EDITOR'S CHOICE

Predictive scoring in non-trauma emergency patients: a scoping review

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ABSTRACT

This study is an inclusive scoping review of the literature relating to outcome prediction in adult non-trauma emergency patients, in order to identify the number and range of risk scores developed for acutely ill adults and to identify the outcomes these scores predict. The data source used was Medline 1950—2009. To be eligible for inclusion, papers had to detail an assessment tool, wholly or predominantly clinical, applied at the point of patient presentation to unscheduled healthcare services with outcome measures up to 30 days after presentation. Papers detailing trauma, paediatrics, purely obstetric or psychiatric presentations, tools wholly applied in a critical care setting, tools requiring an algorithm not freely available, biomarkers or tests not routinely available in an Emergency Department (ED) setting were excluded. 192 papers were reviewed. Within 17 broad disease categories, 80 inclusion criteria were used, 119 tools were assessed (25 of which were non-disease specific), and 51 outcome measures were used (30 of which were disease-specific). The areas under the receiver-operator characteristic curve (AUROCs) varied from 0.44 to 0.984. The multiplicity of tools available presents a challenge in itself to the acute clinician. Many tools require a specific diagnosis, which is not immediately available, and the authors advocate ED development of tools for case-mix adjustment and clinical risk stratification.

INTRODUCTION

Risk scores may be used to predict which non-trauma patients presenting to an Emergency Department (ED) are likely to suffer adverse outcomes. They have two broad purposes within clinical medicine: 1. to guide individual patient management by risk stratification, to determine best site-of-care, to place a ceiling on intensity of intervention, to decide if palliation is appropriate and to support information provided to patients and relatives; and 2. to provide case-mix adjustment for research and audit.

The use of standardised tools to affect site-of-care decisions is most advanced in the prehospital management of trauma; a number of rules have been proposed to identify major trauma patients in need of direct transfer to a specialised trauma centre or of the presence of a full trauma team.[1–5] The use of standardised alert systems in hospital has recently been advocated by the UK National Institute for Health and Clinical Excellence to identify the acutely ill patient and ensure the appropriate level of care.[6]

The science of risk prediction and case-mix adjustment is advanced in trauma and critical care. A multiplicity of predictive tools exists in the critical care literature (APACHE I–IV,[7–10] Mortality Probability Model I–III,[11–13] Simplified Acute Physiology Score I[14] and II[15]), together with refinements based on changes of those scores over time.[16–19] In the UK,[20 21] Australasia,[22] Europe[23–25] and the USA,[26] various audit groups provide analysis to aid comparison between different units. In the USA and the UK, multi-site data collection (the American College of Surgeons Trauma Quality Improvement Programme[27] and the Trauma Audit Research Network[28]) is ongoing to provide risk-adjusted mortality ratios to assist in quality assurance at individual care providers.

The absence of similar tools in non-trauma patients causes problems in risk prediction and case-mix adjustment. Patients with delayed admission to critical care areas have higher rates of mortality than those admitted directly from the ED.[29 30] Not all patients require admission to hospital or critical care, but the lack of existence of a good indicator of future deterioration may engender defensive practice and unnecessary admissions. The lack of a valid tool for case-mix adjustment also causes problems in our era of league tables. Crude mortality estimates may reflect case mix rather than quality of care, and risk-adjustment may be subject to the 'constant risk fallacy'.[31] Failure to take these factors into account

Table 1 Previously identified severity scores for non-trauma patients searched for by name and/or common abbreviation

Altona	Alvarado
APACHE	Balthazar
Blatchford	CTAS/Canadian Triage
ESI/Emergency Severity	Essen
EWS/Early Warning Score	GCS/Glasgow Coma Scale
Geneva	Glasgow pancreas
Goldman	GRACE
Hardman	Manchester Triage/MTG/MTS
Mannheim	MEDS/Mortality in Emergency Department
MEEDS/Mainz Emergency	MELD
MPM/Mortality Probability Model	Norris
Peritonitis Severity Score	POSSUM
PURSUIT	Ranson
RAPS/Rapid Acute Physiology Score	REMS/Rapid Emergency Medicine Score
RISC	Rockall
ROSE	San Francisco (limited to syncope)
SAPS/Simplified Acute Physiology Score	Scorten
SOFA	TIMI
TISS/Therapeutic Intervention Severity Score	Wells

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Table 2 Search strategy for prognostic indicators

Prognosis/OR 'Severity of Illness Index'/OR severity.mp OR risk/plus:

