

Ayman Abd Al-maksoud Yousef, MD, Series Editor

Prognostic categorization of intensive care septic patients

Mohamed Ezzat Moemen

Mohamed Ezzat Moemen, Department of Anaesthesia and Intensive Care, Faculty of medicine, Zagazig University, Zagazig 44519, Egypt

Author contributions: Moemen ME was responsibility for wrighting and revising the full-text review article, in response to an invitation by an editorial office member of the WJCCM.

Correspondence to: Mohamed Ezzat Moemen, Professor, Department of Anaesthesia and Intensive Care, Faculty of medicine, Zagazig University, Zagazig 44519, Egypt. ezzatmoemen@yahoo.com

Telephone: +20-2-22619625 Fax: +20-2-22622159

Received: December 9, 2011 Revised: May 17, 2012

Accepted: May 25, 2012

Published online: June 4, 2012

Abstract

Sepsis is one of the leading worldwide causes of morbidity and mortality in critically-ill patients. Prediction of outcome in patients with sepsis requires repeated clinical interpretation of the patients' conditions, clinical assessment of tissue hypoxia and the use of severity scoring systems, because the prognostic categorization accuracy of severity scoring indices alone, is relatively poor. Generally, such categorization depends on the severity of the septic state, ranging from systemic inflammatory response to septic shock. Now, there is no gold standard for the clinical assessment of tissue hypoxia which can be achieved by both global and regional oxygen extractabilities, added to prognostic pro-inflammatory mediators. Because the technology used to identify the genetic make-up of the human being is rapidly advancing, the structure of 30 000 genes which make-up the human DNA bank is now known. This would allow easy prognostic categorization of critically-ill patients including those suffering from sepsis. The present review spots lights on the main severity scoring systems used for outcome prediction in septic patients. For morbidity prediction, it discusses the Multiple Organ Dysfunction score, the sequential organ failure assessment score, and the logistic organ

dysfunction score. For mortality/survival prediction, it discusses the Acute Physiology and Chronic Health Evaluation scores, the Therapeutic Intervention Scoring System, the Simplified acute physiology score and the Mortality Probability Models. An ideal severity scoring system for prognostic categorization of patients with systemic sepsis is far from being reached. Scoring systems should be used with repeated clinical interpretation of the patients' conditions, and the assessment of tissue hypoxia in order to attain satisfactory discriminative performance and calibration power.

© 2012 Baishideng. All rights reserved.

Key words: Prognostic markers; Genome; Sepsis; Systemic inflammatory Response syndrome; Severity scoring systems

Peer reviewer: Yusuf Kenan Coban, MD, Associated Professor, Burn Unit, Plastic Reconstructive and Aesthetic Surgery Department, Medical Faculty, Inonu University, Malatya 44280, Turkey

Moemen ME. Prognostic categorization of intensive care septic patients. *World J Crit Care Med* 2012; 1(3): 67-79 Available from: URL: <http://www.wjgnet.com/2220-3141/full/v1/i3/67.htm> DOI: <http://dx.doi.org/10.5492/wjccm.v1.i3.67>

INTRODUCTION

Prognostic categorization of the intensive care unit (ICU) patients with systemic sepsis may be tried through sequential clinical interpretations, assessment of tissue hypoxia and the use of severity scoring systems. The major prognostic value of scoring systems is mainly to compare the effectiveness of ICU services in different centers or over time. So, to determine patient outcome both the clinical interpretation of patients, the assessment of tissue hypoxia, and the scoring systems are together needed.

Table 1 Mortality in various degrees of severity of sepsis

Diagnosis	Number (1100)	Deaths (%)
Nil	421	101 (24.0)
SIRS	573	152 (26.5)
Sepsis	50	18 (36.0)
Severe sepsis	23	12 (52.2)
Septic shock	33	27 (81.8)

SIRS: Systemic inflammatory response syndrome.

In 1991^[1], experts from a variety of disciplines met for a Consensus Conference and proposed definitions for sepsis as follows: systemic inflammatory response syndrome (SIRS): It denotes the systemic inflammatory response to a wide variety of severe critical insults, manifested by two or more of the following conditions: temperature $> 38^{\circ}\text{C}$ or $< 36^{\circ}\text{C}$, heart rate > 90 beats/min, respiratory rate > 20 breaths/min or $\text{PaCO}_2 < 32$ mmHg, and white blood counts $> 12\,000/\text{mL}$, $< 4/\text{L}$, or $> 10\%$ immature forms. Sepsis: It denotes the systemic inflammatory response to infection. Severe Sepsis: It denotes sepsis or SIRS associated with organ dysfunction, hypoperfusion or hypotension.

Hypotension and hypoperfusion abnormalities may include lactic acidosis, oliguria or acute alteration in mental status. Systolic blood pressure < 90 mmHg or a reduction of 40 mmHg from the baseline in the absence of other causes of hypotension notify severe sepsis or SIRS. It is usually corrected by fluid loading. Septic Shock: It denotes sepsis or SIRS induced hypotension not corrected by fluid loading and needing inotropic and/or vasopressor support. Perfusion abnormalities to many organs characterize the shock state. Multiple organ dysfunction (MOD) Syndrome: It represents altered organ functions in an acutely-ill patient to the extent that homeostasis cannot be maintained without intervention.

It has been shown that the systemic inflammatory response to severe infection evolves in stages, from sepsis to severe sepsis to septic shock, with corresponding increase in the proportion of patients with positive blood cultures, end-organ failure, and crude mortality^[2].

Severe sepsis and septic shock are major reasons for ICU admission. In critically-ill patients in the ICU, who are already compromised because of co-existing serious co-morbidities, septic shock may be associated with higher mortality^[3]. In septic patients, the number of organ systems with impaired function is important because it correlates with clinical patient outcome^[4].

Sepsis is one of the leading causes of morbidity and mortality worldwide today. It is estimated that there are approximately 700 000 cases of severe sepsis annually in USA and around 400 000 patients die every year as a result of sepsis in both USA and Europe. The incidence of the various degrees of severity of sepsis is not well known but a relatively small Italian study which looked at 1100 ICU admissions as early as 2001, found the following^[5] (Table 1):

CLINICAL ASSESSMENT OF TISSUE HYPOXIA IN SEPSIS

Tissue hypoxia is defined as a decrease in the partial pressure of oxygen in a given tissue or as a condition in which the cells of a tissue have abnormal oxygen utilization such that the tissue is experiencing anaerobic metabolism.

Global oxygen consumption/body oxygen delivery relationship

The relationship between whole body oxygen delivery (DO_2) and oxygen consumption (VO_2) in human sepsis has been extensively studied but remains controversial. The pathological supply dependency is an evidence of occult tissue hypoxia and has been associated with an increased incidence of MODS and poor outcomes in patients with sepsis^[6]. Support for this belief comes from some clinical investigators who have demonstrated improved outcomes in patients with septic shock by pharmacologically augmenting systemic oxygenation to supra-normal levels^[7,8]. However, other investigators thought that these clinical studies should be criticized because of methodological error from mathematical coupling because DO_2 and VO_2 were calculated from a common set of measured variables; cardiac output and arterial oxygen content^[9]. The author of the present review could not report significant reduction in mortality in septic patients managed by using the supra-normal hemodynamic approach^[10].

However, it may be prudent to think that indices of supra-normal oxygenation for management of patients with sepsis may be used for their prognostic categorization. Patients who can attain supra-normal values have decreased morbidity and mortality, mostly due to better physiological reserves. Based on this, it may be concluded that global VO_2/DO_2 relationship based on good oxygen extractability potentiality may denote that the oxygen extraction ratio is an excellent parameter for prognostic categorization of patients with sepsis.

Mixed venous oxygen saturation (SvO_2) determination by pulmonary artery catheterization is a flow-weighted average of venous effluent from all perfused vascular beds. A decrease in SvO_2 can be caused by a decrease in DO_2 and/or an increase in VO_2 . An increased value in septic patients denotes tissue hypoxia and its improvement by normal or supra-normal pharmacological interventional therapy may be used as a good prognostic marker^[7].

