Original Article

Predicting The Risk of Death in Patients in Intensive Care Unit

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Background: **The ability to identify critically ill patients who will not survive until hospital discharge may yield substantial cost savings. The aim of this study was to validate the mortality prediction model II (MPM II) in in-hospital mortality of critically ill patients for quality management and risk-adjusted monitoring.**

Methods: **The data were collected prospectively from consecutive admissions to the Intensive Care Unit of Imam Hossein Medical Center in Tehran. A total of 274 admissions were analyzed using tests of discrimination and calibration of the logistic regression equation for mortality prediction model II at admission (MPM0 II) and at 24th hour (MPM24 II).**

Results: **The mortality prediction model II exhibited excellent discrimination (receiver operating characteristic curve area). Calibration curves and Hosmer-Lemeshow statistics demonstrated good calibration of both models on outcome.**

Conclusion: **We recommend using mortality prediction model II in Iranian ICUs for routine audit requirements. Mortality prediction model II is not affected by the standards of treatment after admission to ICU. The information needed to calculate mortality prediction model II is easy to collect, and the model is applicable to all ICU admitted patients.**

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Keywords: Intensive care • logistic regression • mortality • prediction model

Introduction

The development of intensive care has increased the ability to monitor, diagnose, and treat critically ill and injured patients. Consequently, critical care practice has improved substantially in the past four decades. However, there is a strong perception that intensive care units (ICUs) introduce an inappropriate financial burden. In addition, there is increasing recognition of the wide variation in health-care practices and, more importantly, of the potential effect of this variance on health care delivery and outcomes. Consequently, critical care is under increasing pressure to improve ICU performance and quality of care in ways that will reduce the costs. Substantial progress has also been made in identifying clinical risk factors for death and resource utilization for patients in ICUs.[1, 2]

The ability to identify critically ill patients who will not survive until hospital discharge may yield substantial cost savings. A variety of instruments are now available for severity evaluation and outcome prediction in critical care settings. The most common outcome prediction models used in adult intensive care include the Mortality Probability Model (MPM) II, the Simplified Acute Physiology Score (SAPS) II, and the Acute Physiology and Chronic Health Evaluation (APACHE) II and APACHE III. These models differ considerably in the number and types of variables used, as well as the time frame for data collection. Other tools are clinician prediction model and use of instruments (like transthoracic echocardiography).[1, 3, 4]

The aim of this study was to evaluate the performance of MPM II in Imam Hossein Medical Center (IHMC), in Tehran.

Materials and Methods

The data were gathered from 274 consecutive

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adult admissions (from April 1, 2002, through December 31, 2004) to the ICU of IHMC, a university affiliated hospital, in Tehran, Iran. The ICU of IHMC provides medical and surgical critical care services to a 500-bed adult metropolitan teaching hospital, which is the regional center for trauma, major surgery, medical subspecialties, and psychiatry. Patients admitted for less than four hours or for exclusion of myocardial infarction, cardiac surgery, burns, and those below 16 years were excluded from the study. The patients' data were collected prospectively according to the guidelines of MPM II. Included in this set are variables associated with patients' demographics, day of ICU admission, ICU length of stay, time from hospital admission to ICU admission, admission for elective surgery, emergency surgery, nonsurgical emergency, and initial diagnosis or disease group.

In order to fulfill the aim, it was necessary to carefully define the end point. The outcomes of interest were in-hospital death or survival.

The analyses excluded all ICU readmissions during an episode of hospitalization, in order to prevent double counting of outcomes. For each admission, estimates of in-hospital mortality were calculated by using the guidelines from the website of French Society of Anesthesia and Intensive Care.[5]

For assessment of calibration or model fit, the agreement between predicted and observed mortality rates in risk ranges was assessed. Predicted mortality rates were based on the MPM II estimates. The Hosmer-Lemeshow (H-L) statistics indicates the degree of agreement between the observed and predicted mortality. The null hypothesis of no difference between the observed and predicted frequencies across the risk ranges was rejected when $P < 0.05$.

