Can we predict prognosis using mortality probability model II_0?

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ABSTRACT

Objective: To evaluate Mortality Probability Model (MPM) II_0 as a tool to predict very poor prognosis after intensive care unit admission.

Methods: The study was conducted as a prospective observational study in a medical-surgical intensive care unit in a tertiary care teaching hospital, Riyadh, Kingdom of Saudi Arabia. Data necessary to calculate MPM II_0 predicted mortality was collected from March 1999 through to February 2000 on all intensive care unit admissions. The hospital outcome was documented. We calculated the sensitivity, specificity, positive predictive value and negative predictive value of MPM II_0 using cutoff points of 90% and 95%.

Results: Data was complete on 557/569 patients (98%). Thirty-one patients had predicted mortality of ≥95% and all died yielding a specificity of 100% and positive predictive value of 100%. However, sensitivity was only 18% and negative predictive value 73%. Forty-four patients had predicted mortality of ≥ 90% of whom only one survived yielding a specificity of 99.7% and a positive predictive value of 97.7%. Sensitivity was only 25% and negative predictive value of 75%.

Conclusions: Using a decision-cutoff of 95% predicted mortality using MPMI II_0 had a very high specificity in predicting death after intensive care unit admission, although with a low sensitivity. This information can be used to support clinical judgment regarding the very ill patients who are unlikely to benefit from intensive care unit admission.

Keywords: Mortality, prediction, futility, intensive care.

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Several critical care professional statements called upon reserving intensive care unit (ICU) resources for patients who have a "reasonable prospect of substantial recovery" and that "patients with very poor prognosis and little likelihood of benefit should not be admitted".[1-3] Drawing the line between these 2 categories is not always straightforward explaining why a significant number of patients continue to be admitted to ICU to die. Assessment of futility of a treatment remains for the most part empirical and depends on common sense, prior experiences and the physicians' prediction of the chance of survival.[4] Outcome literature of specific conditions such as patients admitted to ICU after cardiopulmonary resuscitation, bone marrow transplantation and hematologic malignancies is also used in such assessments.[4] However, such assessments are often imprecise and considerably variable.[5] A simple objective assessment of very poor prognosis obtained at the time of ICU admission could be of great value. It can help the intensivist making his triage decision if obtained before

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admission and deciding the extent of life-sustaining therapies if obtained after admission. Mortality Probability Model (MPM) II_0 is an attractive prediction system for this purpose. It has the advantage of being based on simple clinical data collected from the first hour of ICU admission. The purpose of this study is to evaluate MPM II_0 as a tool to predict very poor prognosis after ICU admission.

Methods. King Fahad National Guard Hospital (KFNGH), Riyadh, Kingdom of Saudi Arabia, is a 550-bed tertiary care teaching hospital. The 12-bed medical-surgical ICU admits 600 patients/year. Our institution has been a national leader in raising the awareness regarding the futility of aggressive life support in terminally ill patients. A policy for do not resuscitate (DNR) has been instituted to enforce addressing code status. With this policy and the increasing physicians' understanding of futility, many futile treatments are avoided. In the year 1998, DNR orders were written for 76% of patients who died in the hospital.

Data necessary to calculate MPM II_0 predicted mortality was collected prospectively between March 1999 through to February 2000. Vital status at discharge from the hospital was registered. Predicted mortality was calculated using the logistic regression formula described in the original article[6] and summarized in the Appendix. Standardized Mortality Ratio was calculated by dividing actual mortality over predicted mortality. We calculated the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of MPM II_0 using cutoff points of 90% and 95%. Ninety-five percent confidence intervals (CI) were calculated for all the above values. Continued variables were expressed in mean ± standard deviation. Categorical values were expressed in absolute and relative frequencies. All categorical variables were analyzed by chi-square test. Non-parametric variables were compared by Kruskal-Wallis test. P values of 0.05 or less were considered significant.

Results. Data was complete on 557/569 patients (98%). Demographic data are shown in **Table 1**.

Actual and predicted hospital mortality rates. Mean MPM II_0 predicted mortality was 29 ± 30% which was not statistically different from actual mortality 31% [Standardized Mortality Ratio (SMR) 1.06, 95% CI 0.98-1.16]. The distribution of patients by predicted mortality and hospital outcome is shown in **Figure 1**. Note the absence of survivors for predicted mortality of ≥95%.

Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of predicted mortality of ≥95% and ≥90% (Table 2). Thirty-one patients had a predicted mortality of ≥95% and all died yielding a specificity of 100% (CI 99.1-100%) and PPV of 100% (CI 88.8-100%). However, sensitivity was only 18% (CI 12.6-24.6%) and NPV 73.2% (CI 69.2-76.9). Forty-four patients had a predicted mortality of ≥ 90% of whom only one survived yielding a specificity of 99.7% (CI 98.6-100%) and a PPV of 97.7% (CI 88.0-99.9%). Sensitivity was only 25% (CI 18.7-32.2%) and NPV 74.9% (CI 70.9-78.6%).

