A Comparison of Severity of Illness Scoring Systems for Critically Ill Obstetric Patients*

Ali A. El-Solh, MD; and Brydon J.B. Grant, MD, FCCP

Study objective: To evaluate the predictive ability of three scoring systems, acute physiology and chronic health evaluation (APACHE II), simplified acute physiology score (SAPS II), and mortality probability models (MPM II) in critically ill obstetric patients compared to a control group of nonobstetric female patients of similar age group (range, 17 to 41 years).
Design: A retrospective medical chart review of obstetric and nonobstetric female patients between 17 and 41 years of age.
Setting: Two university hospitals.
Patients: Ninety-three obstetric patients and 96 nonobstetric female patients were identified from 12,740 consecutive ICU admissions.
Results: The actual mortality of the obstetric and the nonobstetric group was 10.8% (95% confidence interval [CI], 5.3 to 19.0%) and 12.5% (95% CI, 6.6 to 21.0%), respectively. The observed mortality was not statistically different from the mortality predicted by APACHE II, SAPS II, and MPM II (14.7%, 7.8%, and 9.1% for the obstetric group and 10.9%, 9.0%, and 9.9% for the nonobstetric group). Predictive accuracy was assessed by the c-index, which is equivalent to the area under the receiver operator characteristic (ROC) curve. There were no significant differences in the c-index for APACHE II, SAPS II, and MPM II within or between the obstetric group ([mean±SE], 0.93±0.02, 0.90±0.04, and 0.91±0.04, respectively) and the nonobstetric group (0.97±0.02, 0.95±0.03, and 0.96±0.02, respectively).
Conclusions: We conclude that APACHE II, SAPS II, and MPM II assess the ICU outcome of critically ill obstetric patients as accurately as nonobstetric critically ill female patients of similar age group.
(CHEST 1996; 110:1299-1304)

Key words: APACHE II; c-index; intensive care unit; mortality prediction; MPM II; obstetric; SAPS II

Abbreviations: APACHE II=acute physiology and chronic health evaluation; AUC=area under the curve; CI=confidence interval; MPM II=mortality probability models; ROC=receiver operator characteristic; SAPS II=simplified acute physiology score

In the last several years, different predictive scoring systems[1-3] have been developed to forecast patient outcome in an attempt to assist physicians in clinical decision making. The application of these scoring systems to patient-specific groups has been subject to some controversy as to their ability to differentiate accurately between survivors and nonsurvivors.[4-7] One group that has attracted attention is the critically ill obstetric patients.

The need for accurate assessment of the severity of disease in critically ill obstetric patients would not only contribute to the assessment of the quality of patient care, but would also enhance risk stratification of pregnant women in the evaluation of new therapies. One retrospective study of 22 critically ill obstetric patients found the acute physiology and chronic health evaluation (APACHE II) scoring system to underestimate ICU maternal mortality.[8] In contrast, the simplified acute physiology score (SAPS II) was found to overestimate the actual mortality rate of 29 obstetric patients.[9]

The aim of this study was to evaluate the predictive ability of three scoring systems, APACHE II, SAPS II, and mortality probability models (MPM II), in critically ill obstetric patients compared to a control group of nonobstetric female patients of similar age group, admitted to medical or surgical ICUs during a 5-year time period, in a much larger patient population.

Materials and Methods

A retrospective medical record review was conducted involving critically ill obstetric patients and nonobstetric female patients (range, 17 to 41 years), who were admitted to the medical and surgical ICUs of two university hospitals. All consecutive obstetric ICU

*From the Department of Medicine, State University of New York at Buffalo, School of Medicine and Biomedical Sciences, Buffalo General Hospital, and Department of Veterans Affairs Medical Center, Buffalo, NY.
Manuscript received December 19, 1995; revision accepted May 1, 1996.

