Comparative Evaluation Of Major Prognostic Scoring Systems

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Need for ICU Severity Scoring System

- Physicians use experience and intuition, history, physical examination, vital signs, & diagnostic testing to decide who is sick
- But this is not reproducible, often includes elements that do not actually predict outcome, and cannot be communicated easily to others in a standardized manner

ICU severity scoring systems are designed to quantify and reduce a number of discrete but interrelated patient characteristics to a single value, with the final value relating to the severity of the condition

Approaches to Severity Assessment

Outcome prediction models

- Assignment of increasing points to worsening physiological and clinical parameters
- Calculation of aggregate scores
- Prediction of risk of death (predefined equations)

Organ dysfunction models

- Assignment of increasing points to worsening organ function
- Generally describe morbidity, & not mortality risk

- Instrument characteristics
- Performance across different countries
- Comparisons between commonly used scoring systems
- The Indian scenario

General Outcome Prediction Models

- Acute Physiology And Chronic Health Evaluation (APACHE) I II III
- Simplified Acute Physiology Score (SAPS) I II
- Mortality Prediction Model (MPM) I II
- Others

General Outcome Prediction Models

	APACHE	SAPS	APACHE II	MPM	APACHE III	SAPS II	MPM II
Year	1981	1984	1985	1988	1991	1993	1993
Countries	1	1	1	1	1	12	12
Participating ICUs	2	8	13	1	40	137	140
Number of patients	705	679	5815	2783	17440	12997	19124
Selection of variables and their weights	Panel of experts	Panel of experts	Panel of experts	Logistic regression	Logistic regression	Logistic regression	Logistic regression
Variables:							
Age	x	✓	✓	✓	✓	✓	✓
Patient origin	x	x	x	x	✓	x	x
Surgical status	x	x	✓	✓	✓	✓	✓
Chr. health status	✓	x	✓	✓	✓	✓	✓
Physiology	✓	✓	✓	✓	✓	✓	✓
Acute diagnosis	x	x	✓	x	✓	x	✓
Number of variables	34	14	17	11	26	17	15
Score	✓	✓	✓	✓	✓	✓	✓
Prediction equation	x	x	✓	✓	✓	✓	✓

	MPM0	MPM24	APACHE	SAPS II
Age	•	•	•	•
Type of admission	•	•	•	•
Comorbid illness(es)	•	•	•	•
CPR prior to admission	•			
Temperature			•	•
Confirmed infection		•		
Respiratory				
Respiratory rate			•	
Need for ventilation	•	•		•
FiO_2			•	•
Arterial blood gases		•	•	•
CVS				
Heart rate	•		•	•
Dysrhythmia	•			
Blood pressure	•		•	•
Vasoactive drug dose		•		

	MPM0	MPM24	APACHE	SAPS II
Hepatic/Gastrointestinal				
Bilirubin				•
GI bleed	•			
Renal				
Urine output		•		•
Urea				•
Creatinine		•	•	
Acute renal failure	•		•	
Electrolytes			•	•
Hematologic/Coagulation				
Hematocrit			•	
TLC			•	•
Prothrombin time		•		
Neurological				
Glasgow coma score	•	•	•	•
CVA	•			
I/C mass effect	•	•		

Organ Dysfunction Scores

SOFA Sequential Organ Failure Assessment

LODS Logistic Organ Dysfunction System

MODS Multiple Organ Dysfunction Score

Parameters to Assess Organ Dysfunction

	MODS	SOFA	LODS
Respiratory	PO_2/FiO_2	PO_2/FiO_2, Need for ventilation	PO_2/FiO_2, CPAP/ ventilation status
Coagulation	Platelet count	Platelet count	Platelet count, WBC count
Hepatic	Bilirubin	Bilirubin	Bilirubin, Prothrombin time
Cardiovascular	HR × (CVP/MAP)	BP, inotropic support	HR, systolic BP
Neurological	Glasgow Coma Score	Glasgow Coma Score	Glasgow Coma Score
Renal	Creatinine	Creatinine, Urine output	Creatinine, Urea, Urine output

BMJ 1999;319;241-244

Which is better ??

