Severity of illness: APACHE II analysis of an ICU population

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■ We reviewed the population of a surgical intensive care unit from July 1, 1987 to June 30, 1988, adjusting for severity of illness using the APACHE II system. Nineteen different departments admitted a total of 613 patients to the surgical intensive care unit. Predicted mortality was 22.9%; actual mortality was 15.7%. APACHE II generated reports which included analysis by age, mortality risk, department, primary physician, and diagnosis. We recommend reporting intensive care unit outcome by APACHE criteria to allow more meaningful comparisons of data and standardization of quality assurance programs. Finally, we present a critical review of the current APACHE II system and describe developments to be included in APACHE III.

□ INDEX TERMS: INTENSIVE CARE UNITS; SEVERITY OF ILLNESS INDEX □ CLEVE CLIN J MED 1991; 58:477–486

THE Acute Physiology and Chronic Health Evaluation (APACHE) system is a physiology-based index of the severity of illness of patients in intensive care units (ICU).[1–3] The system is based on the premise that severity of illness can be graded by measuring simple physiologic parameters and that hospital mortality can thereby be accurately predicted for groups of patients. The second stage of development of the system, APACHE II, has been validated in a multi-institutional study of 5,815 patients.[4]

To quantify severity of illness, APACHE II generates a score for each patient; the score is the sum of three parts of the evaluation—the acute physiology score, an age score, and points for chronic illness. The acute physiology score is based on the worst values for 12 commonly measured physiologic variables obtained during the first 24 hours of ICU stay. It is intended to reflect the patient's "presentation" condition and is not meant to indicate response to treatment or problems that develop in the ICU.

The patient's raw APACHE score is entered into a logistic regression equation[4] together with a disease-specific coefficient that reflects the relative mortality of the underlying condition or pathology. The equation then yields an estimated mortality risk for the individual patient. The expected deaths for a group of patients is the sum of the individual mortality risks. This prediction is not particularly useful for a given individual, but it can provide information of value to quality assurance programs.

Mortality risks are expressed as probabilities. For example, a mortality risk of 0.5 for a group of 100 patients predicts that 50% of them will die while hospitalized. If 75 of these patients died, this would

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TABLE 1
DEPARTMENTS ADMITTING TO SICU

Department	Patients Total(%)	Survivors	Nonsurvivors
Vascular Surgery	293(48)	267	26
General Surgery	79(13)	52	27
Urology	78(13)	74	4
Colorectal Surgery	50(8)	32	18
Pediatrics (over age 15)	19(3)	18	1
Other	94(15)	74	20
Orthopedic Surgery	35	34	1
ENT	13	12	1
Gynecologic Surgery	8	4	4
Cardiothoracic Surgery	6	4	2
Nephrology	6	3	3
Plastic Surgery	5	4	1
Gastroenterology	4	3	1
Neurosurgery	3	3	0
Neurology	3	1	2
Hematology/Oncology	3	0	3
Endocrinology	2	2	0
Cardiology	2	2	0
Peripheral Vascular Disease	2	1	1
Internal Medicine	1	0	1
Pulmonary Medicine	1	1	0
Ophthalmology	1	1	0

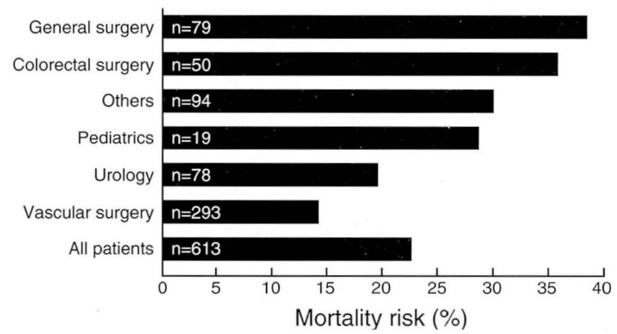

FIGURE 1. Severity of illness (mortality risk) according to admitting service.

indicate that mortality was higher than expected. By comparing expected mortality and actual mortality, groups of patients can be identified whose outcome varied substantially from that predicted. For example, an ICU may do very well caring for patients at low and high risk, but may show a higher mortality rate than expected for those at moderate risk. Opportunities to improve care could then be directed at supportive systems that particularly apply to that group.