Discrimination was assessed by calculating the area under the receiver operating characteristic (ROC) curves and was presented with confidence intervals. The area under the ROC curve estimates the probability that a randomly selected mortality will be given a higher risk-of-death estimate than a randomly selected survivor. It is a global measure of the ability of the model to assign a higher risk of death to patients who actually die. These tests were computed with SPSS software version 13.0.

Results

There were 274 eligible primary adult admissions to IHMC from April 1, 2002, through December 31, 2004. The mean age of these patients was 51.17 years (SD, 19.7), and 63.8% were males. Primary diagnostic categories of ICU admission included intracranial hemorrhages such as extradural, subdural, intraventricular, and intracerebral hemorrhages (100, 36.5%), brain tumor (57, 20.8%), acute abdomen (24, 8.8%), chest and abdominal trauma (16, 5.9%), pulmonary disease (15, 5.4%), stroke (13, 4.7%), sepsis (10, 3.6%), spine fractures (9, 3.3%), gastrointestinal

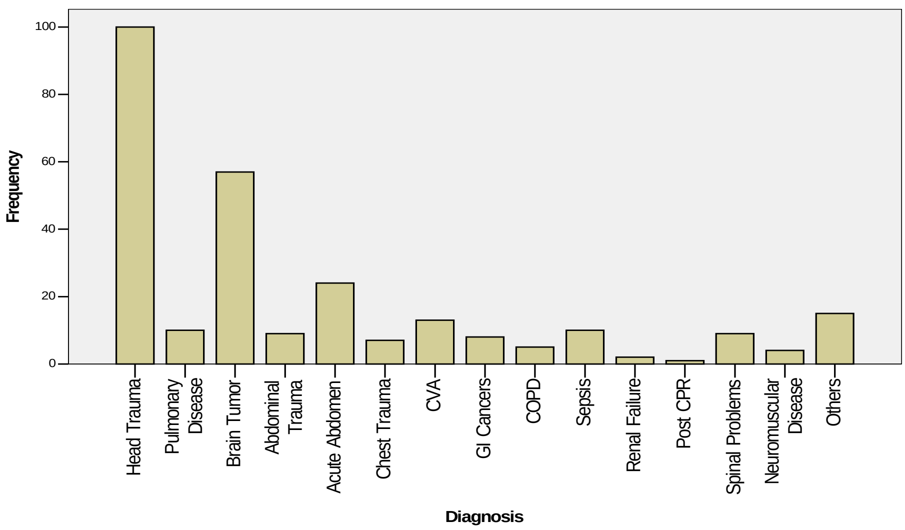

Figure 1. Major disease groups of the patients admitted in ICU.

Table 1. Mortality according to mean age and gender.

Patients	Total number	Mean age	Gender	
			Male	Female
	274	51.17	175	99
Survived	178 (65%)	47.89	111 (64%)	67 (67%)
Dead	96 (35%)	57.24	64 (36%)	32 (33%)

cancers (8, 2.9%), neuromuscular disease (4, 1.5%), renal failure (2, 0.7%), cardiopulmonary arrest (1, 0.4%), and miscellaneous (15, 5.5%) (Figure 1). Totally, 172 patients (62.8%) had intracranial problems.

Of the 274 patients, 96 (35.0%) died in the ICU (Table 1). Of them 53 patients had and 43 cases did not have intracranial problems (30.8% and 42.2%, respectively), but there was no statistical differences between them ($P = 0.06$).

There was no statistical difference between the mortality rate of both genders ($P > 0.05$). The observed and expected mortality for MPM0 II and MPM24 II is demonstrated in Table 2.

As noted in Table 3, the mortality was much higher in patients older than 60 years. The lowest mortality was in the 3rd and 5th decades.

For calibration, the *P* value assessed by H-L statistics for both MPM0 II and MPM24 II was greater than 0.05. Figure 2 and Table 4 show the area under the ROC curve for discrimination.

The mean length of stay was 7.77 days (SD, 10.2) in the ICU and 6.4 days (SD, 7.1) in the hospital after discharge from ICU.

We also used logistic regression equation to determine the parameters that had a significant effect on outcome. The important variables were tachycardia, cardiac dysrhythmias, raised creatinine, need for mechanical ventilation at 24th hour after admission, use of vasoactive drugs, and abnormal prothrombin times.