Table 1—*Diagnostic Categories of Obstetric Patients*

Primary Diagnoses* (n=93)	No. (%)	Mechanical Ventilation (n=35)	Maternal Death (n=10)	Stillborn (n=10)
Respiratory		17 (18)	5 (5)	
Pneumonia		11	4	
NCPE		2		
Pulmonary embolus		0		
Amniotic fluid embolus		2	0	0
Asthma		0	0	0
ARDS		2	1	1
Cardiac		3 (3)	1 (1)	1 (1)
Cardiomyopathy		0	0	0
Cardiac arrhythmias		1	1	1
Pericardial effusion		0	0	0
Structural defects		2	0	0
Other		0	0	0
Neurologic		5 (5)	2 (2)	1 (1)
Intracranial bleed		2	2	0
Seizure		2	0	0
Other		1	0	1
Obstetric		4 (4)	0 (0)	1 (1)
HELLP		1	0	0
Preeclampsia		0	0	0
Postpartum hemorrhage		1	0	0
Infection		2	0	1
Malignancy		2 (2)	2 (2)	2 (3)
Miscellaneous		4 (4)	0 (0)	3 (4)

*NCPE=noncardiogenic pulmonary edema; HELLP=hemolysis, elevated liver enzyme levels, and low platelet count.

admissions between January 1, 1989 and July 31, 1995, of patients 17 years of age and older were reviewed. Both hospitals (Buffalo General Hospital and Sister's of Charity Hospital) are tertiary care centers and are affiliated with the State University of New York at Buffalo. Obstetric patients and nonobstetric female patients were identified from the hospital discharge abstracts. Nonobstetric patients were assigned a number from 0 to n, n being the total number of patients identified. Computer-generated random numbers were used to select the nonobstetric group sample in proportion to the number of obstetric patients identified from each hospital. The study group included pregnant and postpartum patients (up to 10 days postdelivery) who required ICU for more than 24 h. The admissions comprised inpatient transfers and outpatient admissions referred from ambulatory, private clinics, outline hospitals, or from the emergency department. The data collected were of three categories: demographic, obstetric, and ICU-related. Demographic data included maternal age, presence of preexisting medical or surgical problems, date of admission to the hospital, site of admission (emergency department, medical or surgical ward, clinic, or transfer from an outlining hospital), and outcome. Obstetric data consisted of parity, gestational age at the time of ICU admission, type of delivery, and perinatal outcome. ICU-related data included date of admission to the ICU, length of ICU stay, primary diagnosis for ICU admission, date and length of mechanical ventilation, and worst values related to vital signs (temperature, heart rate, respiratory rate, and BP) and laboratory data (arterial blood gas, serum sodium, potassium, chloride, bicarbonate, creatinine, bilirubin, lactate dehydrogenase, liver function tests, CBC count, prothrombin, and prothromboplastin time), and Glasgow coma score in the initial 24 h of ICU admission. Maternal death was considered to have occurred if the patient died prior to delivery or within 6 weeks postpartum. Perinatal death was considered to have occurred if death happened prior or at the time of the delivery.

The primary diagnoses for ICU admission were divided into six categories: respiratory, cardiac, neurologic, obstetric, malignancy, and miscellaneous. For each category, the number of patients requiring mechanical ventilation, the maternal outcome, and the neonatal outcome were tabulated.

Data were abstracted from medical charts and recorded on paper forms. Dichotomous variables were coded as 1 for yes or positive, −1 for no or negative, NA for uncertain or missing data. Continuous data were entered as the actual value or as NA for missing data. A computer program was designed to provide an estimate of mortality for ICU patients based on three widely used severity of illness scoring systems, APACHE II, SAPS II, and MPM II, as described in detail elsewhere.[1-3] In brief, the APACHE II score was derived from 12 physiologic measurements (temperature, arterial BP, heart rate, respiratory rate, arterial pH, oxygenation, serum sodium, potassium, and creatinine, hematocrit, WBC count, and Glasgow coma score), in addition to the age and the chronic health status of the patient. The mortality estimate was then obtained using the equation developed by Knaus et al.[1] SAPS II, score was obtained from eight of the predictor variables already used in the calculation of APACHE II (heart rate, systolic BP, temperature, oxygenation, WBC count, serum potassium, serum sodium, and Glasgow coma score), in addition to BUN level, serum bilirubin, urinary output, and the type of hospital admission. The probability of hospital mortality was calculated according to the equation provided by Le Gall et al.[2] MPM II was assessed at the 24-h time point in the ICU and was estimated from 13 variables (age, metastatic neoplasm, cirrhosis, intracranial mass effect, hospital admission not for elective surgery, coma or deep stupor at 24 h, urine output less than 150 mL in 8-h period, mechanical ventilation, creatinine concentration greater than 2 mg/dL, continuous IV vasoactive drug therapy, prothrombin time greater than 3 s above standard, confirmed infection, and partial pressure of oxygen <60 mm Hg) that were measured routinely in an ICU patient.[3] The hospital mortality for each group was expressed as mean±SE. Comparisons of the means were performed using the Student's *t* test for unpaired data with a Bonferroni correction.