Metabolic lactic acidosis development is one of the most important abnormalities of tissue hypoxia due to the production of hypoxic global lactate during sepsis or septic shock. Plasma lactate has been shown to be a good prognostic indicator of hypo-perfusion in critically-ill patients. Plasma lactate is easy to measure, and lactate clearance can be followed sequentially to assess the prognosis of the response of septic patients to therapy. The more the decrease in pH and the higher the value

of base deficit, the more serious the condition of the septic patient is.

Prognostic markers: Procalcitonin (PCT) and pro-inflammatory mediators such as tumour necrosis factor- α (TNF- α), interleukin (IL)-1 β and IL-6 are important clinical prognostic markers in patients with systemic sepsis^[11].

There has been strong correlation between serum concentrations of pro-inflammatory mediators and scores of severity of illness^[12]. In spite of this, most of these mediators are not established for clinical decision making due to their short half-life^[13].

Casey *et al*^[14] designed a biologic score for application in septic patients. It included levels of endotoxin, IL-1B, TNF- α and IL-6. It proved a strong correlation with mortality in septic patients. However, the same goal could be achieved by estimation of blood lactate level as an easier and cheaper test.

Nylen *et al*^[15] presented the first evidence that PCT, one of the best prognostic markers of sepsis^[16], may actually be a sepsis mediator and could have an integral role in the inflammatory process and its prognostic categorization.

It has been shown that *in vitro* and *in vivo* induction of cytokines leads to the rapid release of PCT which has a long half-life^[17,18].

Ugarte *et al*^[19] showed that PCT concentration on the first day of the diagnosis of sepsis, severe sepsis or septic shock was significantly higher in non-survivors than in survivors. Proving a strong correlation between PCT and survival of septic patients.

Using stepwise discriminant analysis, PCT was proved to be the best single predictor of outcome in patients with systemic sepsis, as it allocated survivors in 95.8% and non-survivors in 83.3% of patients, with an overall prediction accuracy of 80%^[20].

There has been recent reports of altered outcome in sepsis due to the release of lipo-polysaccharide binding protein, bacterial permeability inducing protein, and other key proteins which may result in altered disease susceptibility and severity: as heat shock protein 70 and nitric oxide synthase^[21].

It has long been appreciated that many patients with sepsis demonstrate defects in coagulation and fibrinolytic systems. These are manifested as anti-thrombin III, protein C, and Protein S and the consumption of fibrinogen, together with the appearance of disseminated intravascular coagulation. More recently, there has been a report of a randomized multicenter trial which has examined the use of a novel human activated protein C during the management of patients with severe sepsis^[5]. A total of 1690 patients with severe sepsis were enrolled into the study; 850 patients received the protein C preparation and 840 received placebo. The mortality rate was decreased from 30.83% in the control group to 24.71% in the active treatment group, an effect which was statistically significant. This report may clearly have major implication for the prognostic categorization and management of patients with systemic sepsis.

The general interest in genetics culminated in the publication of the findings of the human genome project which appeared in February 2001 issue of *Nature*. The precise structure of 30 000 genes which make up the human DNA bank is now known and can be downloaded from the USA National Human Genome Project Internet Site. Such knowledge will prove useful because it will increase the understanding of the etiology and pathology of many disease processes. Because the technology used to identify the genetic make-up of individual patients is now advancing so rapidly, it will soon be possible to identify more markers in patients and will allow prognostic stratification of septic patients for future trials of new therapeutic approaches^[21].

Regional VO₂/DO₂ relationship

The technique of gastric or sigmoid tonometry measures intramucosal pH (Phi) by allowing the equilibration of CO₂ pressures between fluid or air-filled balloon and the interstitial fluid of the mucosa. Measurement of gut intramucosal CO₂ can be also achieved through air introduced directly into the gut (balloonless air tonometry), which equilibrates with the interstitial fluid of the mucosa and is then aspirated from the stomach^[22]. Measurement of CO₂ content of fluid aspirated from the stomach has been also described by Mohsenifar *et al*^[23]. Both later methods avoid the use of commercial expensive tonometry catheters costing \$ 200 each^[24].

Phi may decrease due to changes in blood flow to the stomach or sigmoid mucosa due to splanchnic ischemia in shocked patients. Phi appears to be useful for prognostic categorization of ICU patients with systemic sepsis based on serial measurements^[25]. The author of the present review has shown that Phi values were significantly lower in septic patients with MODS on admission to the ICU than in patients with no organ dysfunction^[10].

Global vs regional VO₂/DO₂ relationship

Assessment of both global and regional VO₂/DO₂ relationships can combine both sides of the coin in prognostic categorization of ICU patients with systemic sepsis. However, there is no gold standard for the detection of tissue hypoxia. There are no specific clinical signs and no clearcut threshold for any single laboratory test. But a multitude of tests combined with sequential clinical evaluations of septic patients may be the best way for their prognostic categorization in the ICU. So, management of patients with severe sepsis or septic shock may be through haemodynamic-oriented or splanchnic-directed therapy added to sequential repeated clinical interpretations. This is a gold standard for both therapy and prognostic categorization of ICU patients with systemic sepsis.

SEVERITY SCORING SYSTEMS IN ICU SEPTIC PATIENTS

Severity scoring systems provide numerical scores that

Table 2 Multiple organ dysfunction score

Organ system	Score				
	0	1	2	3	4
Respiratory PaO ₂ /FiO ₂	> 300	226-300	151-225	76-150	≤ 75
Renal creatinine (μmol/L)	≤ 100	101-200	201-350	251-500	> 500
Hepatic bilirubin (μmol/L)	≤ 20	21-60	61-120	121-240	> 240
Cardiovascular PAR ¹	< 10.0	10.1-15	15.1-20	20.1-30	> 30.0
Cardiovascular HR (beats/min)	< 120	120-140	> 140	Dopamine > 3 mg/kg per min Lactate > 5 mmol/L	
Hematologic platelet count (/L)	> 120	81-120	51-80	21-50	≤ 20
Neurologic Glasgow coma score	15	13-14	10-12	7-9	≤ 6

¹Pressure-adjusted heart rate (PAR): Product of the heart rate multiplied by the ratio of the right atrial pressure to the mean arterial pressure.

Table 3 Sequential organ failure assessment score

Organ system	Score				
	0	1	2	3	4
Respiratory PaO ₂ /FiO ₂	> 400	≤ 400	≤ 300	≤ 200	≤ 100
Renal creatinine (μmol/L)	≤ 110	110-170	171-299	300-440 urine output ≤ 500 mL/d	> 440 urine output < 200 mL/d
Hepatic bilirubin (μmol/L)	≤ 20	20-32	33-101	102-204	> 240
Cardiovascular hypotension	No hypotension	MAP < 70 mmHg	Dopamine ≤ 5 ¹ Dobutamine (any dose)	Dopamine > 5 ¹ or epinephrine ≤ 0.1 ¹ or norepinephrine ≤ 0.1 ¹	Dopamine > 15 ¹ or epinephrine > 0.1 ¹ or norepinephrine > 0.1 ¹
Hematologic platelet count (/mL)	> 150	≤ 150	≤ 100	≤ 50	≤ 20
Neurologic Glasgow coma score	15	13-14	10-12	6-9	< 6

¹Adrenergic agents administered for at least 1 h (doses given are in μg/kg per minute).

describe the impact of patients' illnesses on their physiological reserves.

Most of the severity scoring systems include assessment of major organ system functions. A prolonged period of hypoperfusion of critical organ beds, such as the liver, the brain, the heart, and the gastro-intestinal tract, may give rise to MOD and failure, which is associated with a high rate of morbidity and mortality^[26]. It has been shown that the pattern and evolution of organ system dysfunction over the first 3 d of sepsis is significantly related to 30 d mortality.

Two main types of scoring systems have been developed for use in ICU patients: those that focus on describing morbidity as it evolves; organ dysfunction systems, and those that focus on a single end point, survival or mortality^[27]. So, severity scoring systems are usually designed to help in the prognostic categorization of critically-ill patients as regards their morbidity or survival.