Acute coronary syndrome/
Aneurysm, dissecting/
Aneurysm, infected/
Aortic aneurysm/
Arsenic Poisoning/
Exp asthma/
Brain abscess/
Bronchitis, chronic/
Cadmium Poisoning/
Carbon Tetrachloride Poisoning/
Cardiomyopathy, dilated/
Central nervous system bacterial infections/
Central nervous system parasitic infections/
Chagas cardiomyopathy/
Cirrhosis.mp
Coronary aneurysm/
Dermatitis, exfoliative/
Dermatomyositis/
Exp Diabetic Ketoacidosis/
Encephalitis/
Endocarditis/
Endocarditis, subacute bacterial/
Fasciitis, Necrotizing/
Food Poisoning/
Gas Poisoning/
Heart aneurysm/
Exp Heat Exhaustion/
Heavy Metal Poisoning, Nervous System/
Hepatic encephalopathy/
Hepatitis/
Exp Hypothermia/
Intracranial aneurysm/
'Intracranial embolism and thrombosis'/
Ischemic Attack, Transient/
Liver failure/
Manganese Poisoning/
Meningitis/
Meningitis, bacterial/
Meningitis, viral/
Mercury Poisoning/
Mesenteric vascular occlusion/
Mushroom Poisoning/
Myocarditis/
Pancreatitis, acute necrotizing/
Exp peptic ulcer hemorrhage/
Peritonitis, tuberculous/
Pleuropneumonia/
Pneumonia, aspiration/
Pneumonia, pneumocystis/
Poisoning/
Pulmonary embolism/
Renal artery obstruction/
Sepsis/
Skin diseases/
Skin diseases, infectious/
Soft tissue infections/
Exp status asthmaticus/
Subarachnoid Hemorrhage/
Suppuration/
syncope, vasovagal/
Toxemia/
Ventricular dysfunction/
Ventricular dysfunction, right/
aneurysm/
aneurysm, false/
aneurysm, ruptured/
arachnoiditis/
arterial occlusive diseases/
bacteremia/
brain infarction/
bronchopneumonia/
Carbon Monoxide Poisoning/
cardiomyopathy, alcoholic/
cardiomyopathy, hypertrophic/
central nervous system fungal infections/
central nervous system viral diseases/
Ciguatera Poisoning/
confusion/
Delirium/
dermatitis herpetiformis/
Diabetic coma/
empyema, subdural/
encephalomyelitis/
endocarditis, bacterial/
epidural abscess/
Fluoride Poisoning/
fungemia/
exp gastrointestinal hemorrhage/
Heart Failure/
exp Heat Stroke/
exp hematemesis/
hepatic insufficiency/
hyperglycaemic hyperosmolar nonketotic coma/
iliac aneurysm/
intracranial embolism/
intracranial thrombosis/
Lead Poisoning/
liver failure, acute/
exp melena/
meningitis, aseptic/
meningitis, fungal/
meningoencephalitis/
Mercury Poisoning, Nervous System/
MPTP Poisoning/
myocardial infarction/
pancreatitis/
pancreatitis, alcoholic/
peritonitis/
Plant Poisoning/
pneumonia/
pneumonia, bacterial/
pneumonia, viral/
pulmonary disease, chronic obstructive/
pulmonary infarction/
Salmonella Food Poisoning/
shock, septic/
skin diseases, eczematous/
skin diseases, metabolic/
Staphylococcal Food Poisoning/
stroke/
subphrenic abscess/
Syncope/
takotsubo cardiomyopathy/
urinary tract infections/
ventricular dysfunction, left/