Characteristics of patients with predicted mortality of ≥95%. **Table 3** shows the characteristics of patients with predicted mortality of ≥95%. These patients were older than the rest of ICU patients (63 ± 13 versus 47 ± 20, p<0.001). The leading reasons for ICU admission for this group were post cardiac arrest and sepsis. These patients had shorter ICU length of stay. Do not rescusitate orders were written on a similar percentage of patients in the groups with predicted mortality of ≥95% and <95%. **Table 4** shows predictors of having

Table 1 - Patient's demographics.

Characteristic	All patients
n patients	557
Age	48 ± 20
Female/Male	236/321
Predicted hospital monthly	29 ± 30%
Actual hospital mortality	31%
Standardized mortality ratio (SMR)	1.07 (0.93-1.20)
Source of admission	
Emergency room	183 (33)
Floor	156 (28)
Operating/Recovery room	184 (33)
Other hospitals	34 (6)

n - number

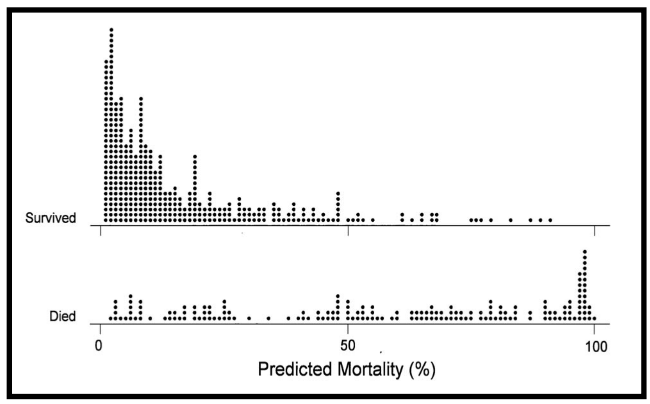

Figure 1 - Distribution of patients by MPM II_0 predicted mortality and hospital outcome. MPM - mortality probability model.

Table 2 - Mortality probability model II_0 as a predictor of very poor hospital outcome.

Cutoff point	Parameter	n (%)	95% CI
95%	Sensitivity	31/172 (18)	12.6-24.6
	Specificity	385/385 (100)	99.1-100
	PPV	31/ 31 (100)	88.8-100
	NPV	385/526 (73.2)	69.2-76.9
90%	Sensitivity	43/172 (25)	18.7-32.2
	Specificity	384/385 (99.7)	98.6-100
	PPV	43/ 44 (97.7)	88-99.9
	NPV	384/513 (74.9)	70.9-78.6

n - number, CI - confidence interval
NPV - negative positive value, PPV positive predictive value

Table 4 - Predictors of being in the very poor prognosis group (predicted mortality ≥95%) as estimated by MPM II_0.

Predictors	OR	Lower	Upper	P
Coma	74.2	17.4	316.6	<0.001
Heart Rate ≥150	4.3	1.6	11.3	0.003
SBP ≤90	25.1	10.0	63.1	<0.001
CRF	5.1	2.3	11.5	<0.001
Cirrhosis	6.3	3.0	13.4	<0.001
Metastatic cancer	5.5	2.05	14.77	0.001
Acute renal failure	119.3	27.8	511.2	<0.001
Arrhythemia	5.0	2.2	11.5	<0.001
CVA	1.6	0.5	4.9	NS
GI bleeding	6.5	2.8	15.4	<0.001
Intracranial mass effect	2.0	0.8	5.1	NS
Mechanical ventilation	29.8	4.0	219.7	0.001
Medical or unscheduled surgery	8.7	1.2	64.3	0.034
Admission post CPR	20.4	8.7	47.9	<0.001

OR - odds ratio, SBP - systolic blood pressure, CRF - chronic renal failure, CVA - cerebrovascular accident
GI - gastrointestinal, CPR - cardiopulmonary resuscitation

Table 3 - Characteristics of patients predicted by MPM II_0 to have very poor prognosis.

Characteristics	≥95%	<95%	p value
n	31	526	
Age (Mean ± SD)	63 ± 13	47 ± 20	<0.001
Reason for admission			<0.001
Post-cardiac arrest	11 (42)	15 (3)	0.01
Sepsis	7 (23)	48 (9)	
LOS in hours Median, (Q1, Q3)	14 (6,31)	48 (22,120)	<0.001
No code	20 (65)	77 (15)	<0.001
Died in ICU with no code order	20 (65)	68 (58)	NS

n - number, LOS - length of stay
ICU - intensive care unit

predicted mortality of ≥95% using univariate analysis.