Morbidity prediction systems

Morbidity prediction systems include a large number of scoring trials by different authors, based on advanced statistical efforts for different populations of critically-ill patients at various centers. We chose to concentrate on three scoring systems that proved useful for clinical applications, namely, the MOD score, the sequential organ failure assessment (SOFA) score, and the logistic organ dysfunction (LOD) score. However, other scoring systems may prove useful and an ideal prediction scoring

system has not been reached yet. It should be noted that these systems do not replace serial clinical interpretations of the septic patients.

The MOD score: The MOD scoring system was developed by Marshall *et al*^[4] in 1995 (Table 2).

It included six key organ systems and a score of zero to four was given to each organ according to function (zero being normal function and four being the most severe dysfunction), with a maximum score of 24. A mortality rate of 25% was observed for patients with a score of 9-12, 50% for a score of 13-16, 75% for a score of 17-20 and 100% for a score > 20. The detailed analysis of the results of daily scoring demonstrated the prognostic insights gained by adopting this system^[28].

A revision^[29] of this score has abandoned the cardiovascular parameter (pressure-adjusted heart rate) in favour of a mixed cardiovascular parameter (Table 3) as follows: 0 = heart rate < 120 beat/min; 1 = heart rate > 120 and < 140 beat/min; 2 = heart rate > 140 beat/min; 3 = need for inotrope: (dopamine > 3 μg/kg per minute), and 4 = lactate > 5 mmol/L. The Revised MOD scoring system proved to be of value, because pressure adjusted heart rate cannot be measured in a significant proportion of ICU patients due to the absence of central venous monitoring. In fact, approximately one half of the patients in the original Marshall *et al*^[4] study could not have a cardiovascular component calculated.

It is recommended that the MOD score and its Re-

Table 4 Logistic organ dysfunction score

Organ system	LOD points						
	Increasing severity/decreasing values			Organ dysfunction free		Increasing severity/increasing values	
	5	3	1	0	1	3	5
Neurologic Glasgow coma score	3-5	6-8	9-13	14-15			
Cardiovascular heart rate (min)	< 30 or < 40	40-69	70-89	30-139	≥ 140 or 240-269		
Systolic blood pressure (mmHg)				90-239		≥ 270	
Renal							
Serum urea (g/L)				< 6	6-9.9	10-19.9	≥ 20
Serum urea nitrogen (mmol)				< 6	6-9.9 or 106-140	10-19.9 or ≥ 141 or ≥ 10	≥ 20
Creatinine (μmol)				< 106			
Urine output (L/d)	< 0.5	0.5-0.74		0.75-9.99			
Pulmonary PaO ₂ /FiO ₂ on MV or CPAP PaO ₂ (kPa)/FiO ₂		< 150 (< 19.9)	≥ 150 (≥ 19.9)	No ventilation, no IPAP or no CPAP			
Hematologic							
White blood cell count (× 10 ⁹ /L)		< 1.0	1.0-2.4 or < 50	2.5-49.9	≥ 50.0		
Platelets (× 10 ⁹ /L)				≥ 50			
Hepatic bilirubin (μmol/L)				< 34.2	≥ 34.2		
Prothrombin time, seconds above standard (% of standard)			(< 2.5%)	≤ 3 (≥ 25%)	> 3		

IPAP: Inspiratory positive airway pressure; CPAP: Continuous positive airway pressure; LOD: Logistic organ dysfunction.

vised form should be measured at the same point in time every day (first morning values). The use of measurements at one particular time avoids capturing momentary physiological changes unrelated to patient condition.

In a small study, Jacobs *et al*^[29] compared daily MOD scores to daily Acute Physiology and Chronic Health Evaluation (APACHE) II scores in 39 septic-shock patients from one Saudi Arabian ICU. The authors found that the maximum MOD score and the maximum change in the score from admission, both discriminated (the ability to predict mortality in one individual patient) very well between survivors and non survivors, whereas APACHE II score did not.

To summarize, the MOD score and its revised form can be used to represent organ dysfunction at baseline and during ICU stay. They can also significantly contribute to the prediction of hospital or ICU mortality.

The SOFA score: The SOFA score (Table 3) was developed in 1994 during a Consensus Conference organized by the European Society of Intensive Care and Emergency Medicine, in an attempt to provide a means of describing the degree of organ failure over time in individuals and groups of ICU septic patients.

It was initially termed the Sepsis-related Organ Failure Assessment score, but it has been realized that it could be applied to non-septic patients as well.

It includes scores for six organ systems where a score of zero is given for normal function and a score of four is given for the most abnormal one. The worst values on each day are recorded and organ function total score can thus be monitored over time^[27].

Vincent *et al*^[30] in 1998 working on "sepsis-related" problems published the first evaluation of the SOFA

score. They found that infected patients had more severe organ dysfunctions compared to those without infection. Antonelli *et al*^[31] in 1999 proved that the mean total maximum SOFA score was significantly higher for non-survivors than survivors denoting a high discriminative power (the ability to predict mortality in an individual patient). Because the total maximum SOFA score can be easily calculated daily for the patient, no restriction based on the patients' ICU length of stay is necessary. So, increasing organ dysfunction as measured by the SOFA score consistently correlates with increasing mortality. The SOFA score is also a reliable measure of organ dysfunction at ICU admission.

There were some early published studies that have since examined the utility and accuracy of the SOFA score, which proved that maximum SOFA score and increasing SOFA score are highly prognostic for stratification of critically ill patients including septic patients^[32-34].

The LOD score: The LOD score (Table 4) was developed in 1996 using multiple logistic regression applied to selected variables from a large database of ICU patients^[35]. The score consists of six organ systems and 12 variables with a maximum of 22 scoring points. If no organ dysfunction is present the score is zero, rising to a maximum of five as the worst severity organ dysfunction.

For maximum dysfunction of the pulmonary and hematologic systems, a maximum of three points can be given for the most severe levels of dysfunction and for the liver, the most severe dysfunction only receives one point. The variables had been recorded as the worst value of each organ dysfunction in the first 24 h of ICU admission. A reference table converts the score to a probability of hospital mortality, the relationship being sigmoid. The

Table 5 Acute physiology score in Acute Physiology and Chronic Health Evaluation II

Physiological variable	High abnormal range					Low abnormal range			
	4	3	2	1	0	1	2	3	4
Temperature-rectal (°C)	≥ 41	39-40.9		38.5-38.9	36-38.4	34-35.9	32-33.9	30-31.9	≤ 29.9
Mean arterial pressure (mmHg)	≥ 160	130-159	110-129		70-109		50-69		≤ 49
Heart rate (ventricular response)	≥ 180	140-179	110-139		70-109		50-69	40-54	≤ 39
Respiratory rate (non-ventilated or ventilated)	≥ 50	35-49		25-34	12-24	10-11	6-9		≤ 5
Oxygenation									
A-a DO ₂ (mmHg)									
FiO ₂ ≥ 0.5	≥ 500	350-499	200-349		< 200				
Record									
A-a DO ₂ (mmHg)									
FiO ₂ < 0.5 record only PaO ₂					PO ₂ > 70	PO ₂ (6-70)		PO ₂ (55-60)	PO ₂ < 55
Arterial pH	≥ 7.7	7.6-7.69		7.5-7.59	7.33-7.49		7.25-7.32	7.15-7.24	< 7.15
Serum sodium (mmol/L)	≥ 180	160-179	155-159	150-154	130-149		120-129	111-119	< 7.15
Serum potassium (mmol/L)	≥ 7	6-6.9		5.5-5.9	3.5-5.4	3-3.4	2.5-2.9		< 2.5
Serum creatinine (10 mg/L)	≥ 3.5	2-3.4	1.5-1.9		0.6-1.4		< 0.6		
(double point score for acute renal failure)									
Hematocrit (%)	≥ 60		50-59.9	46-49.9	30-45.9		20-29.9		< 20
White blood count (total/mm ³) (in 1000)	≥ 40		20-39.9	15-19.9	3-14.9		1-2.9		< 1
GCS: score = 15 minus actual GCS									
Total APS: Sum of the 12 individual variable points									
Serum HCO ₃ (venous-mmol/L) (not preferred, use if no ABG)	≥ 52	41-51.9		32-40.9	22-31.9		18-21.9	15-17.9	< 15

GCS: Glasgow coma score; APS: Acute physiology score .

score can thus discriminate between survivors and non-survivors.