Dividing actual mortality by predicted mortality yields a "mortality ratio" which, in this example, is 75/50, or 1.5. When the mortality ratio is 1.0, the number of deaths occurring matches the number predicted; a mortality ratio of less than 1.0 indicates that fewer than the expected number of deaths have occurred; a mortality ratio greater than 1.0 indicates a higher-than-expected mortality. If a norm is established, such as the APACHE validation database, then the mortality ratio can be used as an indicator in a quality assurance program.

PATIENTS AND METHODS

All patients 16 years of age and older admitted to the Pediatric and Surgical ICU (SICU) at The Cleveland Clinic Foundation from July 1, 1987 to June 30, 1988 were included in our study. Patients younger than 16 years were excluded from the study because APACHE scores have not been validated for the pediatric population. Our population also does not include cardiac surgery, medical or neurological intensive care, or coronary care patients: these are managed elsewhere in the hospital.

APACHE II scores and mortality risk calculations were made by a researcher (J.G.) with extensive experience and training in the APACHE system. Data were analyzed on a microcomputer-based spreadsheet (Microsoft Excel). Specific questions and interpretations of medical diagnostic information were resolved in consultation with an ICU staff physician (J.D.L.). Mortality predictions were made using the diagnostic or system failure categories described by Knaus.[2]

Predicted mortality was compared to outcome data received from the hospital admitting office after the patients were discharged. Since each patient could have only one hospital outcome for each hospital admission, only one APACHE prediction per patient was included, which for the sake of consistency was always the estimation taken at the last ICU admission. For example, if a patient was admitted to the ICU four times during one hospitalization, with estimated mortality risks of 10%, 50%, 35%, and 20%, only the last prediction (20%) was included in our analysis.

RESULTS

Population and hospital outcome

The SICU had 694 admissions for 613 patients age 16 or older. Patients were admitted by primary physicians representing 21 different departments, as shown in *Table 1*. The service group designated "Other" represents 94 patients from 16 departments, involving 53 primary physicians. Some of these

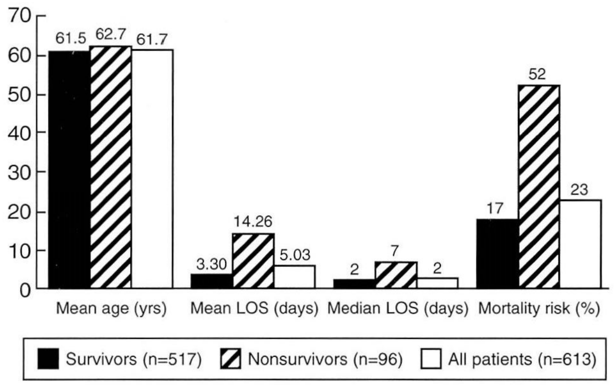

FIGURE 2. **Patient populations compared for mean age, length of stay, and mortality risk.** ***P*<0.05 for mean and median length of stay, and mortality risk.**

patients came to the SICU after surgical procedures as part of our designated population (such as those from Orthopedic Surgery and ENT), and others as a result of triage from other ICU's which had no available beds (such as Neurosurgery, Cardiothoracic Surgery, and Hematology/Oncology).

Severity of illness, as reflected by mortality risk, was reviewed for each of the admitting primary services (*Figure 1*). This varied from 0.144 for the patients of the Department of Vascular Surgery to 0.386 for patients of the Department of General Surgery. The risk of the entire population was 0.229.

Of the 613 patients, 96 (15.7%) did not survive to leave the hospital. The APACHE II system—on the basis of severity of illness—had predicted 22.9% mortality, or 140.38 hospital deaths. Dividing the actual deaths by those predicted yields a mortality ratio of 0.68; that is, the actual deaths amounted to 68% of the deaths predicted by the system.