Discussion

At the ICU, the outcome prediction models compare actual and expected outcome for groups of patients (i.e., the standardized mortality ratio). They are used to compare ICU performance, to determine optimal allocation of critical care resources, and to evaluate the effect of new treatments, procedures, or ICU organization.[1] Some examples of the usefulness of outcome prediction models are predicting survival of patients with acute renal failure,[6] sepsis,[7] HIV infection,[8] malignancy[9], respiratory disease,[10, 11] and liver transplantation.[12] At the patient level, severity scores describe severity of illness and are being used in some centers to support clinical

Table 2. The observed and expected mortality prediction by MPM0 and 24 II.

		Predicted outcome		Percentage correct
		Survived	Dead	
Observed MPM0 II	Survived (178)	169	9	94.9
	Dead (96)	27	69	71.9
	Overall percentage			86.9
Observed MPM24 II	Survived (178)	170	8	95.5
	Dead (96)	26	69	72.6
	Overall percentage			87.5

Table 3. Mortality in different age decades.

Age decades	Outcome			
	Survived		Dead	
	Age range		Age range	
	Count	%	Count	%
2.00	6	3.4%	4	4.2%
3.00	40	22.5%	11	11.5%
4.00	21	11.8%	10	10.4%
5.00	36	20.2%	9	9.4%
6.00	27	15.2%	16	16.7%
7.00	18	10.1%	16	16.7%
8.00	25	14.0%	20	20.8%
9.00	5	2.8%	10	10.4%

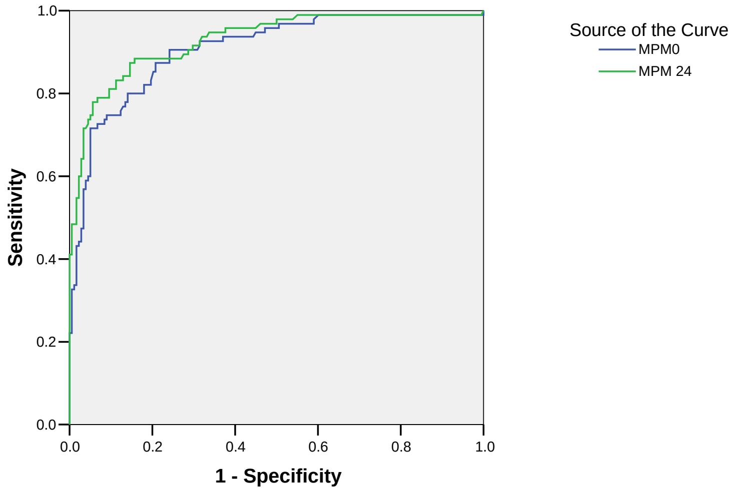

Figure 2. Receiver operating characteristic (ROC) curves for the two systems (MPM0 II, MPM24 II).

decision making and to help guide discussions with patients and families concerning withdrawal of life support.[1,13,14,15] Also, they can be used to evaluative the effects of conditions such as body mass index (BMI)[16,17] and pregnancy,[18] on the outcome.

The mortality prediction model (MPM) II provides predictions for the risk of hospital or ICU mortality. The original MPM was developed from 755 patients at a single hospital, using multiple logistic regression to assign weights to variables that could predict hospital mortality.[19] The MPM II was developed on an international sample of 12,610 patients and validated on a subsequent sample of 6514 patients.[20] MPM, like APACHE, excludes pediatric, burn, and coronary and cardiac surgical patients and estimates hospital mortality risk based partly on physiologic derangement, but considers a smaller number of variables. MPM II uses data obtained at ICU admission (MPM0) and at the end of the first 24 hours (MPM24), whereas APACHE II or III is scored using the worst data obtained during the first 24 hours.

Table 4. Calibration and discrimination of prognostic systems.