The LOD score aims to achieve similar goals to the MOD score, namely, to quantitatively and qualitatively describe organ dysfunction. The goal is to provide a tool that can itself provide a useful outcome measure (e.g., improvement/resolution of organ dysfunction) rather than merely predicting mortality. Though, not originally described as a serial measure, it appears that the LOD score may hold the most promise for patient outcome in the future^[21].

Mortality/survival prediction systems

Mortality/survival prediction scoring systems include a large number of scoring trials by different authors, based on advanced statistical efforts including equations for different populations of critically-ill patients. We chose to concentrate on important examples which are useful for clinical prognostic stratification of mortality/survival of patients namely; the APACHE scores, the therapeutic intervention scoring system, the simplified acute physiology score (APS) and the mortality probability models. However, other scoring systems may prove useful and an ideal scoring system for mortality/survival prediction has not been reached yet. It should be noted that these systems do not replace serial clinical interpretations of the septic patients.

The APACHE scoring systems

The APACHE II scoring system was developed by Knaus

et al^[36] in 1985 as a refinement of the original APACHE score. It consists of: APS, Age points, and Chronic Health points. The reduced number of physiological variables of APS from 34 in the original APACHE to 12 in APACHE II was achieved by a multivariate analysis. The total physiological derangement score is the sum of the individual scores (0-4) for each variable, except the Glasgow coma scale (GCS) where the score is 15 min the GCS. The most deranged value in the first 24 h of ICU admission is used as the scoring for each variable (Table 5). The total physiological derangement score is added to a score of age (0 to 6) and a chronic health score for patients with severe organ insufficiency (2 to 5 dependent upon admission status) as shown in Table 5 and Figure 1. The number of disease groups was 56. The total APACHE II score ranges between zero and 71 points. Points of 25 or less denote less than 50% mortality while points of 35 or more denote more than 80% mortality. However, some investigators have used APACHE II scoring over time to assess the prognosis of individual patients.

Generally, data of the APACHE II score are computed through the following equation to deliver the final risk of hospital mortality:

$$(R/1-R) = -3.517 + (APACHE II \times 0.146 + S + D)$$

where: R = Risk of hospital death, S = Risk imposed by emergency surgery, and D = Risk imposed by specific disease.

Under the APACHE II system, the predicted individual death rate is based on a decision criterion of 0.50.

Temperature : °F °C			Sodium (mmol/L)		
Systolic B/P (mm Hg):			Potassium (mmol/L)		
Diastolic B/P (mm Hg):			Creatinine		
Heart Rate (/m):			Acute Renal Failure (definition)	<input type="radio"/>	
Respiratory Rate (/m):			HCT (%)		
Altitude above sea level: Feet Meter	0		WBC ($\times 10^3$ / mm ³)		
Fio2 (%):			Glasgow Coma Score (calculate)		
PH:			AGE		
PO2:			Chronic Organ Failure: (definition)		
PCO2:			None	<input type="button" value="v"/>	
HCO3 (mmol/L):					
<input type="button" value="Calculate"/> <input type="button" value="Reset"/>					
APACHE Score					

Figure 1 Calculator of Acute Physiology and Chronic Health Evaluation II scoring system.

Any patient with an estimated risk of death greater than 0.50 is simply expected to die.

Although the APACHE II score provides valuable information about the severity of illness of patient groups, they provide little information about the severity of illness of individual patients^[37]. For example, an APACHE II score of 20 does not tell whether the patient has severe renal failure or acute respiratory failure, whereas analysis of component scores of an organ dysfunction score as SOFA will provide an accurate description of the patients' disease status. This does not mean that organ dysfunction scores as the SOFA score should replace APACHE II score but that the two scores can provide different information and may be used to complement each other^[27].

In 1991, Knaus *et al*^[38] published a further refinement to their severity of illness scoring system termed APACHE III (Table 6). Turning first to the APS, they added some variables and eliminated some parameters. Additional weights were assigned to the extremes of physiological measures. For example, the risk associated with extremely high readings is different from that associated with equally low readings. GCS variables were also refined. The authors also re-weighted age and derived an extended chronic health co-morbidity score. The number of disease groups was increased to 94. The APS in APACHE III ranged between zero and 252 points while the total score reached 299 points by adding 24 points for age and 23 points for chronic health evaluation.

The equation of hospital prediction mortality by APACHE III differed from that of APACHE II and included a risk of location denoting the condition of transference of the patient from a previous locality, as

such: $R/1-R = (\text{APACHE III Score} \times 0.053) + \text{Risk of emergency Surgery} + \text{Risk of specific disease category} + \text{Risk of patient location}$.

Similar to APACHE II score, the predicted death rate of the APACHE III score is based on a decision criterion of 0.50 with predicted mortality if R exceeds 0.50.

Independent validation of APACHE III has been undertaken by a number of studies^[39-43], which proved acceptable discrimination performance (the ability to predict mortality in individuals as measured by the area under a receiver operating characteristic curve) and inadequate calibration power (the ability to predict mortality in a large population as measured by a goodness-of-fit test).

A critical prognostic importance of APACHE III, may be based on the premise that the changes in APS would reflect the patient response to therapy. The daily APS component of the risk equation would be given by the formula:

Daily risk = day 1 APS + current day APS + change in APS since yesterday

Day 1 APS is a significant predictor of hospital mortality, but its relative influence decreases dramatically over time. The current day APS, as the most important single factor, should be measured retrospectively as scoring values are the most deranged in any 24 h period.

When the daily risk is added to the remaining patient variables included in the APACHE III score, the coefficients of each variable were established resulting in equations for d 1-7 of ICU admission. Research is going on to extend the model beyond day 7.

Changes in protocols and practices within ICUs prompted a full review and updating of all the mortality APACHE III equations^[38] by using the same variables as APACHE III with added new variables: mechanical ventilation, thrombolysis, impact of sedation on GCS, together with rescaling of GCS and oxygenation index. Updating used the largest group of patients ever used for APACHE equations modeling care from 104 ICUs in 45 hospitals, with a total of 131 618 observations. The two used statistical techniques were logistic and linear regressions. The result was a new version called APACHE IV^[44], whose calculator is shown in Figure 2.

In addition, there were several changes made for the modeling process used in APACHE III. The first involved the laboratory values that were previously considered as "normal". That is, if a measurement was missing, then the value of the previous day was carried forward. If the previous day value was also missing, then the value from 2 d back was carried forward, *etc.* the second change excluded patients transferred from another ICU, because extensive clinical interventions and life support before ICU admission biases the prognostic implications of the first ICU day physiologic measures. The third change was measurement of previous length of hospital stay (LOS) as a continuous rather than an integer value. Previous LOS was defined as the square root of (ICU admission date/time-Hospital admission date/time). Fourth, to more precisely determine the impact of neurological

Table 6 Acute physiology score in Acute Physiology and Chronic Health Evaluation III scoring system

