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Preoperative Early Warning Scores Can Predict In-Hospital Mortality and Critical Care Admission Following Emergency Surgery

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Background. **EWS is frequently used to monitor acute admissions requiring emergency surgery. This study examined preoperative early warning scoring (EWS) and its ability to predict mortality and critical care admission. Postoperative EWS was also evaluated as a predictor of mortality.**

Methods. **Preoperative EWS, age, physiologic and operative severity (POSSUM) scores, ASA grade, and serology were compared in 280 patients undergoing emergency surgery.**

Results. **Two hundred eighty patients were identified with a mortality of 15%. Among the physiological scoring systems, ASA grade and POSSUM scores were the best predictors of mortality (AUC values of 0.81). EWS, APACHE II, and age were the next best predictors (AUC values of 0.70). Postoperative APACHE II and EWS both predicted mortality. EWS on day 2 postoperatively was the best overall predictor of mortality of all the variables studied (AUC value of 0.83). Survival between patients with "improving or stable" EWS and those with "deteriorating or failing to improve" EWS was also found to be significantly different ($P < 0.001$). In addition, both EWS on admission and EWS 1 h preoperatively were found to predict critical care requirement postoperatively (AUC value of 0.78).**

Conclusions. **EWS can predict the need for critical care admission and mortality following emergency surgery. In particular, the progression of EWS preoperatively, that is, whether scores improve or deteriorate, is a highly significant factor in predicting survival following emergency surgery. These findings support the use of EWS in monitoring the acute surgical patient.**

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Key Words: **EWS; POSSUM; emergency surgery; ASA; prediction.**

INTRODUCTION

In the United Kingdom, early warning scoring (EWS) is commonly used in the monitoring of the more severely ill hospital patients. EWS is a simple physiological scoring system that can be measured at the patient's bedside [1]. EWS is calculated from simple physiological parameters, which include blood pressure, urine output, respiratory rate, pulse rate, and conscious level (Tables 1 and 2). Derangement in any of these scores is assigned a number, and the sum of these numbers is used to calculate an overall early warning score. These scores can be calculated at an hourly rate to allow monitoring of patients and within most hospitals in the United Kingdom, EWS is routinely used to monitor patients who are considered at risk. There is little evidence to validate the use of EWS, however, its use has been encouraged by several professional bodies [2–4]. In a surgical setting, EWS is frequently used to monitor acute admissions requiring emergency surgery, both preoperatively and in the postoperative setting. This study examined preoperative EWS and its ability to predict mortality and critical care admission. In addition, postoperative EWS was also evaluated in predicting mortality. To our knowledge, EWS has not been validated in this setting previously.

METHODS

The case notes of all patients undergoing emergency surgery from January 2000 to the present day were identified from computerised

0022-4804/08 $36.00

TABLE 1

Systolic Blood Pressure Monitoring as Part EWS

	200	190	180	170	160	150	140	130	120	110	100	90	80
200	0	0	0	1	1	2	2	2	3	3	4	5	5
190	0	0	0	0	1	1	1	2	2	3	3	4	5
180	0	0	0	0	0	0	1	1	2	2	3	3	4
170	1	1	0	0	0	0	1	1	2	2	3	3	4
160	1	1	1	0	0	0	0	0	1	1	2	2	3
150	1	1	1	1	0	0	0	0	0	1	1	2	2
140	2	2	1	1	1	0	0	0	0	0	1	1	2
130	2	2	2	1	1	0	0	0	0	0	0	1	1
120	2	2	2	2	1	1	0	0	0	0	0	0	1
110	3	3	2	2	2	1	1	0	0	0	0	0	0
100	3	3	3	3	2	2	1	1	0	0	0	0	0
90	4	4	3	3	3	2	2	2	1	0	0	0	0
80	4	4	4	4	3	3	3	2	2	1	1	0	0
70	4	4	4	4	4	3	3	3	2	2	2	1	0
60	4	4	4	4	4	4	4	4	3	3	3	2	1
50	5	5	5	5	5	5	5	5	4	4	4	3	2
40	6	6	6	6	6	6	6	6	5	5	5	4	3

records. Inclusion criteria were all patients undergoing emergency laparotomy for suspected perforation of a viscus, obstruction, fulminant colitis, or upper gastrointestinal bleeding. Also included were patients undergoing surgery for strangulated ventral or groin herniae.