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Table 3 Inclusion criteria

Condition	Inclusion criteria
AAA	Patients undergoing endovascular repair of ruptured AAA[33 34] Patients undergoing repair of ruptured AAA[35–42] Patients undergoing repair of ruptured infrarenal AAA[43]
ACS or potential ACS	Patients with potential ACS[44–49] Patients with ACS[50–68] Patients with AMI[59–65] Patients with NSTEMI[69 70] Patients with STEMI[57 71–74] Patients aged >65 with STEMI[75] Patients thrombolysed for STEMI[76] Patients undergoing PCI for STEMI[77] Patients admitted to inpatient telemetry[75 76] Patients admitted to CCU with NSTEMI[78] Patients admitted to ICU with AMI[79] Patients with chest pain after cocaine use[80] Patients being transported by helicopter with potential ACS[81]
Asthma/COPD	Patients with asthma[82–84] Patients admitted with COPD[85] Patients admitted to critical care with COPD/asthma[86]
GI bleeding	ED patients with GI bleed[87] Inpatients with upper GI bleed[88–91] Inpatients undergoing OGD[91–93] Inpatients undergoing OGD for non-variceal bleed[92] Inpatients undergoing OGD for peptic ulcer[93] Inpatients undergoing OGD for peptic ulcer with age>60, shock, comorbidities or Hb<10[94] Inpatients with lower GI bleed[95]
Heart failure	Patients with acute pulmonary oedema[96] Inpatients with heart failure[97–99]
Hypothermia	Patients admitted with core temperature <35[100]
Meningitis	Patients with bacterial meningitis[101 102]
Myxoedema	Patients with myxoedema coma[103]
Pancreatitis	Inpatients[104–117] Inpatients with 'severe' pancreatitis[118] HIV +ve inpatients[119]
Pneumonia (non-hospital-acquired)	Patients in primary care with CAP >65 years[120] Nursing home patients with pneumonia[121] Patients in primary care and ED[122 123] ED patients[124–134] Inpatients[124–141] Inpatients including those with TB[142] Inpatients aged >60 years[143] Inpatients excluding those from nursing homes[144] Inpatients with pneumococcal pneumonia[145] Inpatients with MRSA pneumonia[146] Inpatients with PSI category V pneumonia[147] Immunosuppressed inpatients[148]
Poisoning	Inpatients with organophosphate poisoning[149 150]
Pulmonary embolism	Patients with a discharge diagnosis of PE[151] ED patients with non-massive PE[152] Patients with PE diagnosed by CT[153] Patients undergoing CT for?PE[151]
Sepsis/infection	ED patients having a blood culture taken[154] ED patients with infection[155] ED patients meeting SIRS criteria[156–159] ED patients with severe sepsis/septic shock[160] Inpatients with first episode infective endocarditis[161] Inpatients with necrotising soft tissue infection[162] Patients with pyogenic liver abscess[163 164] Inpatients meeting criteria for early goal-directed therapy[165] Patients admitted to ICU via ED with sepsis[166]
Surgical	Patients undergoing damage control surgery[167] Patients undergoing emergency or urgent surgery[168] Patients undergoing emergency surgery for peptic ulcer[169] Patients undergoing emergency surgery for colorectal cancer[170 171] Patients undergoing surgery for colonic perforation[172 173] Patients undergoing surgery for complications of diverticulosis[174 175] Patients undergoing surgery for peritonitis[176] Inpatients with peritonitis secondary to hollow viscus perforation[177 178]
Syncope	ED patients with syncope[179–181] ED patients with syncope or near syncope[182 183]
TIA	Primary care[184] ED patients[184–187] Inpatients[188]
Unselected	ED patients[189 190] ED patients aged >65 years[191] ED patients with a non-surgical condition[192 193] ED patients seen in resuscitation area[194 195] Patients on MAU[196–199] Patients on MAU/SAU[200] Patients admitted to critical care from the ED[201 202] Patients admitted to critical care from the ED with shock[203]

AAA: abdominal aortic aneurysm; ACS: acute coronary syndrome; AMI: acute myocardial infarction; CAP: community-acquired pneumonia; CCU: coronary care unit; COPD: chronic obstructive pulmonary disease; ED: emergency department; GI: gastrointestinal; ICU: intensive care unit; MAU: medical assessment unit; MRSA: methicillin-resistant staphylococcus aureus; NSTEMI: non-ST elevation myocardial infarction; OGD: oesophagogastroduodenoscopy; PCI: primary coronary intervention; PE: pulmonary embolism; PSI: pulmonary severity index; SAU: surgical assessment unit; SIRS: systemic inflammatory response syndrome; STEMI: ST elevation myocardial infarction; TB: tuberculosis.

can lead to inappropriate conclusions being drawn about the association between quality of care and mortality.[32]

Attempts to implement risk-prediction methods in clinical decision-making, audit and research are hampered by the substantial range and number of risk scores available. There are so many potential scores for non-trauma patients that deciding which score should be used and which variable measured presents a challenge in itself. Therefore, this study aimed to carry out a scoping review of the literature relating to outcome prediction in adult non-trauma emergency patients, in order to identify the number and range of risk scores developed for acutely ill adults and to identify the outcomes these scores predict.

METHODS

The aim was to identify papers describing assessment tools applied at the point of patient presentation to unscheduled healthcare services (excluding trauma, paediatrics and purely obstetric or psychiatric presentations) and describing short-term outcomes. A search of Medline 1950 to October week 3 2009 was carried out using a deliberately inclusive two-pronged strategy (tables 1 and 2). The search was deliberately designed to achieve breadth rather than depth. It was intended to determine the scope of risk scores available, rather than obtain accurate estimates of the performance of each score.

All searches were limited to English language, humans and adults. Search output was limited by title, abstract or full paper review to those papers fitting three criteria: 1. a wholly or predominantly clinical assessment (ie, not biomarkers or specialist tests not available in the majority of EDs such as myocardial scintigraphy); 2. an adult population and 3. an outcome measure up to 30 days after presentation. Also assessment tools requiring a specialist algorithm not freely available, or those that were applied only to patients in a critical care setting were excluded.