Parameter	Value range	Points	Parameter	Value range	Points
Core temperature (°C)	0-32.9	20	Plasma bilirubin (μmol/L)	0-34	0
	33.0-33.4	16		35-51	5
	33.5-33.9	13		52-85	6
	34.0-34.9	8		86-135	8
	35.0-35.9	2		136 plus	16
	36.0-36.9	0	Urine volume (mL/24 h)	0-399	15
Heart (r/min)	40 or more	4		400-599	3
	0-39	8		600-899	7
	40-49	5		900-1499	5
	50-99	0		1500-1999	4
	100-109	1		2000-3999	0
	110-119	5		4000 plus	1
Mean blood pressure (mmHg)	120-139	7	Plasma Creatinine (μmol/L) (if no acute renal failure or in ARF (< 410 mL urine vol/24 h)	0-43	3
	140-154	13		44-132	0
	155 or more	17		133-171	2
	0-39	23		172 or more	7
	40-59	15		0-132	0
	60-69	7		133 or more	10
Respiratory (r/min) (zero points for 6-12/min rate if on ventilation)	70-79	6	Arterial PO ₂ (kPa) (Inspired O ₂ < 50%) or alveolar/arterial PO ₂ difference kPa (Pa-PaO ₂) (Inspired O ₂ > 50%)	0-6.66	15
	80-99	0		6.67-9.32	5
	100-119	4		9.33-10.6	2
	120-129	7		10.7 plus	0
	130-139	9		0-13.2	0
	140 or more	10		13.3-33.2	7
White cell count (× 10 ⁹ /L)	0-5	17	Age (yr)	33.3-46.5	9
	6-11	8		46.6-66.6	11
	12-13	7		66.7 and over	14
	14-24	0		0-44	0
	25-34	6		45-59	5
	35-39	9		60-64	11
Haematocrit (%)	40-49	11	Chronic health evaluation (do not score in elective surgery patients)	65-69	13
	50 or more	3		70-74	17
				75 or more	24
Plasma sodium (mmol/L)	0-0.9	19		Cirrhosis	4
	1.0-2.9	5		Immunosuppression	10
	3.0-19.9	0		Leukaemia	10
	20.0-24.9	1		Multiple myeloma	10
Plasma albumin (g/L)	25 or more	4		Metastatic cancer	11
	0-19	11		Lymphoma	13
	20-44	0	Neurological score	Hepatic failure	16
	45 or more	4		AIDS	23
Acid base status	Use matrix	0-12		Use matrix	0-48

derangement, a variable was added indicating whether a GCS could not be assessed due to sedation. The most important change involved the new categorization of disease groups. Based on the frequency of selected diagnosis and their mortality rate, the existing 94 groups were expanded to 116^[3,44]. However, the major changes to the equations included the addition of new variables, the recalling of previous LOS, and increasing the number of disease groups from 94 to 116.

The APACHE systems are the only validated ICU

risk adjustment models that provide performance information about 2 separate outcomes of care; mortality and ICU LOS, the APACHE IV model is the most recent version. Researches are enthusiastic nowad to discontinue the use of APACHE II and III and move to the more contemporary and accurate APACHE IV, now that both the score and the two predictions are in public^[44].

The Therapeutic Intervention scoring system

The Therapeutic Intervention scoring system was devel-

APACHE IV Calculator
 APACHE is a registered trademark of Corner Corporation, Kansas City, Missouri, USA
Non-CABG Patients only

- Enter the lowest and the highest values for the physiologic parameter
- Use the worse values during the 24 hour period

Select the Unit: ☐ Conventional Units ☐ International Units (SI)

Lowest	Highest	Lowest	Highest
Temperature		Sodium (mmol/L)	
Systolic B/P (mm Hg):		Glucose	
Diastolic B/P (mm Hg):		Creatinine	
Heart Rate (/m):		BUN	
Respiratory Rate (/m):		Urine (ml/24hrs) Output	
Altitude above sea level:		Albumin	
Fio2 (%):		Bilirubin	
PH:		HCT (%)	
PO2:		WBC ($\times 10^3 / \text{mm}^3$)	
PCO2:			

Glasgow Coma Score

Check only if unable to obtain GCS due to Meds, anesthesia, or sedation ☐

Eye Opening	Verbal Response	Motor Response
spontaneous	converses & oriented	obeys
to speech	converses & disoriented	localizes pain
to pain	inappropriate	withdraws (flexion)
absent	incomprehensible	decorticate (flexion) rigidity
	absent	decerebrate (extension) rigidity
		absent

Glasgow Coma Score=

Age (years)

Chronic Health Condition

CRF/HD (used for APS)	Metastatic Cancer
AIDS	Leukemia/Multiple Myeloma
Hepatic Failure	Immunosuppression
Lymphoma	Cirrhosis

ICU Admission Information

Admitted from:

Pre ICU LOS (days)

Emergency Surgery ☐

Readmission ☐

Ventilated at any time (first 24 hrs) ☐

Admitting Diagnosis

If Dx Acute MI: ☐ Thrombolytic Therapy: ☐

APACHE IV Score

APS Score

Logit

APACHE Disease Mapping Code

Predicted Mortality Rate

Predicted ICU LOS

Programmed by Mazen Kherallah, MD, FCCP

Figure 2 Calculator of Acute Physiology and Chronic Health Evaluation IV scoring system.

oped by Cullen *et al*^[45] in 1974 as the earliest severity scoring system. It is composed of 76 monitoring and therapeutic parameters. Each modality is assigned a weighted score, ranging from 1 to 4, depending on the intensity of intervention. For example, a peripheral *iv* line or a urinary catheter is assigned one point. A central venous line or two peripheral *iv* catheters are assigned two points. A central *iv* line for hyperalimentation or the application of a chest tube is assigned three points. A pulmonary artery catheter for vaso-active drug infusion is assigned four points. Each modality is assigned to one of three categories: active therapy, ICU monitoring or standard floor care. Points are totaled and TISS score is obtained by a calculator (Figure 3). Patients can be then stratified into one of four classes based on the number of TISS points. TISS is based on the premise that, regardless of the diagnosis, the amount of therapy based on the amount of monitoring reflects the degree of physiological impairment. The TISS does not predict outcome on patient admission to the ICU. However, trends of the score over the first three d in ICU correlate well with survival. If the TISS points do not improve at the third day, the likelihood of death increases. So, it discriminates between survivors in whom the score falls progressively and non-survivors in whom the score remains static. Moreover, the TISS can identify those patients who require monitoring only.

The TISS is used most frequently in conjunction with the APACHE systems. So, Both together can be used to evaluate concordance between severity of illness and quantity of needed therapy. Either the TISS alone or in conjunction with the APACHE scoring systems can be used for prognostic categorization of patients with systemic sepsis.

Simplified APS

In 1984, Le Gall *et al*^[46], published the Simplified Acute Physiology Score. It was designed to overcome some of the problems of APS of the APACHE systems. The authors selected the 13 “most easily measured” physiological variables available in 90% of patients from a previous survey employing the APS that they had conducted. SAPS scores these variables (0-4) in an identical manner to the APS of the APACHE II system, adds a score for age (0-4) and replaces respiratory rate or the P(A-a) O₂ which is difficult to measure with a fixed score of 3 for patients receiving mechanical ventilation or CPAP. The most abnormal values from the first 24 h of ICU admission are taken as the total scoring value. Le Gall *et al*^[46] concluded that SAPS performed at least as well if not better than APS of the APACHE system but was more useful as it was much simpler. They stressed that SAPS is applicable to a wide range of pathologies but that its

(Therapeutic Intervention Scoring System - Update 1983)