Preoperative Data

Data collected preoperatively included age, body mass index, and diagnosis. Preoperative serology was recorded, as was the physiologic and operative severity (POSSUM) score, ASA grade, and EWS. The EWS recorded was the single worst score on admission, the single worst score every 24 h prior to their operation, and the single worst score 1 h before any operative intervention. In addition to recording the individual scores, patients were further divided into those with "improving or stable" EWS and those with "deteriorating or failing to improve" EWS. Since an early warning score of 3 or above is an index of significant organ dysfunction, this was used as a cut-off value for failure in improvement. Patients whose scores improved following admission and those scoring less than 3 on admission (whose scores stayed below this) were classed in the "improving or stable" scores. Patients with scores rising above 3 from admission and those with scores that were initially above 3 and remained there were classed as having "deteriorating or failing to improve" EWS.

Operative Data

Findings from the operation were recorded, as was the duration of both the procedure and the anaesthetic.

Postoperative Data

Length of stay on critical care was recorded, as were the number of days requiring inotrope, renal, or ventilatory support. For patients not returning to the critical care unit, the single worst EWS from the first 3 d postoperatively were recorded. Since EWS is a ward-based scoring system, it was not possible to record EWS for patients in critical care. APACHE II scores for all postoperative patients were also recorded. Length of stay in hospital and in-hospital mortality were also recorded.

Statistical Analysis

Student's and Fisher exact tests were used to compare data between survivors and nonsurvivors. Receiver Operative Characteristics was used to calculate the predictive power of the various parameters examined by the study in predicting mortality. Kaplan-Meier survival curves were used to compare survival between patients with improving or deteriorating EWS. All statistical analysis was undertaken using SPSS for Windows (SPSS Inc., Chicago, IL).

RESULTS

Two hundred eighty patients were included in the analysis. There were 42 deaths in this group giving a mortality of 15%. The median age among the nonsurvivors was significantly greater than those who survived (76 y *versus* 60 y, respectively) and the proportion of patients requiring critical care postoperatively was also greater among the nonsurvivors, 66.7% *versus* 21.9%, respectively) (Table 3). All other demographic data were equal between the two groups. All preoperative physiological scoring, including ASA grade, POSSUM score, and EWS were significantly greater in the mortality group when compared to the survivors (Table 4). In addition, there was a greater percentage of patients with improving or stable EWS among the survivors (80.3% *versus* 38.1%). Haemoglobin, urea, creatinine, and albumin were also significantly different.

Among the physiological scoring systems, ASA grade and POSSUM scores were the best predictors of mortality (AUC values of 0.81) (Table 5). EWS, APACHE II, and age were the next best predictors with AUC values of around 0.70. Among the serological markers, a low albumin was the best predictor of mortality, followed by

TABLE 2

Pulse Rate, Respiratory Rate, Temperature, Alertness, and Urine Output Scoring

	3	2	1	0	1	2	3
Heart rate (per min)		<40	40 to 50	51 to 100	101 to 110	111 to 119	≥130
Respiratory rate (per min)		≤8		9 to 14	15 to 20	21 to 29	≥30
Temperature (°C)		<35		35 to 38.4		≥ 38.5	
Central nervous system				Alert	Voice	Pain	Unconscious
Urine output	Nil	<0.5 mL/kg/h for 2 h	<0.5 mL/kg/h for 1 h		>3 mL/kg/h for 1 h		
Blood pressure	See Table 1						

urea and haemoglobin (AUC of 0.79, 0.72, and 0.72, respectively) (Table 5). Postoperative APACHE II and EWS on days 1, 2, and 3 following surgery all predicted mortality. On day 2 postoperatively, EWS was the best overall predictor of mortality of all the variables studied with an AUC value of 0.83. Survival between patients with improving or stable EWS and those with deteriorating or failing to improve EWS was also found to be significantly different (Fig. 1). In addition, both EWS on admission and EWS 1 h preoperatively were found to predict critical care requirement postoperatively (Fig. 2).