Mortality *vs*. Morbidity

	Outcome Prediction Scores	Organ Dysfunction Scores
Correlation with vital outcome	+++	+
Prediction of risk of mortality	+++	–
Assessment of groups of patients	++	+
Assessment of individual patients	+	++
Description of change in clinical status	±	+++
Analysis of individual organ dysfunction	–	+++

A 55 year old man with ARDS, and no comorbidities, is transferred to RICU from ward, and provided mechanical ventilatory support

Worst vital values during day 1

- Temp 38 ^{o}C
- RR 40 /min
- HR 120 /min
- BP 116/80 mmHg
- GCS 5
- Urine 100 ml in 24 hrs

Worst laboratory parameters during day 1

- Hematocrit 35 %
- TLC 13600 /mm^3
- Urea 46 mg/dl
- Creatinine 0.9 mg/dl
- Sodium 131 meq/l
- Potassium 3.7 meq/l
- Bilirubin 3.5 mg/dl

Peak FiO_2 requirement 0.50

Worst ABG: pO_2 50 pCO_2 35 HCO_3 19 pH 7.45

APACHE II Score and Mortality Risk

	+4	+3	+2	+1	0	+1	+2	+3	+4	Score
Rectal temp (C)	≥41	39-40.9		38.4-38.9	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 (bpm)	≥180	140-179	110-139		70-109		55-69	40-54	<39	
Respiratory rate (bpm)	≥50	35-49		25-34	12-24	10-11	6-9		<5	
AaDo2 if FiO2>0.5	≥500	350-499	200-349		<200					
PO2 (mmHg), if FiO2 <0.5					>70	61-70		55-60	<55	
Arterial pH	≥7.70	7.60-7.69		7.50-7.59	7.33-7.49		7.25-7.30	7.15-7.20	<7.15	
Serum Sodium (mmol/l)	≥180	160-179	155-159	150-154	130-149		120-129	111-119	<110	
Serum Potassium (mmol/l)	≥7	6-6.9		5.5-5.9	3.5-5.4	3.0-3.4	2.5-2.9		<2.5	
Serum creatinine (mg/dl)	≥3.5	2-3.4	1.5-1.9		0.6-1.4		<0.6			
Haematocrit (%)	≥60		50-59.9	46-49.9	30-45.9		20-29.9		<20	
White cell count (1000/mm^3)	≥40		20-39.9	15-19.9	3-14.9		1-2.9		<1	
GCS score (15 – GCS)										
Total Physiology Score (A)										

Age Points (B)	
<45 years	0
45-54 years	+2
55-64 years	+3
65-74 years	+5
≥75 years	+6

Chronic Health Points (C)	
History of severe organ system insufficiency, or immunocompromised (as defined)	
- Nonoperative / emergency postoperative	+5
- Elective postoperative	+2
None of above	0

Total APACHE II Score (A+B+C)

Logit = – 3.517 + (APACHE II score × 0.146) + weight *

Risk of Death

$= e^{\text{logit}} / 1 + e^{\text{logit}}$

** Weights are predefined based on indication for ICU admission; Add extra 0.603 if post-emergency surgery*

APACHE II Score and Mortality Risk

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Heart rate (bpm)	≥180	140-179	110-139		70-109		55-69	40-54	<39	+2
Respiratory rate (bpm)	≥50	35-49		25-34	12-24	10-11	6-9		<5	+3
AaDo2 if FiO2>0.5	≥500	350-499	200-349		<200					+2
PO2 (mmHg), if FiO2 <0.5					>70	61-70		55-60	<55	
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White cell count (1000/mm^3)	≥40		20-39.9	15-19.9	3-14.9		1-2.9		<1	0
GCS score (15 – GCS)										+10
Total Physiology Score (A)										**17**