Test	Area under ROC	H-L (*P*)
MPM0 II[1]	0.824	0.327
MPM24 II[2]	0.836	0.231
APACHE III[3]	0.91	0.36
Hospital MPM0 II	0.906	0.395
Hospital MPM24 II	0.928	0.320

The admission model contains 15 variables. The 24-hour model (MPM24) uses five of the 15 MPM0 variables plus eight additional ones. Age and chronic health status are included in both MPM0 and MPM24.[20]

While APACHE generates a score and then, with additional information, converts that score into a probability estimate of survival, MPM directly calculates a probability of survival from the available data. The MPM24 recognizes that patients who remain in ICU for 24 hours or longer differ from those who die or are well enough to be discharged. Additional variables in MPM24 are prothrombin time, urinary output, serum creatinine, arterial oxygenation, continuing coma or deep stupor, confirmed infection, mechanical ventilation, or intravenous vasoactive drug therapy.[21]

There are several articles that compare the prognostic systems. Some concluded that the MPM II system performs better than APACHE II, SAPS II, and Glasgow Coma Score for head trauma patients.[22] Shann noted the substantial theoretical, practical, and financial advantages of MPM over the APACHE model for use in adults in intensive care.[23]

The most important difference between MPM and other systems is that the MPM0, with the exception of information related to cardiopulmonary resuscitation, produces a probable estimation that is available at the time of ICU admission and is independent of ICU treatment. MPM does not require specifying a diagnosis, which can be an advantage in "complex" ICU patients, but it may also make it more sensitive to changes in the case mix. MPM II calibrates well and has ROC areas of 0.837 for the admission model and 0.844 for the MPM24.[20]

This paper provides information about the performance of the MPM II ICU and hospital mortality model. It confirms that the MPM II mortality models can have good discrimination and calibration in an Iranian adult ICU population.

In this observational study of 274 adult patients, 178 patients (65%) survived. MPM0 II and MPM24 II estimated a survival of 169 (94.9%) and 170 (95.5%) patients, respectively. For the 96 deceased patients, both MPM0 II and MPM24 II estimated a probability dying of 69 (71.9%) patients. These data confirm the tendency of MPM II systems to underestimate the risk of ICU mortality.

The admission model, MPM0 II, calibrated well [H-L tests: $P = 0.395$, where a high P represents good fit between observed and expected values] and discriminated well (area under the ROC curve = 0.906). The 24-hour model, MPM24 II, also calibrated well ($P = 0.320$) and discriminated well (area under the ROC curve = 0.928) (Figure 2 and Table 3).

We had a substantially higher mortality rate than other reports. The case mix of our patients may play a role. ICUs with a large number of low-risk admissions are likely to have less mortality than those units admitting high-risk patients. The case mixes in the IHMC patient samples consist of predominance of male and neurosurgery cases. The case mix can be different in centers with different proportions of general surgery, medical problems, and so on.[24]

As noted before, more than half of our patients (62.8%) had intracranial problems. Surprisingly, there were no statistical differences between the mortality of those who had intracranial problems with those who did not have such problems, which might be due to admitting high-risk patients.

This study demonstrates that the MPM II model performs well on independent assessment in an Iranian hospital. The fundamental limitation of our study was the derivation of the mortality ratios from relatively small numbers of patients studied during a relatively brief-time period. This limitation can be overcome by using a large number of patients in several ICUs.

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I am a painter, a maker of pictures; every moment I shape a beauteous form,
And then in thy presence I melt them all away.

I call up a hundred phantoms and imbue them with a spirit;
When I behold thy phantom I cast them in the fire.

Art thou the vintner’s cup-bearer or the enemy of him who is sober,
Or is it thou who mak’st a ruin of every house I built?

In thee the soul is dissolved, with thee it is mingled;
Lo! I will cherish the soul, because it has a perfume of thee.

Every drop of blood which proceeds from me is saying to thy dust:
“I am one color with thy love, I am the partner of thy affection.”

In the house of water and clay this heart is desolate without thee;
O Beloved, enter the house! or I will leave it.

Jalal al-Din Mohammad Rumi (1207-1273 A.D.), the greatest mystical poet of Iran, Selected Poems from Divan-e-Shams-e Tabrizi translated by Professor Renyold A. Nicholson (1868-1945), the former professor at University of Cambridge