Age

Using the Wilcoxon two-sample test, survivors differ from nonsurvivors in severity of illness and length of stay ($P<.001$), but not in mean age (*Figure 2*). For each age decile the mortality ratio was below 1.0, indicating that fewer deaths occurred than were predicted (*Table 2*). The most severely ill patients were the youngest (ages 16 to 25) and the oldest (over age 85). These groups also show the best mortality ratios, but the only groups with populations large enough to show a mortality ratio statistically different from 1.0 are the deciles from 56 to 65 and 66 to 75.

TABLE 2
MORTALITY BY AGE DECILES

Age decile	n(%)	Mortality risk	Predicted deaths	Actual deaths	Mortality ratio
16-25	28 (4.6)	.27	7.6	4	0.52
26-35	24 (3.9)	.25	6.1	3	0.39
36-45	35 (5.7)	.21	7.4	7	0.95
46-55	66 (10.8)	.21	14.0	11	0.79
56-65	153 (25.0)	.19	29.0	17	0.59*
66-75	217 (35.4)	.24	52.9	37	0.70†
76-85	79 (12.9)	.26	20.2	17	0.84
>85	11 (1.8)	.28	3.1	1	0.33

*P=0.02 † P=0.023

Risk of hospital death

Table 3 compares actual and expected deaths for each risk group and shows the resultant mortality ratios. Because of the relatively large numbers of patients involved and the low mortality ratios, the patients most likely to benefit from the care in this particular ICU are those with expected mortality of less than 30%. Note, however, that there were 55 patients with expected mortality >60%. The mortality ratio for this high-risk group was 42/38, or 0.89. The severity of illness (reflected by mortality risk) compared with length of ICU stay shows, not surprisingly, that sicker patients require a longer ICU stay, but that the most severely ill patients (mortality risk >69%) occupy ICU beds for fewer days than those with a 50 to 69% risk of hospital death.

Chronic health

The APACHE II system allows estimates of severity of illness to be adjusted for patients with chronic ill health: points can be added to the APACHE score to reflect chronic health conditions. However, very strict definitions are observed to meet this condition in order to avoid subjectivity. To qualify for chronic health points, the patient must have had any of the following indications of organ insufficiency or immunocompromise prior to the present hospitalization: (1) biopsy-proven cirrhosis and documented portal hypertension, episodes of past upper gastrointestinal bleeding attributable to portal hypertension, or prior episodes of hepatic failure, encephalopathy, or coma; (2) New York Heart Association class IV cardiovascular status; (3) chronic restrictive or obstructive pulmonary disease resulting in severe exercise intolerance, chronic hypoxia, hypercarbia, secondary polycythemia, pulmonary hypertension, or ventilator dependency; (4) chronic dialysis; (5) immunosuppres-

TABLE 3
MORTALITY RATIO AND LENGTH OF STAY BY RISK OF HOSPITAL DEATH

Mortality risk (%)	n	Predicted deaths	Actual deaths	Mortality ratio	Length of stay (days) Mean (median)
0-9	230	13.1	3	0.23	2.81 (2.0)
10-19	133	17.6	7	0.44	3.67 (2.0)
20-29	88	21.3	11	0.52	3.30 (3.0)
30-39	47	16.3	16	0.98	5.00 (3.0)
40-49	39	17.3	13	0.75	8.49 (5.0)
50-59	21	11.6	8	0.69	16.32 (2.0)
60-69	21	13.4	10	0.74	12.82 (4.5)
70-79	10	7.4	9	01.2	23.76 (2.5)
80-89	10	8.5	7	0.82	9.74 (4.0)
90-99	14	13.1	12	0.91	7.53 (3.0)
all pts ≥ 60%	55	42.5	38	0.89	–

sion, chemotherapy, radiation, long term or recent steroid usage, or an immunosuppressing disease such as AIDS or leukemia.