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Chronic Health Points (C)	
History of severe organ system insufficiency, or immunocompromised (as defined)	
- Nonoperative / emergency postoperative	+5
- Elective postoperative	+2
None of above	0

Total APACHE II Score (A+B+C)

20

Logit = – 3.517 + (APACHE II score × 0.146) + weight *

Risk of Death

$= e^{\text{logit}} / 1 + e^{\text{logit}}$

** Weights are predefined based on indication for ICU admission; Add extra 0.603 if post-emergency surgery*

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Respiratory rate (bpm)	≥50	35-49		25-34	12-24	10-11	6-9		<5	+3
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White cell count (1000/mm^3)	≥40		20-39.9	15-19.9	3-14.9		1-2.9		<1	0
GCS score (15 – GCS)										+10
Total Physiology Score (A)										**17**

Age Points (B)	
<45 years	0
45-54 years	+2
55-64 years	+3
65-74 years	+5
≥75 years	+6

Chronic Health Points (C)	
History of severe organ system insufficiency, or immunocompromised (as defined)	
- Nonoperative / emergency postoperative	+5
- Elective postoperative	+2
None of above	0

Total APACHE II Score (A+B+C)

20

Logit = – 3.517 + (APACHE II score × 0.146) + weight *

= – 3.517 + (20 × 0.146) – 0.251 = – 0.848

Risk of Death

$= e^{logit} / 1 + e^{logit} =$ 30.0%

** Weights are predefined based on indication for ICU admission;*
Add extra 0.603 if post-emergency surgery

SAPS II Score and Mortality Risk

	Points
Age	
Heart rate	
Systolic BP	
Body temperature	
PaO_2	
- If ventilated, PaO_2/FiO_2	
Daily urine output	
Serum Urea	
White cell count	
Serum Potassium	
Serum Sodium	
Serum Bicarbonate	
Serum Bilirubin	
GCS score	
Chronic diseases	
Type of admission	
Sum of points	

$$\text{Logit} = -7.7631 + 0.0737 \times \text{SAPS II score} + 0.9971 \times \ln(\text{SAPSII score} + 1)$$

$$\text{Risk of death} = e^{\text{logit}} / 1 + e^{\text{logit}}$$

SAPS II Score and Mortality Risk

	Points
Age	+7
Heart rate	+4
Systolic BP	0
Body temperature	0
PaO_2	
- If ventilated, PaO_2/FiO_2	+9
Daily urine output	+11
Serum Urea	0
White cell count	0
Serum Potassium	0
Serum Sodium	0
Serum Bicarbonate	+3
Serum Bilirubin	0
GCS score	+26
Chronic diseases	0
Type of admission	+6
Sum of points	66

Logit = -7.7631
+
0.0737 x SAPS II score
+
0.9971 x ln (SAPSII score + 1)

= 1.294

Risk of death = $e^{logit} / 1 + e^{logit}$

= 78.5%

International Comparisons

APACHE II and MPM II

- Good agreement in overall predicted mortality for 11,320 ICU patients
- Wide discrepancies between the two scores for some patients

Lemeshow et al. Intensive Care Med 1995

International Comparisons

SAPS II and MPM

- 10,027 patients in 89 ICUs in 13 European countries
- Good discrimination (AUROC >0.75)
- Poor calibration
- Both scores overestimated mortality risk
- Large variations across patient subgroups

Moreno et al. Crit Care Med 1998

International Comparisons

APACHE II and MPM II

- 8724 patients from 26 general ICUs in Britain and Ireland
- Better discrimination and calibration for APACHE II model

Rowan et al. Crit Care Med 1994

International Comparisons

APACHE II and SAPS II

- 681 patients in a Greek ICU
- Good discrimination (AUROC >0.80)
- Poor calibration
- Both models perform similarly