The APACHE II, SAPS II, and MPM II mortality estimates were computed for the obstetric and the nonobstetric group. A receiver

Table 2—*Diagnostic Categories of Nonobstetric Patients**

Primary Diagnoses (n=96)	No. (%)	MV (n=23)	Nonsurvivors (n=12)
Metabolic			1 (1)
Ketoacidosis			0
Overdose			1
Respiratory			5 (5)
Pneumonia			2
Asthma			0
ARDS			2
Chest trauma			1
Pulmonary embolus			0
GI			0 (0)
Inflammatory bowel disease			0
Pancreatitis	2	0	0
Perforated peptic ulcer	1	1	0
Neurologic	8 (9)	2 (2)	1 (1)
Head trauma	4	1	1
Seizure	3	1	0
CVA	1	0	0
Infection	8 (9)	3 (4)	1 (1)
Meningitis	2	1	0
Cholecystitis	2	1	0
Sepsis syndrome	2	1	1
Epiglottitis	1	0	0
Necrotizing fasciitis	1	0	0
Neoplasms	3 (3)	2 (2)	2 (2)
Brain	2	1	1
Breast	1	1	1
Miscellaneous	10 (11)	2 (2)	2 (2)
Sickle cell disease	6	1	1
Others	4		1

*MV=mechanical ventilation; CVA=cerebrovascular accident.

operator characteristic (ROC) curve was generated for each predictive scoring system.[10] The ROC curve represents a graphic display of sensitivity plotted against 1-specificity for all possible selection of decision thresholds that can be used to predict survival. We also calculated the c-index, which is equivalent to the area under the ROC (AUC). It is calculated by determining the probability of identifying survival correctly in every possible pair of patients: one of whom survived, the other did not. A bootstrap method was used to calculate directly this measure of accuracy by generating 1,000 datasets from our database by random sampling with replacement. The mean and SE of the c-index was calculated by the bootstrap method. The mean value was identical within three decimal places to the AUC calculated with the trapezoid rule. For each group of patients, comparisons between the c-index for APACHE II, SAPS II, and MPM II were assessed from the confidence intervals (CIs). Comparisons of the c-index between obstetric and nonobstetric patients for each scoring system were performed using the Student's *t* test for unpaired data. A p value <0.05 was considered statistically significant.

Results

There were 96 obstetric patients identified out of 12,740 ICU admissions (0.7%) between January 1, 1989, and July 31, 1995. Three medical charts were not available at the time of the study. A control group of 96 nonobstetric female patients was selected randomly from both hospitals as described in the "Materials and Methods" section. The mean age was 27.8±0.6 years for obstetric patients and 27.1±0.9 years for nonobstetric patients. The primary diagnoses for ICU admission in the obstetric group are shown in Table 1. Sixty-five (70%) of all obstetric patients were admitted

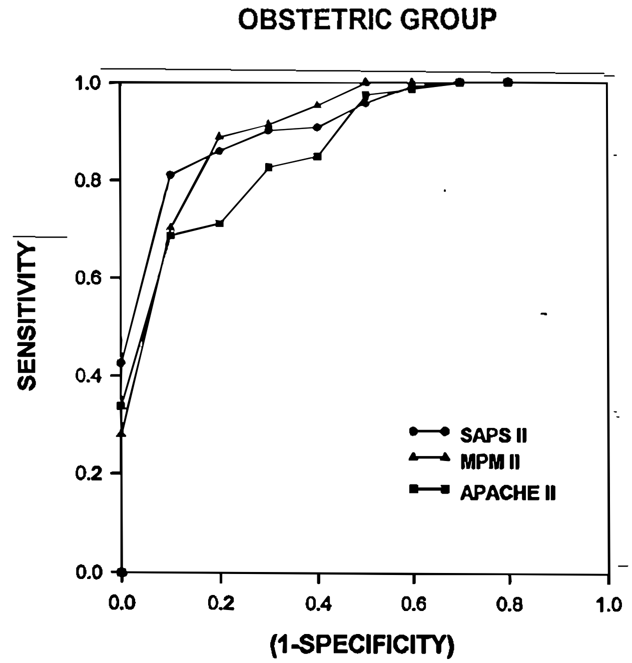

FIGURE 1. ROC curves of APACHE II (squares), SAPS II (circles), and MPM II (triangles) for obstetric patients. There were no significant differences among the c-index for APACHE II, SAPS II, and MPM II.