4 points		3 points	
a. Cardiac arrest and/or countershock within past 48 h	<input type="radio"/> yes <input type="radio"/> no	a. Central iv hyperalimentation (includes renal, cardiac, hepatic failure fluid)	<input type="radio"/> yes <input type="radio"/> no
b. Controlled ventilation with or without PEEP	<input type="radio"/> yes <input type="radio"/> no	b. Pacemaker on standby	<input type="radio"/> yes <input type="radio"/> no
c. Controlled ventilation with intermittent or continuous muscle relaxants	<input type="radio"/> yes <input type="radio"/> no	c. Chest tubes	<input type="radio"/> yes <input type="radio"/> no
d. Balloon tamponade of varices	<input type="radio"/> yes <input type="radio"/> no	d. IMV or assisted ventilation	<input type="radio"/> yes <input type="radio"/> no
e. Continuous arterial infusion	<input type="radio"/> yes <input type="radio"/> no	e. CPAP	<input type="radio"/> yes <input type="radio"/> no
f. Pulmonary artery catheter	<input type="radio"/> yes <input type="radio"/> no	f. Concentrated K ⁺ infusion via central catheter	<input type="radio"/> yes <input type="radio"/> no
g. Atrial and/or ventricular pacing	<input type="radio"/> yes <input type="radio"/> no	g. Nasotracheal or orotracheal intubation	<input type="radio"/> yes <input type="radio"/> no
h. Hemodialysis in unstable patient	<input type="radio"/> yes <input type="radio"/> no	h. Blind intratracheal suctioning	<input type="radio"/> yes <input type="radio"/> no
i. Peritoneal dialysis	<input type="radio"/> yes <input type="radio"/> no	i. Complex metabolic balance (frequent intake and output)	<input type="radio"/> yes <input type="radio"/> no
j. Induced hypothermia	<input type="radio"/> yes <input type="radio"/> no	j. Multiple ABG, bleeding, and/or STAT studies (> 4 shift)	<input type="radio"/> yes <input type="radio"/> no
k. Pressure-activated blood infusion	<input type="radio"/> yes <input type="radio"/> no	k. Frequent infusion of blood products (>5 units /24 h)	<input type="radio"/> yes <input type="radio"/> no
l. G-suit	<input type="radio"/> yes <input type="radio"/> no	l. Bolus iv medication (nonscheduled)	<input type="radio"/> yes <input type="radio"/> no
m. Intracranial pressure monitoring	<input type="radio"/> yes <input type="radio"/> no	m. Vasoactive drug infusion (1 drug)	<input type="radio"/> yes <input type="radio"/> no
n. Platelet transfusion	<input type="radio"/> yes <input type="radio"/> no	n. Continuous antiarrhythmia infusions	<input type="radio"/> yes <input type="radio"/> no
o. IABP (Intra Aortic Balloon Pressure)	<input type="radio"/> yes <input type="radio"/> no	o. Cardioversion for arrhythmia (not defibrillation).	<input type="radio"/> yes <input type="radio"/> no
p. Emergency operative procedures (within past 24 h)	<input type="radio"/> yes <input type="radio"/> no	p. Hypothermia blanket	<input type="radio"/> yes <input type="radio"/> no
q. Lavage of acute GI bleeding	<input type="radio"/> yes <input type="radio"/> no	q. Arterial line	<input type="radio"/> yes <input type="radio"/> no
r. Emergency endoscopy or bronchoscopy	<input type="radio"/> yes <input type="radio"/> no	r. Acute digitalization - within 48 h	<input type="radio"/> yes <input type="radio"/> no
s. Vasoactive drug infusion (> 1 drug)	<input type="radio"/> yes <input type="radio"/> no	s. Measurement of cardiac output by any method	<input type="radio"/> yes <input type="radio"/> no
		t. Active diuresis for fluid overload or cerebral edema	<input type="radio"/> yes <input type="radio"/> no

Figure 3 Calculator of Therapeuti Intervensi scoring system.

Type of admission	Chronic diseases	Glasgow Coma Scale
0	0	0
Age	Syst. Blood Pressure	Heart rate
0	0	0
Temperature	If MV or CPAP PaO ₂ /FIO ₂ (mmHg)	Urine output
0	0	0
Serum Urea or BUN	WBC	Potassium
0	0	0
Sodium	HCO ₃ ⁻	Bilirubin
0	0	0
SAPS II		
0		
Predicted Mortality	Logit = -7,7631+0,0737*(SAPS II)+0,9971*ln((SAPS II)+1) Predicted Mortality = e ^(logit) / (1 + e ^(logit))	
0	0	
Calc		

Figure 4 Calculator of Simplified Acute Physiology scoring system I .

predictive value and performance can only be applied to groups of patients, not to individual patients.

In 1993, Le Gall *et al*^[47] published a refined version of their original SAPS termed SAPS II whose calculator is shown in Figure 4, and the variables were 17 (12 physiological, age, type of admission and 3 chronic health diagnosis).

The main advantage of SAPS II over APACHE III is the ability to accurately predict mortality in stratified

groups of patients without recourse to defining a single diagnosis, which is only possible in a minority of patients.

It is clear that SAPS II can be useful for prognostic stratification for groups of critically ill patients including those with systemic sepsis. It can also be useful for guiding therapy, comparing the management of these patients overtime and comparing ICU performance of groups of patients in different ICU's.

The SAPS II score varies between zero and 163 points: 116 points for physiological variables, 17 points for age and 30 points for previous diagnosis.

SAPS III assesses 12 physiological variables: at the first 24 h of ICU admission as SAPS II, and includes weighing for pre-admission health status and age. It has been poorly studied, with the exception of some formal analysis of data accuracy in the original publication and external validation studies^[48,49].

The mortality probability models

In 1985, Lemeshow *et al*^[50] published their first attempt at an outcome prediction model. They actually developed four models: MPM₀ (probability of death from data collected at ICU admission), MPM₂₄ (probability of death from data collected at 24 h), MPM₄₈ (probability of death from data collected at 48 h) and MPM_{OT} (probability of death "overtime" based on MPM₀ and the change in probability between MPM₀ and MPM₂₄, and between MPM₂₄ and MPM₄₈). Patients whose probability of mortality started high and remained high, or increased by > 10% had a very high actual mortality. It deserves mentioning that for ICU triage purposes, MPM₀ is the most valid model at present.

(Mortality Probability Models)

Variables (Help)	Values (1 if yes, 0 otherwise)	Beta
Medical or unscheduled surgery admission	<input type="checkbox"/>	0
Metastatic neoplasm	<input type="checkbox"/>	0
Cirrhosis	<input type="checkbox"/>	0
Chronic renal insufficiency	<input type="checkbox"/>	0
C.P.R. prior to admission	<input type="checkbox"/>	0
Coma (Glasgow 3-5) (Help)	<input type="checkbox"/>	0
Heart Rate >= 150	<input type="checkbox"/>	0
Systolic Blood Pressure <= 90 mmHg	<input type="checkbox"/>	0
Acute renal insufficiency	<input type="checkbox"/>	0
Cardiac dysrhythmia	<input type="checkbox"/>	0
Cerebrovascular incident	<input type="checkbox"/>	0
Gastrointestinal bleeding	<input type="checkbox"/>	0
Intracranial mass effect	<input type="checkbox"/>	0
Mechanical ventilation	<input type="checkbox"/>	0
Age	0	0.03057
Predicted Death rate :		Logit = 0
<input type="text" value="0"/> <input type="button" value="Compute"/> <input type="button" value="Clear"/>		Logit = Sum (values * beta) + age * 0.03057 -5.46836 Predicted death rate = (e ^{Logit}) / (1 + e ^{Logit})

Figure 5 Calculator of mortality probability model.

In common with APACHE and SAPS systems, MPM had low sensitivity (ability to predict those patients who are going to die) but high specificity (ability to predict those patients who are going to live).

Lemeshow *et al*^[51] published a revision of their MPM termed MPM II. They employed a near identical method to that they had used in developing their original MPM. The authors initially developed MPM II₀ and MPM II₂₄, deciding to temporarily abandon the MPM₄₈ and MPM_{OT} of the original model. MPM II₀ was determined by 15 variables. Lemeshow *et al*^[52] in 1994, found that patients alive but still requiring to be on ICU at 24 h differed markedly from those who had either died or been discharged. They emphasized that MPM II₂₄, including 13 variables, is a companion model to MPM II₀ and represents a different population of patients. The authors argue that this approach exposes one of the main weaknesses of the APACHE and SAPS models, which take the worst data from the first 24 h of ICU admission, and failed to differentiate between the two originally observed populations.

The following year, Lemeshow *et al*^[53] published two further models based upon their data set, MPM II₄₈ and MPM II₇₂. Both these models use the same 13 variables as MPM II₂₄. They pointed out that the probability of death changes with time, while an APACHE or SAPS score is only valid at 24 h of ICU admission. They also emphasized that an ICU patient whose condition failed to improve day after day, was in fact deteriorating and had an increasing risk of death. This well recognized clinical phenomenon is accurately modeled over the first 72 h of their ICU stay by MPM II. The same could not be said for sequential APACHE II scoring. The authors described an on-going process to develop MPM II models for successive time points beyond 72 h. (MPM II_{OT}). Figure 5 shows the calculator of the MPM.