Katsaragakis et al. Crit Care Med 2000

International Comparisons

APACHE II, SAPS II, MPM0 and MPM24

- 1325 patients in three Tunisian ICUs
- No major differences in performance
- Good discrimination (AUROC >0.80)
- Unsatisfactory calibration

Nouira et al. Crit Care Med 1998

International Comparisons

APACHE II, SAPS II, MPM0 and MPM24

- 969 patients at a Saudi Arabian ICU
- Largely similar performance
- Overall mortality prediction accurate (SMRs 0.92 to 1.09)
- Poor calibration
- Good discrimination (AUROC 0.79 to 0.85)

Arabi et al. Crit Care 2001

International Comparisons

General trends:

- Outcome prediction models perform less well in settings other than those in which models have been developed
- Moderate to good discrimination
- Poor calibration
- Little to chose between individual models

APACHE II in Indian ICUs

Medical / Neurological ICU at Mumbai

- 993 patients, 36.2% mortality
- Nonsurvivors had higher APACHE scores
- SMR 1.67

Parikh et al. Crit Care Med 1999

APACHE II in Indian ICUs

Medical / Neurological ICU at Mumbai

- 1000 patients, 33.7% mortality
- SMR 1.37
- Poor calibration (except at higher risks)
- Moderate discrimination (AUROC 0.77)

Nimgaonkar et al. Intensive Care Med 2004

APACHE II in Indian ICUs

Respiratory ICU at Delhi

- 330 patients, 13.0% mortality
- Nonsurvivors had higher APACHE scores
- SMR 1.65
- Poor calibration (except at risk extremes)
- Poor discrimination (AUROC 0.63)

Gupta et al. Indian J Med Res 2004

Performance comparison in Indian ICU

- Multidisciplinary ICU at Chennai
- 4877 patients, mortality rate 15.6%
- Both SAPS II and APACHE II had poor discrimination (AUROC 0.71 and 0.66)
- Overall SMRs: APACHE II 0.72
  SAPS II 1.42
- Both systems underestimated mortality at low risks, & overestimated it at high risks