Discussion. The main findings of our study can be summarized as follows: 1. Using a decision-cutoff of 95% risk of death using MPM II_0 had very high specificity and PPV in predicting death after ICU admission, although with low sensitivity. 2. The clinical characteristics of patients with predicted mortality of ≥95% confirm the devastating nature of their illness. Furthermore, these patients died after a very short stay in ICU, another indicator of the severity of their illness. 3. The proportion of patients with DNR orders at the time of death was not different from those who had predicted mortality of <95%. In other words, a group of gravely ill patients continue to receive full aggressive life-sustaining measures up to the time of death, including cardiopulmonary resuscitation. The treating physicians were not aware of the MPM II_0 predicted mortality of their patients. It is not clear whether the decision to pursue or forego aggressive treatment would have changed if this information were available at the time of admission.

It has been shown that the likelihood of survival as predicted by physicians is the most important factor in the decision to provide or forego life support.[7] However, subjective assessment of outcome has been shown to have several shortcomings. When physicians were asked to estimate probability of death, considerable variability was noted.[5] As many as 45% of patients provoked at least 20% difference in physicians' assessments of probability of death. Critical care attending physicians provided the most accurate estimates.[5] This variability was also noted in the SUPPORT study where a substantial variation was seen among institutions and among physicians' specialties in the likelihood of writing a DNR order.[8] Patients whose attending physicians were cardiologists had the fewest DNR orders; those whose attending physicians were pulmonologists or intensivists had the most. Surgeons took the longest time to write DNR orders compared to internists.[8] Furthermore, the same study found that DNR orders were written earlier and more often for older patients, a fact that could not be explained by prognostic data.[9]

Several studies, including the SUPPORT study, showed that physicians' mortality estimates are as accurate as mortality prediction systems. However, the best estimates were obtained by combination of an objective prognosis with a physician's clinical assessment.[10] The SUPPORT study included hospitalized patients (not necessarily in ICU) and excluded patients with certain diagnoses and those who died within 48-hours of hospitalization. These points make it difficult to apply the finding to ICU patients on admission. Most ICU mortality prediction systems are based on data collected after a defined period is elapsed from ICU admission. Therefore, the predicted mortality cannot be available at the time of admission. Mortality Probability Model II_0 has the advantage of being based on data collected in the first hour of admission, which makes it potentially helpful for the treating physician to make early decisions. We found that withholding treatment to be more acceptable to many patients and families than withdrawal of an ongoing therapy.

There is limited literature examining MPM II_0 as predictor of very poor prognosis. Rodriguez et al[11] compared physicians predictions and MPM II_0 predicted survival predictions of <2%, 0-10% and 0-25%. At all cutoff values, the specificity and positive value of MPM II_0 was higher than those of the physicians' prediction, but with lower sensitivity. We doubt that prediction systems will substitute the clinical judgement of experienced physicians. In fact, most comparisons failed to prove superiority of prediction systems over physicians' estimates.[12] Nevertheless, incorporating the results of prediction systems may enhance physicians' predictive accuracy, as was the case in the SUPPORT study.[10]

In conclusion, using a decision-cutoff of 95% risk of death, MPM II0 had very high specificity in predicting death after ICU admission, although with a low sensitivity. This information can be used to support clinical judgment regarding the very ill patients who are unlikely to benefit from ICU admission.

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Appendix - Steps to calculate predicted mortality by MPM II_0.

1. Compute the logit g(x) defined as:

   $g(x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_{15} x_{15}$, where is β_0 is the constant and β_1 is the coefficent for the variable x_1. All variables in MPM II_0, except age, take the value 0 if absent and 1 if present. A list of the variables and their coefficients is displayed in **Table 5**. The definitions of the variables are available in the original article.[6]

2. Predicted hospital mortality is calculated then from the following formula:

   Predicted hospital mortality = $[e^{g(x)} / 1 + e^{g(x)}]$

Variable	β
Constant	-5.46836
Coma or deep stupor	1.48592
Heart rate ≥ 150 beats/min	0.45603
Systolic blood pressure ≤ 90 mm Hg	1.06127
Chronic renal insufficiency	0.91906
Cirrhosis	1.13681
Metastatic neoplasm	1.19979
Acute renal failure	1.48210
Cardiac dysrhythmia	0.28095
Cerebrovascular incident	0.21338
Gastrointestinal bleeding	0.39653
Intracranial mass effect	0.86533
Age (Years)	0.03057
Cardiopulmonary resuscitation prior to admission	0.56995
Mechanical ventilation	0.79105
Medical or unscheduled surgery admission	1.19098