Limitations of scoring systems

Data-base still continues about the accuracy of scoring systems, their efficiency in assessing the severity of illness, and whether they have a prognostic role in the estimation of illness outcome. Additionally, these tools have to be validated in the population in question before they are adopted for outcome prediction and decision-making^[53].

The most important potential limitation of scoring systems is the inappropriate interpretation of the score. Clinicians must be aware that the probability of in-hospital mortality based on a particular score relates to a similar group of patients and not to an individual patient. This is important to understand before attempting to use scoring systems in clinical practice. So, although it can be useful to know the predicted mortality of a group of patients with a similar score, we cannot be sure which patients will die and which will survive. A well calibrated model, applied to an individual patient, may for example predict a hospital mortality of 46% for this patient, which just means that for a group of 100 patients with a similar severity of illness, 46 patients are predicted to die, but it makes no statement if the individual patient is included in the 46% who will die or in the 54% that will survive. Consequently, scoring systems should not be used to make predictions for individual cases. Conversely, scoring systems can appropriately be used to assist the clinical decision making as they do allow an objective assessment of a patient's severity of illness, and therefore reflect the likelihood of mortality in a similar cohort of patients. Overall, they should be considered as a fact to assist the clinician.

OVERVIEW

It is now about 30 years since the original APACHE

study was published. Tens of thousands of patients have been studied and mortality prediction models and prognostic categorization morbidity models developed on universal ICU critically ill patients.

Severity scoring systems are usually designed to predict morbidity or mortality in critically- ill patients. Examples of general scoring systems are APACHE III; SAPS II and MPM II. Examples of organ dysfunction scoring systems are MODS, SOFA and LODS. Examples of specific severity scoring systems include Acute Pancreatitis and Acute Lung Injury scores. Biological scores include measurements of serum lactate and PHi. Examples of overtime or dynamic severity scoring systems are APACHE III, MPM²⁴⁻⁷² and intermediate TISS.

Because general severity scoring systems are developed and validated using admission data from large ICU populations, they are most fitted to predict mortality for groups of ICU patients rather than predicting mortality for individual patients. They are used for determining ICU proficiency (in quality assurance) and treatment efficacy (in clinical practice). Decisions regarding ICU triage are often more dependent on values than probabilities and so, these systems should not determine the utility or futility of ICU for individuals.

Even if a severity scoring index could perfectly predict the mortality of a septic patient from admission data, one should be cautious, because death cannot actually be predicted except just before its occurrence and by that time, there would be little to be gained. By contrast, early prediction of death might be more useful to design patient management. It would be likely to be associated with a greater risk of a false positive result.

Outcome estimates may influence the clinical management. The clinical awareness of the treating physician of a poor outcome for his/her patient may tempt him/her to give less than optimal therapy or to prevent ventilating him or even to withdraw active therapy. To date, however, it is almost impossible to find documented evidence of change in medical practice that have resulted from application of different prognostic scoring systems^[21]. There is clearly no "best" severity scoring model, and the performance of such models varies both with time and with the population under study, and so should be periodically addressed. For this, severity scoring systems should be used in conjunction with sequential patient clinical interpretation and clinical assessment of tissue hypoxia for prognostic categorization of critically-ill patients in general and septic patients in particular.

REFERENCES

- 1 **Bone RC**, Balk RA, Cerra FB, Dellinger RP, Fein AM, Knaus WA, Schein RM, Sibbald WJ. Definitions for sepsis and organ failure and guidelines for the use of innovative therapies in sepsis. The ACCP/SCCM Consensus Conference Committee. American College of Chest Physicians/Society of Critical Care Medicine. *Chest* 1992; **101**: 1644-1655
- 2 **Rangel-Frausto MS**, Pittet D, Costigan M, Hwang T, Davis CS, Wenzel RP. The natural history of the systemic inflammatory response syndrome (SIRS). A prospective study. *JAMA* 1995; **273**: 117-123
- 3 **Le Gall JR**, Lemeshow S, Leleu G, Klar J, Huillard J, Rué M, Teres D, Artigas A. Customized probability models for early severe sepsis in adult intensive care patients. Intensive Care Unit Scoring Group. *JAMA* 1995; **273**: 644-650
- 4 **Marshall JC**, Cook DJ, Christou NV, Bernard GR, Sprung CL, Sibbald WJ. Multiple organ dysfunction score: a reliable descriptor of a complex clinical outcome. *Crit Care Med* 1995; **23**: 1638-1652
- 5 **Webster NR**. Activated protein C in sepsis. *AJAIC* 2001; **4** (Suppl 1): 41-42
- 6 **Beal AL**, Cerra FB. Multiple organ failure syndrome in the 1990s. Systemic inflammatory response and organ dysfunction. *JAMA* 1994; **271**: 226-233
- 7 **Shoemaker WC**, Appel PL, Kram HB, Waxman K, Lee TS. Prospective trial of supranormal values of survivors as therapeutic goals in high-risk surgical patients. *Chest* 1988; **94**: 1176-1186
- 8 **Edwards JD**, Brown GC, Nightingale P, Slater RM, Faragher EB. Use of survivors' cardiorespiratory values as therapeutic goals in septic shock. *Crit Care Med* 1989; **17**: 1098-1103
- 9 **Russell JA**, Phang PT. The oxygen delivery/consumption controversy. Approaches to management of the critically ill. *Am J Respir Crit Care Med* 1994; **149**: 533-537
- 10 **Moemen ME**, Omran SA, Rifky MA, Hasan AAS. Tissue oxygenation guided resuscitation in patients with sepsis. Thesis in Anaesthesia and Intensive Care, Faculty of medicine, Zagazig university, Egypt, 2001
- 11 **Dahaba AA**, Elawady GA, Rehak PH, List WF. Procalcitonin and proinflammatory cytokine clearance during continuous venovenous haemofiltration in septic patients. *Anaesth Intensive Care* 2002; **30**: 269-274
- 12 **Montón C**, Torres A, El-Ebiary M, Filella X, Xaubert A, de la Bellacasa JP. Cytokine expression in severe pneumonia: a bronchoalveolar lavage study. *Crit Care Med* 1999; **27**: 1745-1753
- 13 **Wakefield CH**, Barclay GR, Fearon KC, Goldie AS, Ross JA, Grant IS, Ramsay G, Howie JC. Proinflammatory mediator activity, endogenous antagonists and the systemic inflammatory response in intra-abdominal sepsis. Scottish Sepsis Intervention Group. *Br J Surg* 1998; **85**: 818-825
- 14 **Casey LC**, Balk RA, Bone RC. Plasma cytokine and endotoxin levels correlate with survival in patients with the sepsis syndrome. *Ann Intern Med* 1993; **119**: 771-778
- 15 **Nylen ES**, Whang KT, Snider RH, Steinwald PM, White JC, Becker KL. Mortality is increased by procalcitonin and decreased by an antiserum reactive to procalcitonin in experimental sepsis. *Crit Care Med* 1998; **26**: 1001-1006
- 16 **Assicot M**, Gendrel D, Carsin H, Raymond J, Guillaud J, Bohuon C. High serum procalcitonin concentrations in patients with sepsis and infection. *Lancet* 1993; **341**: 515-518
- 17 **de Werra I**, Jaccard C, Corradin SB, Chiolerio R, Yersin B, Gallati H, Assicot M, Bohuon C, Baumgartner JD, Glauser MP, Heumann D. Cytokines, nitrite/nitrate, soluble tumor necrosis factor receptors, and procalcitonin concentrations: comparisons in patients with septic shock, cardiogenic shock, and bacterial pneumonia. *Crit Care Med* 1997; **25**: 607-613
- 18 **Nijsten MW**, Olinga P, The TH, de Vries EG, Koops HS, Groothuis GM, Limburg PC, ten Duis HJ, Moshage H, Hoekstra HJ, Bijzet J, Zwaveling JH. Procalcitonin behaves as a fast responding acute phase protein in vivo and in vitro. *Crit Care Med* 2000; **28**: 458-461
- 19 **Ugarte H**, Silva E, Mercan D, De Mendonça A, Vincent JL. Procalcitonin used as a marker of infection in the intensive care unit. *Crit Care Med* 1999; **27**: 498-504
- 20 **Fathia HK**, Mokhtar MS, Ragab FA, Rizk AF. Role of decisive markers in diagnosis and outcome of patients with septic shock. Thesis in critical care medicine, Faculty of medicine, Cairo University, Egypt, 2000