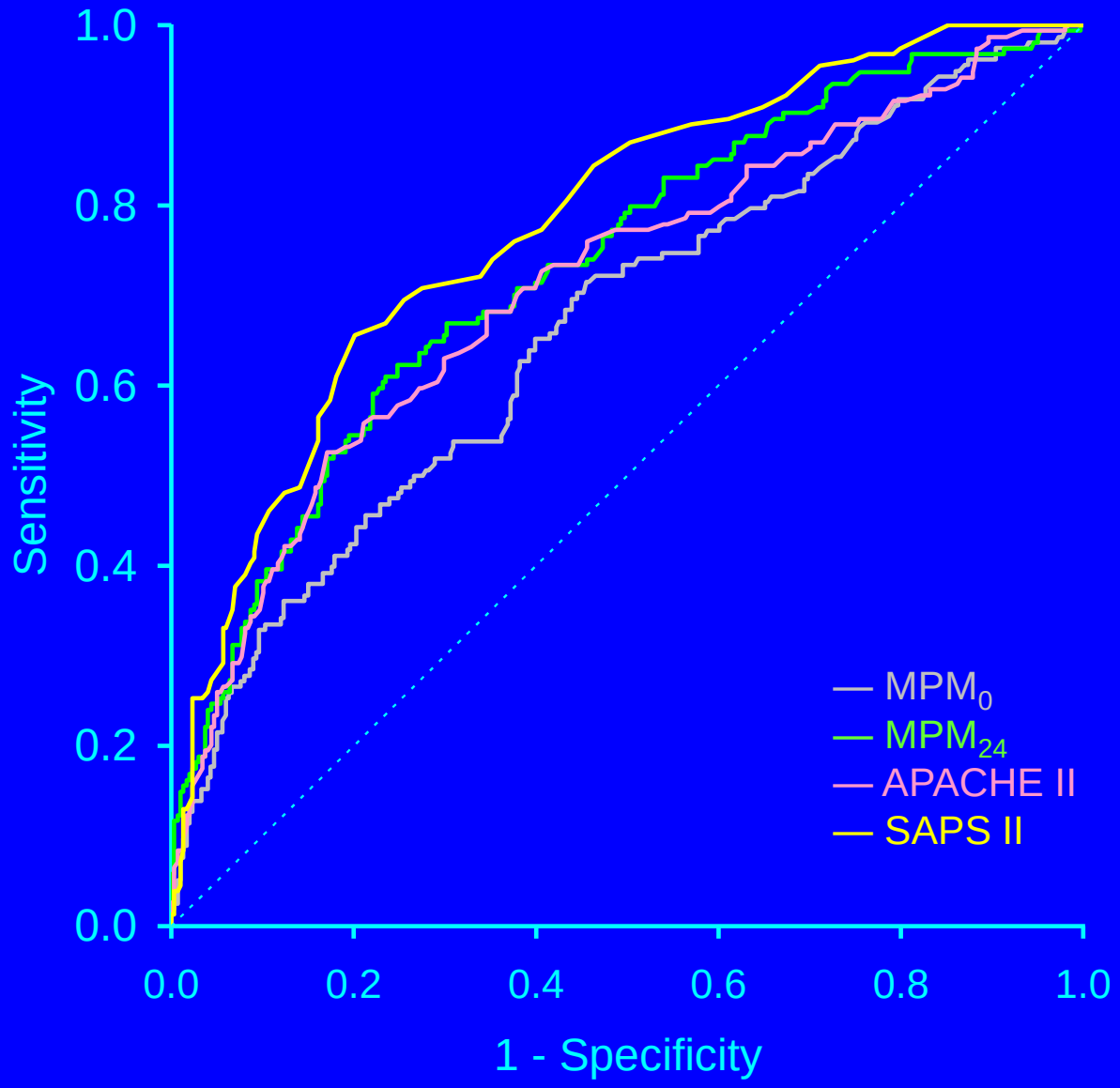
Arunkumar et al. Indian J Crit Care Med 2002

Overall Performance in RICU

	MPM_0	MPM_{24}	APACHE II	SAPS II
No. of patients	459	452	452	452
Survivors	301 (65.6%)	198 (65.9%)	198 (65.9%)	198 (65.9%)
Nonsurvivors	158 (34.4%)	154 (34.1%)	154 (34.1%)	154 (34.1%)
Mean predicted mortality (± SD)*				
Survivors	0.01 ± 0.12	0.16 ± 0.15	0.15 ± 0.14	0.11 ± 0.16
Nonsurvivors	0.19 ± 0.22	0.34 ± 0.27	0.30 ± 0.23	0.32 ± 0.27
Goodness of fit	p <0.001	p <0.001	p <0.001	p <0.001
SMR (95% CI)	2.7 (2.3-3.2)	1.6 (1.3-1.8)	1.7 (1.4-2.0)	1.9 (1.6-2.2)
AUROC (± SE)	0.66 ± 0.03	0.73 ± 0.03	0.71 ± 0.03	0.78 ± 0.02