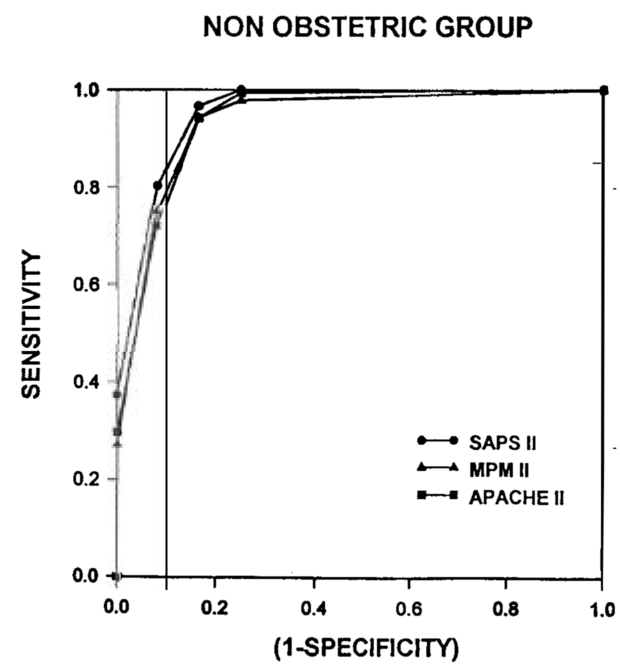

FIGURE 2. ROC curves of APACHE II (squares), SAPS II (circles), and MPM II (triangles) for nonobstetric patients. There were no significant differences among the c-index for APACHE II, SAPS II, and MPM II.

Table 3—*Predictor Variables of Survivors and Nonsurvivors Group in Critically Ill Obstetric Patients**

	Survivors, Mean±SEM	Nonsurvivors, Mean±SEM	p Values
LOMV, d	2.82±1.14	22.90±11.55	
LOICU, d	6.75±1.11	25.30±11.82	
Age, yr	27.70±0.67	28.80±1.67	
Temperature, °C	36.78±-17.16	38.8±-17.54	
Systolic BP, mm Hg	128.89±4.11	98.60±9.28	
Respiratory rate, min^{-1}	26.47±0.95	39.0±4.89	
Heart rate, min^{-1}	115.37±3.33	148.7±6.73	
pH, U	7.42±0.006	7.34±0.03	
Potassium, mmol/L	3.80±0.07	4.25±0.46	
HCO_3, mEq/L	22.16±0.56	20.5±2.76	
Creatinine, mg/dL	0.94±0.09	1.76±0.62	
Bilirubin, mg/dL	0.91±0.16	1.44±0.41	
LDH, U/mL	790.26±110.85	1,779.70±789.76	
Hemoglobin, g/dL	9.77±0.20	9.13±0.49	
Urine output, mL/24 h	2,332.90±141.20	1,988.80±544.58	
Glasgow coma scale	14.28±0.15	10.4±1.64	

*LOMV=length of mechanical ventilation; LOICU=length of ICU stay; LDH=lactate dehydrogenase.
†Indicates statistical significance between survivors and nonsurvivors.

to the ICU for medical reasons, and 28 (30%) were admitted for surgical reasons. Fifteen (16%) were admitted after an elective surgery, while 13 patients (14%) required intensive care after an emergency surgery. Eighty-three obstetric patients (89%) were discharged from the hospital. Of all admissions, there were 72 delivery and 10 perinatal death (14%). Fifty-eight (62%) of the 93 obstetric patients were admitted antepartum to the ICU. Twenty (21%) were discharged home prior to delivery. The mean gestational age of these patients was 30.5±8.2 weeks and 24.7±7.2 weeks, respectively. Thirty-five (38%) patients were admitted postpartum. Twenty-four were postpartum day 1; the remaining 11 patients were between postpartum days 2 and 10. Twenty-three (25%) patients were transferred from the floor, and 26 (28%) were transferred from outline hospitals. Thirty patients (32%) were admitted from the emergency department and 14 (15%) from private or ambulatory clinics. Respiratory complications were the most common reasons for ICU admission (32%) and the major cause of maternal death. Obstetric complications (19%) were second in the causes of ICU admission, and were mostly related to postpartum hemorrhage. Neurologic and cardiac were both responsible for 14% each of the total ICU admissions.