The following data were extracted from each article selected for inclusion: the name and/or acronym of the score, the target condition or conditions, the patient groups included in the target condition(s), the main outcomes measured and the discriminant value of the score, expressed as the area under the receiver-operator characteristic curve (AUROC) or sensitivity and specificity. The AUROC is also known as the c-statistic. It is the probability that a randomly selected patient from those with the outcome of interest will have a higher score than a randomly

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Table 4 Tools assessed

Condition	Tools
AAA	APACHE II[43] Edinburgh aneurysm score[38 39] Glasgow aneurysm score[38–40] Hardman[33–36 38–40 42] Modified Hardman[35] POSSUM[43] RAAA-POSSUM[42] V-POSSUM[41]
ACS or potential ACS	APACHE II[79 204] Acute Physiology Score[79] Bazzino[65] Chang[72] Coronary prognostic index[79] EMMACE[205] Freedom-from-event score[55] Goldman[49 52 53 206 207] GRACE[51 54 59 61 67–69 77 205] Hasdai[76] IHDI[204] Mayo[208] MINAP[73] Normand[209] Norris[210] PAMI[77] PREDICT[69] PURSUIT[59 64 67–69 78 205] Rapid Acute Physiology Score[81] Sanchis[49] Simplified Acute Physiology Score[79] Selker[48] Simple risk index[75 205 211] TIMI[45 47 50 56–62 66 68–70 74 77 80] Modified TIMI[45 47 58] TIMI risk index[44 46 71 212] Troponin Prediction Score[63]
Asthma/COPD	Acute asthma index[84] APACHE II Acute physiology[86] BAP-65[85] CAPS[86] National asthma guidelines[82] Rodrigo[83]
GI bleed	Blatchford[91 92 194 213] Modified Blatchford[195] BLEED[87] Bordley[88] Rockall[89 94] Rockall (clinical component)[90–93 213] Strate[95]
Heart failure	ADHERE decision rule[97] ADHERE logistic regression[97] Brigham[97] EFFECT[97 99] Le Conte[96] Pulmonary edema prognostic score[98]
Hypothermia	Elbaz[100]
Meningitis	Aronin[101] Weisfelt[102]
Myxoedema	SOFA[103]
Pancreatitis	APACHE II[104 107–109 111 112 114–119] APACHE III[104] APACHE-O[111 114] BALI[112] BISAP[105] EWS[115] Glasgow[112 117 119] Glasgow at admission[116] Modified Glasgow[106 109] Imrie[110 115 118] MODS[115] Ranson[104 110 112 116–119] Ranson (Biliary)[109] SAPS[113]
Pneumonia	APACHE II[146] American Thoracic Society 2001[139 140 214] Modified ATS[147 215] American Thoracic Society 2007[124 139 215] British Thoracic Society[140] Modified BTS[142] CORB[216] CRB[122 216] CRB-65[120 122 123 129 130 134 137 144–146 215–217] CURB[122 132 139 147 214 216 218] CURB-65[124 125 127–131 133 134 137 138 141 144 146 147 214–222] Pitt Bacteremia score[215] PMEWS[141] PSI[121 124–127 130–132 134–140 143 148 214–223] REA-ICU[138] SCAP[127 138 219] SEWS[129 130] SIRS[129 145] SMART-COP[131] SMRT-CO[131]
Poisoning	GCS[149] Modified APACHE[150] Poison severity score[149]
Pulmonary embolism	Aujesky[151 152] PESI[153]
Sepsis/infection	APACHE II[162 163 165] APS[161] CURB-65[155] MEDS[154–156 158–160 165 166] MEWS[158] MPM0[165] REMS[155] SAPS II[157 164 165] SOFA[157]
Surgical	Altona[172] APACHE II[170 172 177] APACHE III[170] CR POSSUM[170 173] Mannheim[172 175 176 178] MPM II[170] Peritonitis severity score[178] POSSUM[174] POSSUM physiology[169] P-POSSUM[167 168 171] SAPS II[170]
Syncope	EGSYS[180] OESIL[181] San Francisco[179 182 183]
TIA	ABCD[185 186 188] ABCD2[184 187]
Unselected	APACHE II[224 225] ESI[190 191] HOTEL[199] Kellett[198] LODS[203] Manchester Triage[190 201] MEWS[198 225] MPM0[202 203] PEDS[225] RAPS[189 192 193 224] REMS[189 192 193 224 225] RTS[225] SAPS II[196 203] SEWS[200] Worthing[197]

AAA, abdominal aortic aneurysm; ACS, acute coronary syndrome; COPD, chronic obstructive pulmonary disease; GI, gastrointestinal; TIA, transient ischaemic attack.

selected patient without the outcome of interest. A score with a c-statistic of 0.5 or less has no value for discriminating which patients will suffer the outcome of interest. Similarly, a dichotomised score for which the sensitivity and specificity add up to 100% or less has no discriminatory value.