DISCUSSION

EWS was originally designed to secure the presence of skilled clinical help for patients exhibiting signs of impending critical illness [5] and were not designed as predictors of outcome. However, the results from this study show that the Early Warning Scores preoperatively can predict outcome following emergency surgery and can also predict the need for admission to a critical care unit. EWS is out-performed by validated scoring systems designed specifically to predict postoperative mortality or risk, such as the ASA grade and POSSUM score, but only by a small margin. No other study has examined EWS in this setting before, although previous work has shown EWS to be able to discriminate between patients requiring intensive care unit admission in patients with surgical pathology [6].

A limitation to this study may be that for many patients, preoperative EWS was a factor that influenced the decision regarding operative intervention. For example, for patients with small bowel obstruction secondary to adhesions, a deteriorating EWS could have been viewed as a sign of impending ischaemia and hence precipitate a laparotomy. Patients who responded to resuscitation and improved their EWS were also found to fare significantly better, in terms of postoperative survival, than those who deteriorated or failed to improve on an "at-risk" initial score. A period of active resuscitation prior to surgical intervention has long been one of the main aims of the emergency surgeon, and this philosophy appears to be borne out by these findings. What has not been proven, however, is that EWS facilitates targeted therapy, which is then is able to improve the success of the resuscitation period and thus is able to reduce postoperative mortality.

The center conducting this study has no acute vascular admissions, and, consequently, the spectrum of admissions to the surgical unit is not representative of a normal surgical population. Among all the admissions, there was surprisingly only one patient presenting with upper gastrointestinal hemorrhage, and it is unclear how well EWS would function in the presence of major hemorrhage, such as that found with a ruptured aortic aneurysm. Previous studies on EWS in

TABLE 3

Pre- and Postoperative Demographics Between Survivors and Nonsurvivors

		Survivors ($n = 238$)		Nonsurvivors ($n = 42$)		
		Value	Range or %	Value	Range or %	Significance
Median age (y)		60	16 to 96	76	25 to 93	$P < 0.005$
Gender	Male	126	52.9%	17	40.5%	ns
	Female	112	47.1%	25	49.5%	ns
Diagnosis	Small bowel obstruction	40	16.8%	8	19.0%	ns
	Large bowel obstruction	34	14.3%	5	11.9%	ns
	Peritonitis	123	51.7%	20	47.6%	ns
	Strangulated hernia	22	9.2%	2	4.8%	ns
	Upper GI bleed	0	0	1	2.4%	ns
	Fulminant colitis	10	4.2%	2	4.8%	ns
	Small bowel ischemia	9	3.8%	4	9.5%	ns
Findings at laparotomy	Free fluid	101	42.4%	22	52.4%	ns
	Blood	5	2.1%	2	4.8%	ns
	Fecal soiling	47	19.7%	7	16.7%	ns
	Pus	85	35.7%	11	26.2%	ns
Median body mass index		23	15 to 42.0	22	14 to 28.6	ns
Median operation duration (min)		90	28 to 240	115	40 to 315	ns
Median anesthetic duration (min)		120	40 to 210	130	40 to 155	ns
Number of patients on critical care postoperatively		52	21.9%	28	66.7%	$P < 0.005$
Median length of stay on critical care (d)		3.5	1 to 45	3	1 to 30	ns
Number of ventilated d		4	1 to 23	3	1 to 30	ns
Number of inotrope-dependent d		3	1 to 7	2	1 to 10	ns
Number of renal support d		1	5 to 9	4	3 to 24	ns
Median hospital stay (d)		14	2 to 190	13	3 to 30	ns

TABLE 4

Pre and Postoperative Predictors of Outcome, Including Serology, Between Survivors and Nonsurvivors