Table 2 lists the admitting diagnoses of nonobstetric patients to the ICU. Seventy-two (75%) patients were admitted for medical reasons and 24 (25%) for surgical reasons. There were 84 survivors (88%) and 12 nonsurvivors (12%).

Table 3 displays a comparison of predictor variables between survivors and nonsurvivors in the obstetric group. Six variables (temperature, systolic BP, respiratory rate, heart rate, pH, and Glasgow coma scale) were statistically different between the survivors and the nonsurvivors. The actual mortality of the obstetric and the nonobstetric group was 10.8 (95% CI, 5.3 to 18.9) and 10.4 (95% CI, 5.1 to 18.3), respectively. APACHE II, SAPS II, and MPM II estimated mor-

Table 4—*Comparison of Predicted Mortality of Obstetric and Nonobstetric Patients Based on APACHE II, SAPS II, and MPM II (Mean±SE)*

Obstetric	Total (n=93)	Survivors (n=83)	p Value	Nonsurvivors (n=10)
APACHE II	14.7±1.8	11.1±1.2*	0.005§	44.4±9.2
SAPS II	7.7±1.6	4.1±0.6†	0.01§	37.7±10.4
MPM II	9.1±1.3	6.2±0.6‡	0.01§	32.7±8.3

*$p<0.001$, compared with survivors of the nonobstetric group.
†$p<0.02$, compared with survivors of the nonobstetric group.
‡$p<0.006$, compared with survivors of the nonobstetric group.
§Indicates statistical significance between survivors and nonsurvivors of the same group.

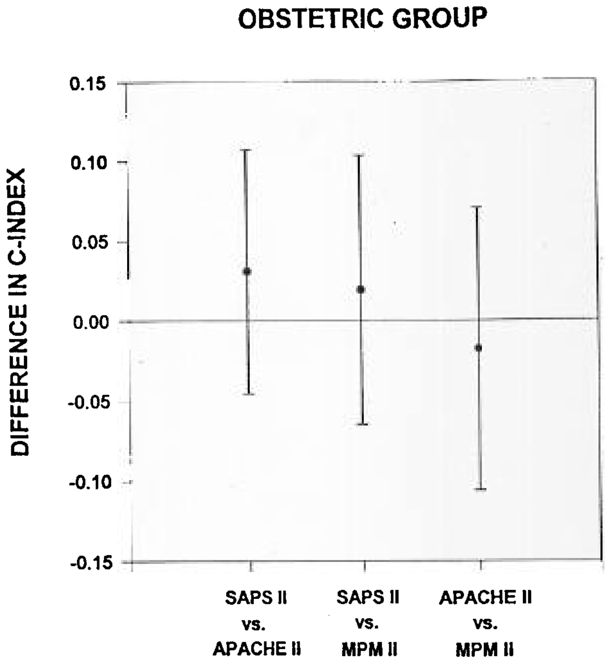

FIGURE 3. Power analysis of the differences among APACHE II, SAPS II, and MPM II expressed as the mean and the 95% confidence limits for the obstetric group.

tality for obstetric and nonobstetric patients is shown in Table 4. The predicted mortality was significantly higher for the nonsurvivors than the survivors. The survivors of the obstetric patients had significantly higher predicted ICU mortality than the survivors of the nonobstetric patients by all three indexes ($p<0.001$ for APACHE II, $p<0.05$ for SAPS II, and $p<0.01$ for MPM II); however, the difference in predicted mortality for the nonsurvivors was not significant between the obstetric and nonobstetric patients ($p=0.28$ for APACHE II; $p=0.2$ for SAPS II; and $p=0.1$ for MPM II). Similarly, the predicted mortality of obstetric patients was not significantly different from that of nonobstetric patients in all three scoring systems ($p=0.18$ for APACHE II, $p=0.61$ for SAPS II, and $p=0.7$ for MPM II).