It was not planned to synthesise data, but to present descriptive data outlining the breadth of scores available for

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Table 5 Outcome measures

Condition	Outcome measures
AAA	'Immediate' postoperative death[40] 30/7 death[33] Inpatient death [34–36 38 42 43] Inpatient or 30/7 death [39 41]
ACS or potential ACS	12 h troponin rise[63] 14/7 death [50] 14/7 AMI[50] 14/7 revascularisation[50] 14/7 death, AMI or recurrent ischaemia[57] 30/7 death[46 57 64 72 74 75 77 78 205 208 209 211 212] 30/7 death or AMI[59 64] 30/7 death, AMI or revascularisation[44 45 47 53 58 60–62 66 70 77 80] Inpatient death[48 51 67–69 71 73 79 81 204 210] Inpatient death preventable by monitoring or VF or VT[207] Inpatient ACS[49] Inpatient malignant arrhythmia[69] Inpatient death or AMI[65] Inpatient death, AMI or revascularisation[56 66] Inpatient heart failure, shock, AF, VF, cardiac arrest, VT, MI, stroke, major bleed, death[52 54 55 206] Cardiogenic shock[76]
Asthma/COPD	Poor treatment response[84] Hospitalisation[82 83] Requirement for mechanical ventilation[85] Inpatient death[85 86]
GI bleed	30/7 rebleed[92 94 213] 30/7 death [94] Inpatient death[89 92 93] Inpatient rebleed[89] Inpatient intervention or death[91] Inpatient rebleed or death[195] Inpatient rebleed, surgery or death[87 88] Requiring transfusion, surgery or endoscopic intervention[194] Requiring >2 unit transfusion, >20% fall in haematocrit, rebleed >24 h[95] Requiring endoscopic intervention[90] High risk stigmata at OGD[195]
Heart failure	30/7 death[99] Inpatient death[96–98] Inpatient death or life-threatening condition[97]
Hypothermia	Inpatient death[100]
Meningitis	Inpatient death[101] Glasgow Outcome Score 1–4[102]
Myxoedema	Inpatient death[103]
Pancreatitis	Inpatient death[105 106 112 113 115 117 118] Atlanta severity criteria[104 108 114 115] Admission to critical care[107 117] Admission to critical care >1/7[109] Admission to critical care >5/7[116] Admission to critical care, necrosis or death[111] Admission to critical care, local complications, surgery or death[119] Severe complications[110] Infection (bacteraemia/infected necrosis)[117]
Pneumonia	2/7 death[136] 14/7 death[215] 28/7 death[123] 30/7 death[120–122 126 128 129 133 134 137 140 141 143 144 146 217 218 220–223] Inpatient death[124 135 139 142 145 148 214] Hospitalisation[121 141] Complicated effusion or empyema[130] Severe sepsis[127] Critical care admission[124 127 131 132 134 136 139–141 147 214 220] Critical care admission or death[125 216 219] Critical care admission in 1-3/7[138]
Poisoning	Inpatient death[149] Requirement for endotracheal intubation[150]
Pulmonary embolism	30/7 death[151 153] Inpatient death[152] Haemodynamic instability[152]
Sepsis/infection	5/7 death[159] 28/7 death[155 156 158 166] 30/7 death[157 159] Inpatient death[154 160–165]
Surgical	30/7 death[168 173] Inpatient death[167 170–172 174–178] Complication[169]
Syncope	7/7 serious outcome[179 182 183] Adverse cardiac outcome[181] Final diagnosis cardiac syncope[180]
TIA	2/7 CVA[184] 7/7 CVA[184–188] 30/7 CVA[186 188]
Unselected	Hospital admission[190 191] Admission to critical care[201] 24 h death[199] 7/7 death or ICU admission[225] 14/7 death[224] 30/7 death[198 225] Inpatient death[189 192 193 196 197 200 202 203]

AAA, abdominal aortic aneurysm; ACS, acute coronary syndrome; AMI, acute myocardial infarction; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; ICU, intensive care unit; MI, myocardial infarction; OGD, oesophagogastroduodenoscopy; TIA, transient ischaemic attack; VF, ventricular fibrillation; VT, ventricular tachycardia.

different conditions, the outcomes measured and the range of AUROC values reported.

RESULTS

The initial searches identified 14 659 (method 1) and 46 605 (method 2) titles. A significant number of titles were identified by more than one search. Six hundred and eighty-two (method 1) and 1661 (method 2) abstracts were screened and 192 papers deemed to fit the inclusion criteria.

Scoring systems were available for 17 broad conditions. Within these 17 conditions, 80 different inclusion criteria were used (table 3).

