 29–36.
23 Hanley J, McNeil B. A method of comparing the areas under receiver operating characteristic curves derived from the same cases. *Radiology* 1983; **148:** 839–43.
24 Lemeshow S, Hosmer DW Jr. A review of goodness of fit statistics for use in the development of logistic regression models. *Am J Epidemiol* 1982; **115:** 92–106.
25 Lemeshow S, Teres D, Pastides H, Avrunin JS, Steingrub JS. A method for predicting survival and mortality of ICU patients using objectively derived weights. *Crit Care Med* 1985; **13:** 519–25.
26 Meade MO, Cook DJ. A critical appraisal and systematic review of illness severity scoring systems in the intensive care unit. *Curr Opin Crit Care* 1995; **1:** 221–7.
27 Moreno R, Morais P. Outcome prediction in intensive care: results of a prospective, multicentre, Portuguese study. *Intensive Care Med* 1997; **23:** 177–86.
28 Knaus WA, Rauss A, Alperovitch A *et al.* Do objective estimates of chances for survival influence decision to withhold or withdraw treatment? *Med Decis Making* 1990; **10:** 163–71.
29 Livingston BM, MacKirdy FN, Howie JC, Jones R, Norrie JD. Assessment of the performance of five intensive care scoring models within a large Scottish database. *Crit Care Med* 2000; **6:** 1820–7.
30 Zhu BP, Lemeshow S, Hosmer DW *et al.* Factors affecting the performance of the Mortality Probability Model II system and strategies of customization: a simulation study. *Crit Care Med* 1996; **24:** 57–63.
31 Terese D, Lemeshow S. Why severity models should be used with caution. *Crit Care Clin* 1994; **10:** 93–110.
32 Jenchs SF, Williams DK, Kay TL. Assessing hospital-associated deaths from discharge data. *JAMA* 1988; **260:** 2240–6.
33 Knaus WA, Wagner DP, Zimmerman JE *et al.* Variations in mortality and length of stay in intensive care units. *Ann Intern Med* 1993; **118:** 753–61.
34 Antman EM, Cohen M, Bernink PJ *et al.* The TIMI risk score for unstable anginga/non-ST elevation MI: a method for prognostication and therapeutic decision making. *JAMA* 2000; **284:** 835–42.
35 Lindahl B, Toss H, Siegbahn A, Venge P, Wallentin L. Markers of myocardial damage and inflammation and long-term cardiac mortality in unstable coronary artery disease. *N Engl J Med* 2000; **343:** 1139–47.
36 Fiorelli M, Alperovitch A, Argentino C. *et al.* Prediction of long-term outcome in the early hours following acute ischemic Stroke. *Arch Neurol* 1995; **52:** 250–4.
37 Rodrigo G, Rodrigo C. A new index for early prediction of hospitalization in patients with acute asthma. *Am J Emerg Med* 1997; **15:** 8–13.
38 Turner JS, Potgieter PD, Linton DM. Systems for scoring severity of illness in intensive care. *SAMJ* 1989; **76:** 17–20.

Correspondence: Thomas Olsson, The Research and Development Unit, Jamtland County Council, Hospital of Östersund, S-83138 Östersund, Sweden (e-mail: thomas.olsson@jll.se).