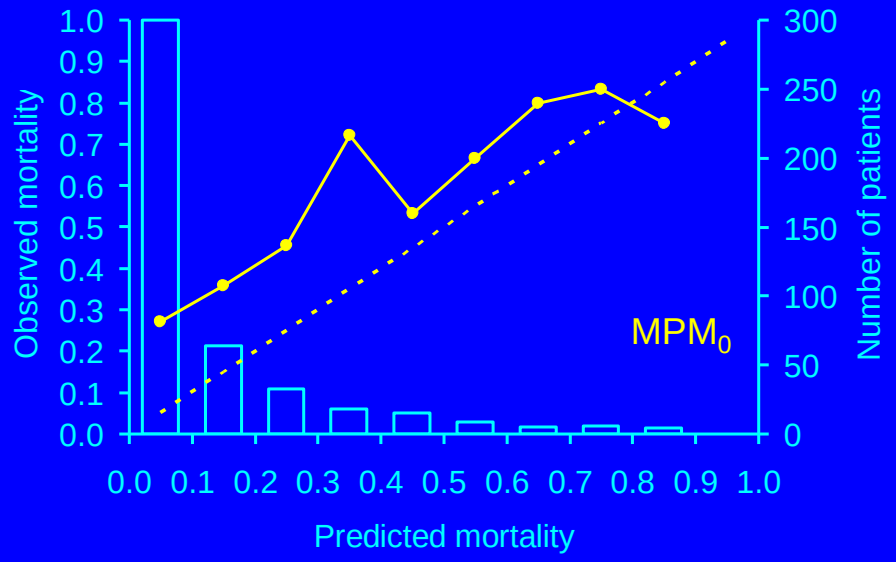
Aggarwal et al. Respirology (In press)

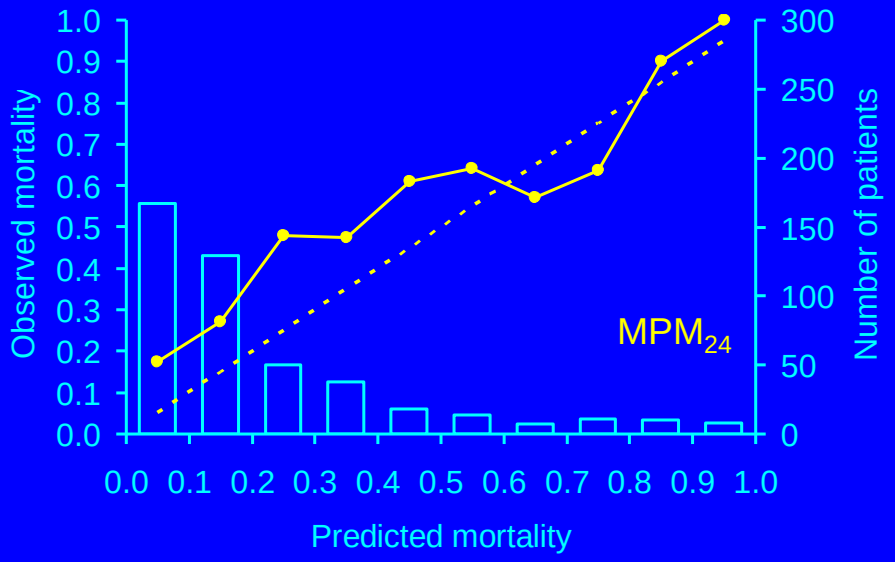
Discrimination in Acute Respiratory Failure