One-hundred and nineteen tools were assessed (table 4). Of these, 25 were generic (non-disease-specific). A number of tools were assessed in multiple disease categories.

Fifty-one different outcome measures were used (table 5). Of these, 30 were disease-specific.

A variety of different measures were used to report score performance. Of 247 analyses using death as an outcome, 190 reported an AUROC, of which 69 reported an AUROC greater than 0.8. Of 215 analyses not including death as an outcome, 151 reported an AUROC, of which 30 reported an AUROC greater than 0.8. A number of studies (22) used the same dataset to compare the predictive value of a single tool for different outcomes (table 6). For comparison, the lowest AUROC in the study was 0.44 (PIMI for predicting hospital death in patients with acute myocardial infarction[204]) and the highest was 0.984 (APACHE II for predicting hospital death in patients with peritonitis[177]). It is generally accepted that an AUROC of over 0.8 represents good discriminatory capacity.[226]

Studies were variously purely derivation, mixed derivation and validation, external validation and secondary analysis of other datasets (including disease registries) (table 7).

DISCUSSION

A wide variation in the patient groups to which scoring systems are applied has been demonstrated, and an equally wide variation in patient outcomes considered relevant. The sheer number of available tools makes it impossible for the working clinician to use more than a few in daily practice. The discriminant value of the scores, expressed as an AUROC or sensitivity and specificity, often varies between studies and is poor in many cases, suggesting the score will have limited value in practice. Furthermore, most scores

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Table 6 Studies with comparison of different outcome measures