		Survivors ($n = 238$)		Nonsurvivors ($n = 42$)		
		Value	Range or %	Value	Range or %	Significance
APACHE II preoperatively		9	2 to 31	12.5	7 to 23	$P < 0.005$
Median EWS on admission		1	0 to 10	2	0 to 7	$P < 0.0001$
Median EWS 1 h preoperatively		1	0 to 10	3	0 to 11	$P < 0.001$
Patients with improving/stable EWS preoperatively		191	80.3%	16	38.1%	$P < 0.001$
Patients with deteriorating/not improving EWS preoperatively		47	19.8%	26	61.9%	$P < 0.001$
Median ASA grade		2	1 to 4	4	1 to 5	$P < 0.0001$
Preoperative serology	CRP mg/L	67	5 to 414	102.5	22 to 345	ns
	WCC $\times 10^9$/L	11.6	2.1 to 32.7	11.2	3.5 to 46.6	ns
	Hemoglobin g/dL	13.7	3.3 to 19.8	11.2	6.3 to 18.9	$P < 0.001$
	Platelets $\times 10^9$/L	246	13 to 895	220	25 to 608	ns
	Sodium mmol/L	137	36 to 155	134	119 to 142	ns
	Potassium mmol/L	4	2.5 to 6.0	4.0	2.8 to 6.9	ns
	Urea mmol/L	5.6	1.4 to 40.9	9.7	3.2 to 55.1	$P < 0.001$
	Creatinine μmol/L	87	45 to 303	102	56 to 534	$P < 0.05$
	Albumin g/L	40	14 to 52	33	15 to 43	$P < 0.0001$
	Bilirubin μmol/L	13	3 to 383	13	46 to 353	ns
	Alkaline phosphatase IU/L	81	17 to 1016	96.5	20 to 330	ns
POSSUM score		4.2	0.6 to 96.6	32.1	2.5 to 79.4	$P < 0.0001$
APACHE II postoperatively		10	3 to 25	16	7 to 21	$P < 0.0001$
Median EWS day 1 postoperatively		2	0 to 9	4	1 to 7	$P < 0.05$
Median EWS day 2 postoperatively		2	0 to 6	4	2 to 9	$P < 0.005$
Median EWS day 3 postoperatively		2	0 to 4	3	2 to 7	$P < 0.005$

medical patients have shown it to be reliable in the prediction of mortality for most patients [7–10], but there have been concerns raised regarding it applicability where patients are at risk of very sudden and catastrophic deterioration, such as cardiac arrests [11]. Other studies looking at the predictive power of EWS in the accident and emergency setting, where patients may also deteriorate very rapidly without warning, have also found it to have poor discriminatory power [12]. It is conceivable that EWS predominantly predicts

TABLE 5

Predictive Values of All Pre- and Postoperative Parameters in Predicting Mortality (AUC Values From ROC Analysis Displayed)

		AUC value	Standard error	Significance
Age		0.70	0.04	$P < 0.0001$
APACHE II preoperatively		0.70	0.05	$P < 0.005$
EWS on admission		0.71	0.05	$P < 0.0001$
EWS 1 h preoperatively		0.70	0.05	$P < 0.0001$
ASA grade		0.81	0.03	$P < 0.0001$
Preoperative serology	CRP mg/L	0.65	0.05	$P < 0.05$
	WCC $\times 10^9$/L	0.51	0.05	ns
	Hemoglobin g/dL	0.72	0.05	$P < 0.0001$
	Platelets $\times 10^9$/L	0.43	0.06	ns
	Sodium mmol/L	0.65	0.05	$P < 0.005$
	Potassium mmol/L	0.47	0.05	ns
	Urea mmol/L	0.72	0.04	$P < 0.0001$
	Creatinine μmol/L	0.67	0.05	$P < 0.001$
	Albumin g/L	0.79	0.03	$P < 0.0001$
	Bilirubin μmol/L	0.47	0.06	ns
	Alkaline Phosphatase IU/L	0.43	0.05	ns
POSSUM score		0.81	0.03	$P < 0.0001$
APACHE II postoperatively		0.76	0.05	$P < 0.0001$
Median EWS day 1 postoperatively		0.67	0.08	$P < 0.05$
Median EWS day 2 postoperatively		0.83	0.05	$P < 0.0005$
Median EWS day 3 postoperatively		0.80	0.05	$P < 0.005$