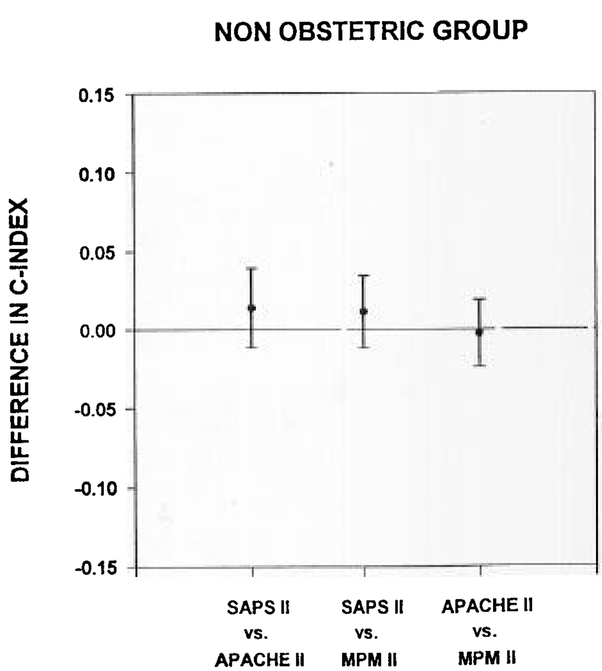

FIGURE 4. Power analysis of the differences among APACHE II, SAPS II, and MPM II expressed as the mean and the 95% confidence limits for the nonobstetric group.

Table 5—*Comparison of the Predicted Mortality of Obstetric Patients Between the Two Hospitals Based on APACHE II, SAPS II, and MPM II (Mean±SE)*

	Hospital A	Hospital B	p Value
APACHE II			
SAPS II			
MPM II			

Table 5 shows a comparison of the predicted mortality of the obstetric group for each hospital involved in the study using APACHE II, SAPS II, and MPM II. The difference was not statistically significant as reflected by the p value (0.47, 0.65, and 0.57, respectively).

A ROC curve was drawn for SAPS II, APACHE II, and MPM II (Fig 1 and 2). The c-indexes of both groups for SAPS II, APACHE II, and MPM II are shown in Table 6. In each group, the c-index for SAPS II was not significantly different from that of APACHE II and MPM II (0.037 ± 0.039 and 0.019 ± 0.043, respectively, for the obstetric group; 0.014 ± 0.013 and 0.0114 ± 0.0119, respectively, for the nonobstetric group). Similarly, the c-index for APACHE II was not significantly different from MPM II (-0.018 ± 0.045 for the obstetric group, and -0.0026 ± 0.011 for the nonobstetric group). These results are plotted with the 95% CI in Figures 3 and 4 to display the posttrial power analysis,[11] as there were no significant differences in the c-index within approximately ±0.1 for the obstetric group and ±0.05 for the nonobstetric group.

Furthermore, the c-indexes for APACHE II, SAPS II, and MPM II derived from the obstetric patients were not significantly different from those of the nonobstetric patients ($p>0.2$ for APACHE II, $p>0.2$ for SAPS II, $p>0.2$ for MPM II).

Table 6—*The c-Index of SAPS II, APACHE II, and MPM II in Obstetric and Nonobstetric Patients*

c-Index	SAPS II	APACHE II	MPM II
	0.9336±0.0216	0.8966±0.0439	
	0.9683±0.0181	0.9549±0.0255	

*There was no significant difference among the c-indexes of SAPS II, APACHE II, and MPM II in the obstetric group.
†There was no significant difference among the c-indexes of SAPS II, APACHE II, and MPM II in the nonobstetric group.

Discussion

The actual mortality of the critically ill obstetric patients in this study was 10.8% (95% CI, 5.3 to 18.9). This rate was similar to the estimated mortality rates of 12 to 20% reported in the literature in this group of patients.[12] This observed mortality was not statistically different from the predicted mortality obtained by three separate severity scoring systems, APACHE II, SAPS II, and MPM II 14.7% (95% CI, 11.2 to 18.2%), 7.8% (95% CI, 4.6 to 10.8%), and 9.1% (95% CI, 6.5 to 11.5%), respectively. Previous reports have indicated that scoring systems could either overestimate or underestimate the actual mortality in critically ill obstetric patients.[8,9,13] One group of investigators found in a study of 22 pregnant patients an actual mortality of 36.4% compared with an estimated mortality of 11.5% by APACHE II.[8] Another study of 29 critically ill obstetric patients revealed that the actual mortality in the group studied was 0% compared with 3% predicted by SAPS II.[9] These results are in contrast to our findings in this study. Our data showed that APACHE II, SAPS II, and MPM II were good predictors of mortality in this specific group of patients as judged by the c-index.[14] The differences between our study and previous reports could be attributed to inadvertent selection bias related to the much smaller numbers of patients in those studies. In addition, the disparity in the results could be ascribed to differences in the characteristics of the patient population. The use of a control group of nonobstetric patients was helpful in eliminating the possibility of differences in medical management or discrepancy in the quality of care among obstetric and nonobstetric patients. The lack of statistical difference in the c-index for all three scoring systems between the obstetric and the nonobstetric patients ($p>0.2$) reflected rather a homogeneous population and a uniform quality of care for both groups.