- 21 **Moemen ME.** Prognostic categorization in systemic sepsis. *Eg J Anaesth* 2003; **19**: 183-194
- 22 **Salzman AL,** Strong KE, Wang H, Wollert PS, Vandermeer TJ, Fink MP. Intraluminal "balloonless" air tonometry: a new method for determination of gastrointestinal mucosal carbon dioxide tension. *Crit Care Med* 1994; **22**: 126-134
- 23 **Mohsenifar Z,** Hay A, Hay J, Lewis MI, Koerner SK. Gastric intramural pH as a predictor of success or failure in weaning patients from mechanical ventilation. *Ann Intern Med* 1993; **119**: 794-798
- 24 **Corke CF,** Prisco G, Gizycki P, Selvakumaran A. A simple method for frequent monitoring of gastric carbon dioxide. *Anaesth Intensive Care* 1996; **24**: 590-593
- 25 **Gutierrez G,** Palizas F, Doglio G, Wainsztein N, Gallesio A, Pacin J, Dubin A, Schiavi E, Jorge M, Pusajo J. Gastric intramucosal pH as a therapeutic index of tissue oxygenation in critically ill patients. *Lancet* 1992; **339**: 195-199
- 26 **Swank GM,** Deitch EA. Role of the gut in multiple organ failure: bacterial translocation and permeability changes. *World J Surg* 1996; **20**: 411-417
- 27 **Vincent JL,** Ferreira F, Moreno R. Scoring systems for assessing organ dysfunction and survival. *Crit Care Clin* 2000; **16**: 353-366
- 28 **Cook R,** Cook D, Tilley J, Lee K, Marshall J. Multiple organ dysfunction: baseline and serial component scores. *Crit Care Med* 2001; **29**: 2046-2050
- 29 **Jacobs S,** Zuleika M, Mphansa T. The Multiple Organ Dysfunction Score as a descriptor of patient outcome in septic shock compared with two other scoring systems. *Crit Care Med* 1999; **27**: 741-744
- 30 **Vincent JL,** de Mendonça A, Cantraine F, Moreno R, Takala J, Suter PM, Sprung CL, Colardyn F, Blecher S. Use of the SOFA score to assess the incidence of organ dysfunction/failure in intensive care units: results of a multicenter, prospective study. Working group on "sepsis-related problems" of the European Society of Intensive Care Medicine. *Crit Care Med* 1998; **26**: 1793-1800
- 31 **Antonelli M,** Moreno R, Vincent JL, Sprung CL, Mendoça A, Passariello M, Riccioni L, Osborn J. Application of SOFA score to trauma patients. Sequential Organ Failure Assessment. *Intensive Care Med* 1999; **25**: 389-394
- 32 **Oda S,** Hirasawa H, Sugai T, Shiga H, Nakanishi K, Kitamura N, Sadahiro T, Hirano T. Comparison of Sepsis-related Organ Failure Assessment (SOFA) score and CIS (cellular injury score) for scoring of severity for patients with multiple organ dysfunction syndrome (MODS). *Intensive Care Med* 2000; **26**: 1786-1793
- 33 **Ferreira FL,** Bota DP, Bross A, Mélot C, Vincent JL. Serial evaluation of the SOFA score to predict outcome in critically ill patients. *JAMA* 2001; **286**: 1754-1758
- 34 **Moreno R,** Miranda DR, Matos R, Fevereiro T. Mortality after discharge from intensive care: the impact of organ system failure and nursing workload use at discharge. *Intensive Care Med* 2001; **27**: 999-1004
- 35 **Le Gall JR,** Klar J, Lemeshow S, Saulnier F, Alberti C, Artigas A, Teres D. The Logistic Organ Dysfunction system. A new way to assess organ dysfunction in the intensive care unit. ICU Scoring Group. *JAMA* 1996; **276**: 802-810
- 36 **Knaus WA,** Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. *Crit Care Med* 1985; **13**: 818-829
- 37 **Chang RW.** Individual outcome prediction models for intensive care units. *Lancet* 1989; **2**: 143-146
- 38 **Knaus WA,** Wagner DP, Draper EA, Zimmerman JE, Bergner M, Bastos PG, Sirio CA, Murphy DJ, Lotring T, Damiano A. The APACHE III prognostic system. Risk prediction of hospital mortality for critically ill hospitalized adults. *Chest* 1991; **100**: 1619-1636
- 39 **Beck DH,** Taylor BL, Millar B, Smith GB. Prediction of outcome from intensive care: a prospective cohort study comparing Acute Physiology and Chronic Health Evaluation II and III prognostic systems in a United Kingdom intensive care unit. *Crit Care Med* 1997; **25**: 9-15
- 40 **Pappachan JV,** Millar B, Bennett ED, Smith GB. Comparison of outcome from intensive care admission after adjustment for case mix by the APACHE III prognostic system. *Chest* 1999; **115**: 802-810
- 41 **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; **28**: 1820-1827
- 42 **Zimmerman JE,** Wagner DP, Draper EA, Wright L, Alzola C, Knaus WA. Evaluation of acute physiology and chronic health evaluation III predictions of hospital mortality in an independent database. *Crit Care Med* 1998; **26**: 1317-1326
- 43 **Sirio CA,** Shepardson LB, Rotondi AJ, Cooper GS, Angus DC, Harper DL, Rosenthal GE. Community-wide assessment of intensive care outcomes using a physiologically based prognostic measure: implications for critical care delivery from Cleveland Health Quality Choice. *Chest* 1999; **115**: 793-801
- 44 **Zimmerman JE,** Kramer AA, McNair DS, Malila FM. Acute Physiology and Chronic Health Evaluation (APACHE) IV: hospital mortality assessment for today's critically ill patients. *Crit Care Med* 2006; **34**: 1297-1310
- 45 **Cullen DJ,** Civetta JM, Briggs BA, Ferrara LC. Therapeutic intervention scoring system: a method for quantitative comparison of patient care. *Crit Care Med* 1974; **2**: 57-60
- 46 **Le Gall JR,** Loirat P, Alperovitch A, Glaser P, Granthil C, Mathieu D, Mercier P, Thomas R, Villers D. A simplified acute physiology score for ICU patients. *Crit Care Med* 1984; **12**: 975-977
- 47 **Le Gall JR,** Lemeshow S, Saulnier F. A new Simplified Acute Physiology Score (SAPS II) based on a European/North American multicenter study. *JAMA* 1993; **270**: 2957-2963
- 48 **Strand K,** Søreide E, Aardal S, Flaatten H. A comparison of SAPS II and SAPS 3 in a Norwegian intensive care unit population. *Acta Anaesthesiol Scand* 2009; **53**: 595-600
- 49 **Metnitz PG,** Moreno RP, Almeida E, Jordan B, Bauer P, Campos RA, Iapichino G, Edbrooke D, Capuzzo M, Le Gall JR. SAPS 3--From evaluation of the patient to evaluation of the intensive care unit. Part 1: Objectives, methods and cohort description. *Intensive Care Med* 2005; **31**: 1336-1344
- 50 **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**: 519-525
- 51 **Lemeshow S,** Teres D, Klar J, Avrunin JS, Gehlbach SH, Rapoport J. Mortality Probability Models (MPM II) based on an international cohort of intensive care unit patients. *JAMA* 1993; **270**: 2478-2486
- 52 **Lemeshow S,** Klar J, Teres D. Outcome prediction for individual intensive care patients: useful, misused, or abused? *Intensive Care Med* 1995; **21**: 770-776
- 53 **Lemeshow S,** Le Gall JR. Modeling the severity of illness of ICU patients. A systems update. *JAMA* 1994; **272**: 1049-1055

S- Editor Gou SX L- Editor A E- Editor Zheng XM