Condition		
ACS	GRACE	30/7 death AUROC 0.471 vs major cardiac event AUROC 0.544[77]
		Death AUROC 0.578 (0.457–0.699) vs malignant arrhythmia AUROC 0.573 (0.444–0.701)[69]
	PAMI	30/7 death AUROC 0.742 vs major cardiac event AUROC 0.65[77]
	PREDICT	Death AUROC 0.829 (0.744–0.914) vs malignant arrhythmia AUROC 0.531 (0.366–0.697)[69]
	PURSUIT	30/7 death AUROC 0.814 vs death or reinfarct AUROC 0.669[64]
		Death AUROC 0.86 (0.778–0.942) vs malignant arrhythmia AUROC 0.523 (0.358–0.688)[69]
	TIMI	Death AUROC 0.74 vs death/MI AUROC 0.63 vs MI AUROC 0.66 vs revascularisation AUROC 0.68[50]
		30/7 death AUROC 0.724 vs major cardiac event AUROC 0.635[77]
		Death AUROC 0.638 (0.515–0.76) vs malignant arrhythmia AUROC 0.486 (0.328–0.645)[69]
Asthma/COPD	BAP-65	Death AUROC 0.72 (0.7–0.74) vs IPPV AUROC 0.77 (0.75–0.79) Death AUROC 0.71 (0.7–0.73) vs IPPV AUROC 0.77 (0.75–0.79)[85]
GI bleed	Blatchford	Death sens 1, spec 0.08, PPV 0.01, NPV 1 vs rebleed sens 1, spec 0.09, PPV 0.07, NPV 1[92]
	Clinical Rockall	Death sens 1, spec 0.19, PPV 0.01, NPV 1 vs rebleed sens 0.69, spec 0.18, PPV 0.06, NPV 0.89[92]
	Rockall	Death AUROC 0.834 vs rebleed AUROC 0.798[89]
Heart failure	ADHERE decision rule	Inpatient death AUROC 0.68 (0.67–0.7) vs death/life-threatening event AUROC 0.58 (0.57–0.59)[97]
	ADHERE logistic regression	Inpatient death AUROC 0.73 (0.72–0.75) vs death/life-threatening event AUROC 0.61 (0.6–0.62)[97]
	Brigham	Inpatient death AUROC 0.61 (0.59–0.62) vs inpatient death/life-threatening event AUROC 0.61 (0.6–0.62)[97]
	EFFECT	Inpatient death AUROC 0.74 (0.72–0.75) vs inpatient DEATH/life-threatening event AUROC 0.62 (0.61–0.63)[97]
Pancreatitis	APACHE II	Death AUROC 0.875 vs Atlanta severity AUROC 0.861[115]
		Death AUROC 0.81 vs organ dysfunction AUROC 0.88 vs infection AUROC 0.73[117]
	EWS	Death AUROC 0.827 vs Atlanta severity AUROC 0.853[115]
	Glasgow	Death AUROC 0.73 vs organ dysfunction AUROC 0.74 vs infection AUROC 0.73[117]
	Imrie	Death AUROC 0.794 vs Atlanta severity AUROC 0.747[115]
	MODS	Death AUROC 0.783 vs Atlanta severity AUROC 0.793[115]
	Ranson	Death AUROC 0.83 vs organ dysfunction AUROC 0.84 vs infection AUROC 0.82[117]
Pneumonia	ATS 2001	30/7 death AUROC 0.6 (0.54–0.65) vs ICU admission AUROC 0.61 (0.57–0.65)[140]
		Inpatient death AUROC 0.63 vs ICU admission AUROC 0.9[214]
		Death sens 0.65, spec 0.71, PPV 0.25, NPV 0.93 vs ICU admission sens 0.9, spec 0.8, PPV 0.53, NPV 0.97[139]
	Modified ATS 2001	Death sens 0.75 spec 0.8 PPV 0.53 NPV 0.91 vs ICU admission sens 0.72 spec 0.77 PPV 0.44 NPV 0.91[147]
	ATS 2007	Death sens 0.75, spec 0.65, PPV 0.24, NPV 0.95 vs ICU admission sens 0.9, spec 0.72, PPV 0.44, NPV 0.97[139]
	ATS 2007 minor criteria	Death AUROC 0.88 (0.86–0.91) vs ICU admission AUROC 0.85 (0.81–0.88)[124]
	BTS	30/7 death AUROC 0.62 (0.57–0.69) vs ICU admission AUROC 0.58 (0.53–0.63)[140]
	CURB	Inpatient death AUROC 0.74 vs ICU admission AUROC 0.7[214]
		Death (score >1) sens 0.5, spec 0.75, PPV 0.22, NPV 0.91 vs ICU admission (score >1) sens 0.58, spec 0.79, PPV 0.4, NPV 0.89[139]
		Death sens 0.78 spec 0.45 PPV 0.3 NPV 0.87 ICU admission sens 0.72 spec 0.42 PPV 0.24 NPV 0.86[147]
	CURB-65	Inpatient death AUROC 0.74 vs ICU admission AUROC 0.61[214]
		30/7 death AUROC 0.79 (0.74–0.85) vs need for IPPV/vasopressor AUROC 0.77 (0.72–0.83)[130]
		Death AUROC 0.82 (0.78–0.85) vs ICU admission AUROC 0.68 (0.63–0.72)[124]
		Death sens 0.73 spec 0.8 PPV 0.53 NPV 0.85 vs ICU admission sens 0.6 spec 0.44 PPV 0.21 NPV 0.81[147]
	PSI	30/7 death AUROC 0.75 (0.71–0.78) vs ICU admission AUROC 0.6 (0.56–0.65)[140]
		Inpatient death AUROC 0.73 vs ICU admission AUROC 0.65[214]
		30/7 death AUROC 0.79 (0.73–0.84) vs need for IPPV/vasopressor AUROC 0.73 (0.67–0.78)[130]
		2/7 death class I 0, class II 0.2%, class III 0.3%, class IV 1.3%, class V 7.5% versus ICU admission class I 2.5%, class II 3.7%, class III 3.9%, class IV 5%, class V 10.2%[136]
		Death (class IV/V) sens 0.95, spec 0.49, PPV 0.21, NPV 0.99 vs ICU admission (class IV/V) sens 0.81, spec 0.5, PPV 0.28, NPV 0.91[139]
		Death AUROC 0.86 (0.83–0.88) vs ICU admission AUROC 0.75 (0.71–0.79)[124]
Pulmonary embolism	Aujesky	Death score <65 0, 65–85 0, 86–105 11%, 106–25 23%, >125 22% vs haemodynamic instability score <65 0, 65–85 20%, 86–105 56%, 106–125 39%, >125 56%[152]
Sepsis	MEDS	5/7 death AUROC 0.89 vs 5–30/7 death AUROC 0.78[159]
TIA	ABCD	CVA 7/7 AUROC 0.75 (0.63–0.88) vs 30/7 AUROC 0.76 (0.66–0.86)[186]
	ABCD2	CVA 2/7 AUROC 0.72 (0.6–0.84) vs 7/7 AUROC 0.63 (0.57–0.69) CVA 2/7 AUROC 0.79 (0.68–0.9) vs 7/7 AUROC 0.83 (0.75–0.91) CVA 2/7 AUROC 0.72 (0.61–0.82) vs 7/7 AUROC 0.75 (0.68–0.83) CVA 2/7 AUROC 0.73 (0.57–0.89) vs 7/7 AUROC 0.74 (0.64–0.84)[184]
Unselected	APACHE II	30/7 death AUROC 0.838 (0.793–0.876) vs 1/52 death or ICU AUROC 0.733 (0.681–0.78)[225]
	MEWS	30/7 death AUROC 0.754 (0.703–0.799) vs 1/52 death or ICU AUROC 0.761 (0.711–0.806)[225]
	PEDS	30/7 death AUROC 0.898 (0.86–0.928) vs 1/52 death or ICU AUROC 0.909 (0.872–0.938)[225]
	REMS	30/7 death AUROC 0.771 (0.722–0.816) vs 1/52 death or ICU AUROC 0.696 (0.643–0.745)[225]
	RTS	30/7 death AUROC 0.766 (0.717–0.811) vs 1/52 death or ICU AUROC 0.748 (0.698–0.794)[225]