The observed difference in the survivors' predicted mortality between the obstetric patients and the nonobstetric patients could be explained by analyzing the primary diagnosis of these two groups for ICU admission. In the obstetric group, most admissions to the ICU were related to respiratory complications or emergent obstetric procedures, which carry a significant diagnostic category weight in the severity of illness scoring systems, thus a higher score on the mortality scale. In contrast, the ICU admissions of the nonobstetric patients were in the majority secondary to diabetic ketoacidosis or drug overdose, which carry a much less weight in deriving the total severity score.

The limitation of the present study is twofold. The first stems from the fact that our data are based on a retrospective review of medical records, and the second is related to the potential differences among physicians in the criteria for ICU admissions. Despite these limitations, our series, which included 93 obstetric patients, is, to our knowledge, the largest such series reported, to evaluate the predictive scoring systems currently available. Moreover, the affiliation of both hospitals to the university program and the lack of statistical difference in obstetric outcome among the three different scoring systems for each hospital are consistent with standard practice.

In summary, this study showed that APACHE II, SAPS II, and MPM II can predict accurately the severity of illness in the critically ill obstetric patients, and therefore can be utilized in monitoring quality of care and in establishing a better risk stratification for clinical and therapeutic trials.

References

1 Knaus WA, Draper EA, Wagner DP, et al. APACHE II: a severity of disease classification system. Crit Care Med 1985; 13:818-29
2 Le Gall JR, Lemeshow S, Saulnier F. A new simplified acute physiologic score (SAPS II) based on a European/North American multicenter study. JAMA 1993; 270:2957-63
3 Lemeshow S, Teres D, Klar J, et al. Mortality probability models (MPM II) based on an international cohort of intensive care unit patients. JAMA 1993; 270:2478-86
4 Cerra FB, Negro F, Abrams J. APACHE II score does not predict multiple organ failure or mortality in postoperative surgical patients. Arch Surg 1990; 125:519-22
5 Fedullo AJ, Swinburne AJ, Wahl GW, et al. APACHE II score and mortality in respiratory failure due to cardiogenic pulmonary edema. Crit Care Med 1988; 16:1218-21
6 Godeau B, Boudjadja A, Dhainaut JF, et al. Outcome of patients with systemic rheumatic disease admitted to medical intensive care units. Ann Rheum Dis 1992; 51:627-31
7 Schein M, Gecelter G. APACHE II score in massive upper gastrointestinal haemorrhage from peptic ulcer: prognostic value and potential clinical applications. Br J Surg 1989; 76:733-36
8 Koch KA, Rodeffer HD, Sanchez-Ramos L. Critically ill obstetrical patients: outcome and predictability. Crit Care Med 1988; 16:A409
9 Scarpinato L. Critically ill obstetric patients: outcome and predictability utilizing the SAPS II score in a 314 bed community hospital. Chest 1995; 108:184S
10 Hanley JA, McNeil BJ. The meaning and use of the area under the receiver operating characteristic (ROC) curve. Radiology 1982; 143:29-36
11 Detsky AS, Sackett, DL. When was a 'negative' clinical trial big enough? How many patients you needed depends on what you found. Arch Intern Med 1985; 145:709-12
12 Lapinsky SE, Kruczynski K, Slutsky AS. Critical care in the pregnant patient. Am J Respir Crit Care Med 1995; 152:427-55
13 Lewinsohn G, Herman A, Leonov Y, et al. Critically ill obstetrical patients: outcome and predictability. Crit Care Med 1994; 22:1412-14
14 Harrell FE, Califf RM, Pryor DB, et al. Evaluating the yield of medical tests. JAMA 1982; 247:2543-46