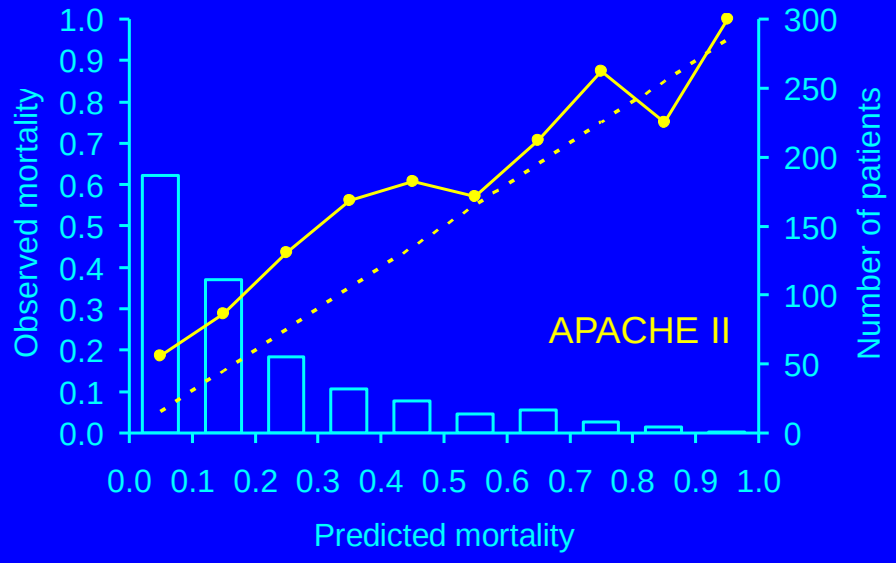


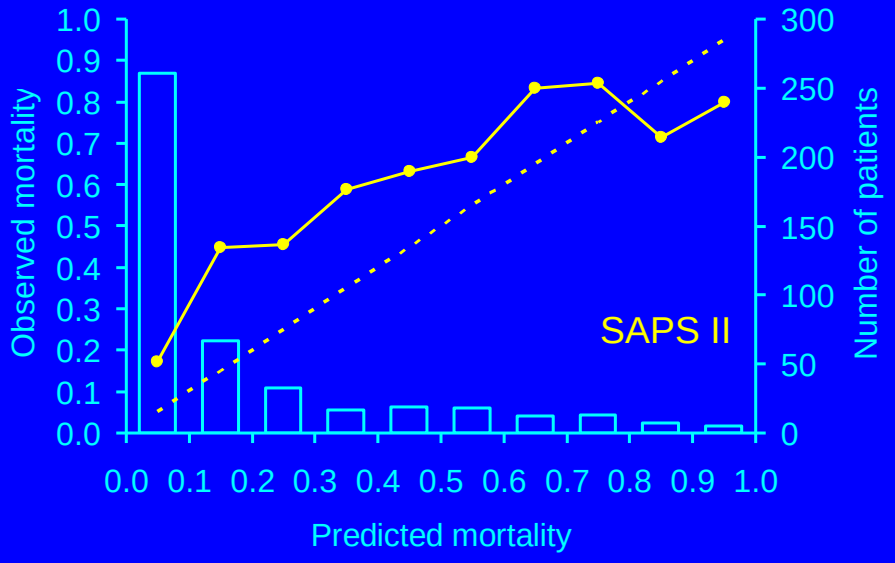
Aggarwal et al. Respirology (In press)