ACS, acute coronary syndrome; AUROC, area under ROC curve; COPD, chronic obstructive pulmonary disease; GI, gastrointestinal; ICU, intensive care unit; IPPV, intermittent positive pressure ventilation; MI, myocardial infarction; NPV, negative predictive value; PPV, positive predictive value; sens, sensitivity; spec, specificity; TIA, transient ischaemic attack.

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Table 7 Source of datasets

Studies reporting purely derivation sets	AAA[35 38] ACS[65 73] Heart failure[96 98] Hypothermia[100] Unselected[193 225]
Studies reporting derivation and validation sets	ACS[38 42 61 208] Asthma/COPD[83 85 86] GI bleed[88 95] Heart failure[99] Meningitis[101 102] Pneumonia[127 131 146 148 151] Pulmonary embolism[151] Sepsis[154] Syncope[180] Unselected[215–217]
Studies providing external validation	AAA[33 37 177 189 193 204 226–229] ACS[34–36 43 44 46 47 49–51 56 59 66 72 74–80] Asthma/COPD[82 84 86] GI bleed[86 88–91 93–97] Myxoedema[103] Pancreatitis[107–114 117 118 121 122] Pneumonia[123–129 131–134 136 138 139 141 144–147 149–152 154 155 157 158 160] Poisoning[150] Pulmonary embolism[163–165] Sepsis[158 162 168 171 173 175 176 179] Surgical[180–188 191 196 197] Syncope[198 200–202] TIA[188 203 205–207] Unselected[190 194 195 211–214 216 219 220]
Studies with secondary analysis of data collected for another purpose as derivation set	ACS[40 45 53 54 69 71 73] Pancreatitis[112]
Studies with secondary analysis of data collected for another purpose as validation set	ACS[37 39 41 48 52 53 63–65 67 68 71 73] GI bleed[195] Heart failure[97] Pancreatitis[112] Pneumonia[130 135 137 140 143 144 153] Poisoning[149] Sepsis[167 169 172 178] Unselected[209 218 221]

AAA, abdominal aortic aneurysm; ACS, acute coronary syndrome; COPD, chronic obstructive pulmonary disease; GI, gastrointestinal; TIA, transient ischaemic attack.

have only been tested in the population in which they were developed. This will tend to overestimate the discriminatory value and further reduce the value of the scores in practice.

The authors are not aware of any previous systematic reviews that have attempted to characterise the full scope of risk scores available for non-trauma patients. Although there is obviously a huge amount of primary data relating to risk scores, there have been few attempts to systematically evaluate these data and draw broader conclusions for clinical practice. Indeed, one of the characteristics of the literature relating to risk scores is that each risk score seems to be developed de novo with very little reference to previous studies or other scores. This may reflect the tendency for studies developing risk scores to be secondary analyses of existing datasets rather than studies undertaken for the primary purpose of developing a risk score. The present review suggests that further unfocussed primary research is unlikely to clarify the situation. Instead, future studies of risk scores should aim to build on existing data and be designed specifically to develop an optimal risk score.

The study is limited by the structure and the lack of information in many included papers. Few were precise about the timing of the assessment, leaving potential for lead-time bias. The majority focused on hospital-specific outcomes, and it is often unclear to what extent patient-relevant out-of-hospital outcomes have been investigated. The often restricted nature of patient sets (eg, requiring consultant radiologist confirmation for the diagnosis of pneumonia) limits the generalisability of many of the results to the day-to-day ED population where formal diagnosis is often not known initially; only four papers could be identified assessing a truly unselected group of ED patients.[189 190 192 193]

Although a number of reviews have analysed the performance of systems identifying high-risk inpatients,[227–229] the authors are unaware of any previous review of similar tools available to the ED clinician.

It is apparent that one outcome measure does not fit all; in the limited literature assessing the performance of the same tool for two different outcomes, the results rarely matched. Clinicians must therefore examine their practice and decide which outcomes are relevant to their patients and situation. It is highly unlikely that a tool developed for case-mix adjustment will perform equally well at clinical risk stratification; currently the ED community lacks a tool for either and both should be developed. It is likely, given the heterogeneity of ED patients, that it will be challenging to develop a single overall predictive tool; it may be that a variable of presenting complaint (along the lines of APACHE) will be required in such a tool for it to be of benefit in simplifying risk prediction for the practising Emergency Physician.

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