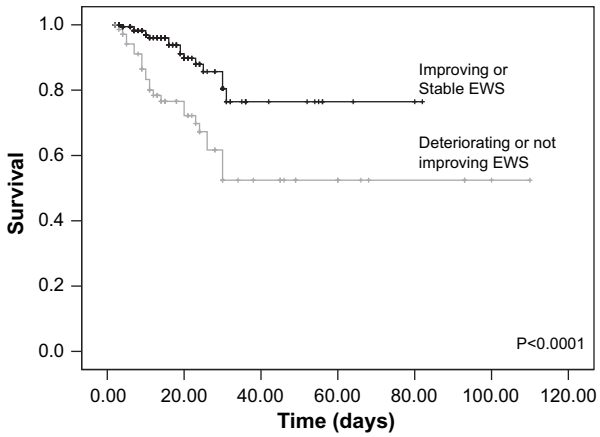

FIG. 1. Kaplan-Meier survival plot of all admissions displaying survival among patients with improving EWS on admission and those with deteriorating EWS on admission.

a systemic inflammatory response (SIRS) mediated organ dysfunction. Hence, it may be less valuable in patients with hemorrhage, a hypothesis further borne out by the very high predictive accuracy of EWS in patients with acute pancreatitis, where the SIRS-mediated response is the primary cause of mortality [13].

Postoperative EWS was also found to be predictive of mortality; indeed by day 2 postoperatively EWS was the best overall predictor of mortality. It has to be stressed that the postoperative patients are a sub-group of the overall population studied, since those who went to critical care were excluded from this analysis. However, the findings are clinically relevant. The median EWS postoperatively for those patients who went on to succumb from their pathology was 4, and patients scoring

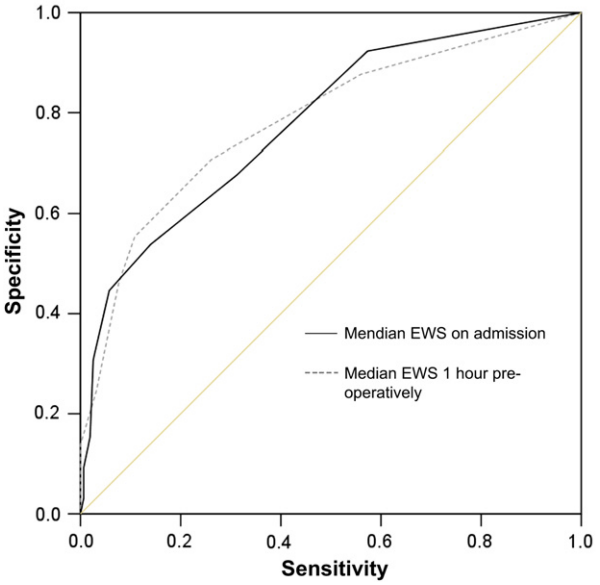

FIG. 2. ROC analysis demonstrating prediction of critical care postoperatively by preoperative EWS both on admission and 1 hour preoperatively (AUC values of 0.78, respectively). (Color version of figure is available online.)

at this level postoperatively may be good candidates for admission to critical care, in spite of the initial assessment intraoperatively suggesting that they were suitable for management on a surgical ward.

CONCLUSIONS

Many factors may limit the efficacy of EWS in a ward-based setting. These include the response times of medical staff when receiving a report of a deteriorating EWS, whether appropriate action is taken based on EWS findings, and the involvement of senior colleagues where appropriate [14]. In addition, accuracy of recording and calculation of the scores by members of nursing staff is essential to ensure that EWS do actually track the clinical status of the patient. This study is not able to determine whether introduction of EWS is able to decrease mortality among acute surgical admissions and a much larger multicenter trial would be needed to evaluate that fully. However, it has shown that preoperative EWS and the changes in a patient's EWS correlates with mortality postoperatively and critical care requirements. Whilst EWS was not designed primarily as an "outcome" predictor, we feel that these findings validate the use of EWS on surgical wards. A high ($\geq$4) postoperative EWS also predicts mortality and early referral to critical care should be considered in these patients.

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