Calibration in Acute Respiratory Failure



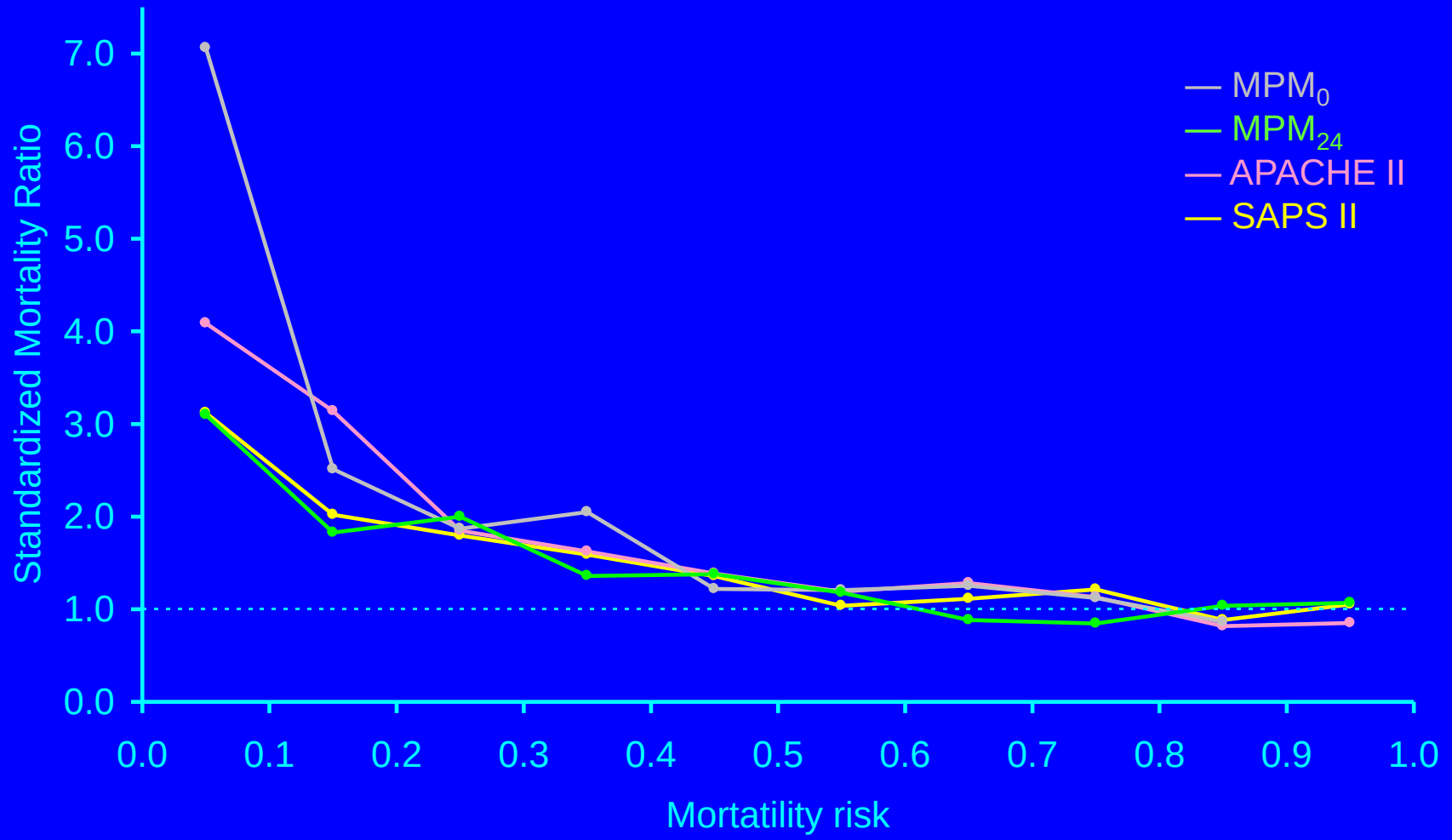






Aggarwal et al. Respirology (In press)

SMRs in Acute Respiratory Failure



Aggarwal et al. Respirology (In press)

What's New on Horizon?

SAPS III

- More patients in more countries
- Region specific prediction of mortality risk
- Performance in Indian ICUs is poor

Intensive Care Medicine. 2005

APACHE® IV

- More diagnostic categories, more variables
- Equations to predict mortality and length of stay from day 1 data are in public domain

www.cerner.com/public/MillenniumSolution.asp?id=3562

What's New on Horizon?

Artificial Neural Networks

- Dynamic and self training algorithms
- Trained to predict outcome based on set of selected patient variables
- Specific to the case-mix at a particular ICU
- May prove superior to the standard severity scoring systems

- One model also developed at IIT Mumbai

Nimgaonkar et al. Intensive Care Med 2004

Why Models Do Not Generalize?

- Unreliability of the model itself
- Differences in ICU case-mix
- Variations in institutional practices
- Patient selection bias for ICU transfer
- Lead time bias
- Development of new therapies over time

SUMMARY

- Outcome models are predictive while organ dysfunction models are descriptive
- No model clearly superior to another
- Definite problems in using general models to predict outcome in other populations
- Need to locally validate/customize existing instruments, or develop locally appropriate new models

… extreme caution about using a score meant to classify *groups* of patients to determine an individual patient's likelihood of survival or therapeutic requirements …

Knaus WA. Crit Care Med 1981;9:591-597


Thank You