Of the 613 patients in our study, 150 (24.5%) had scores adjusted for chronic ill health. The chronically ill patients had an estimated mortality risk of 0.35, nearly twice that of the patients without chronic health points (0.19). Among patients with chronic health points, 24.7% (37) died during hospitalization, compared with 12.7% (59/463) of the patients without chronic health points. However, the mortality ratio was nearly identical in the two groups (0.70 for patients with chronic health points and 0.68 for patients without), showing that the percentage of deaths in the chronically ill group was not disproportionate when adjusted for severity of illness.

The three organ systems most often responsible for the assigning of chronic health points were the renal, hepatic, and immune. Among these, the mortality ratio was best for the patients with renal failure (0.47), which probably reflects the availability of treatment in the form of dialysis and renal transplantation. However, mortality ratios were also less than 1 for patients with hepatic failure (0.78) and immunosuppression (0.84).

APACHE II DIAGNOSIS

The APACHE II system uses 40 diagnostic categories. Patients who do not fall under a specific diagnosis are assigned to a group based on the major organ system that was the principle reason for ICU admission. The distribution of our patients by diagnosis is shown in *Table 4*.

To help analyze ICU performance and characterize the patient population, APACHE II can generate reports based on the patient's location prior to ICU admission, and on the level of care provided. Specific definitions are provided to classify patients as operative or nonoperative. For example, a patient received into the ICU after stabilization in a recovery room would be considered operative, but one who was admitted after care in an overnight recovery room would be considered a transfer from another ICU and, therefore, nonoperative. Seventy percent of our patients were received from the operating room or the post-anesthesia care unit, and only 0.6% from the emergency ward, reflecting the particular nature of the surgical practice of the Cleveland Clinic Hospital.

The mortality ratio for operative and nonoperative patients was similar (0.62 and 0.76, respectively), and mortality in both groups was significantly lower than predicted values. The risk of hospital death was lower for operative patients (0.17) than for nonoperative (0.38, $P<.001$ based on the Wilcoxon two-sample test). Although the nonoperative group was more severely ill, the similarity of the mortality ratios indicates no disparity in the quality of care these patients received.

Levels of care are defined as (1) active therapy; (2) monitored high-risk; and (3) monitored low-risk. Active-therapy patients are those who received one or more of a list of 31 specific therapies that reasonably require ICU utilization, such as mechanical ventilation, and intra-aortic balloon assist. Monitored high-risk patients, while receiving no active therapy, are estimated to be at greater than 10% risk of requiring such therapy, based on analysis of 5,790 ICU admissions reported by Wagner.[5] In patients defined as monitored low-risk, the estimated risk of requiring ICU active therapy is less than 10%.

Strict adherence to these definitions allows further description of the ICU population and helps when comparing data with other published reports. This will aid in standardization as ICUs compare their experiences. We departed from the standard APACHE II definitions in this area only in not including the use of low-dose dopamine infusion (<5 μg/kg/min) under the category "vasoactive drug infusion." If this was the sole "active therapy" a patient received in our ICU, the patient was classified as "monitored" rather than "active therapy." Our population was distributed as 89.2% active therapy, 7.2% monitored high-risk, and 3.6% monitored low-risk.

The Glasgow coma evaluation is an element used in the calculation of the acute physiology score. Since many of our patients arrive in the ICU after surgery and are sedated, tracheally intubated, or under the influence of neuromuscular blocking agents, we adjusted the coma score to reflect the patients' estimated condition had they not been under these influences. For instance, if a patient arrived sedated and paralyzed, but subsequently recovered, it was assumed that the patient was able to move and speak appropriately at all times. This adjustment nearly always improved the patient's coma score: we chose to underestimate rather than overestimate the severity of the patient's neurological condition. Since our population includes very few neurological surgery and head trauma patients, low coma scores did not have much effect on our evaluation.

Documenting the distribution of coma scores is important: in a strict application of the Glasgow coma score, sedated postoperative patients would systematically appear to have a greater severity of illness. ICU performance would thereby seem to be better than the APACHE score would predict. Ninety-one percent of our patients had no neurological abnormalities, and in only 5.9% did the coma score add more than two points to the acute physiology score score.

Analysis by primary service

Mortality ratios vary widely when the population is broken down by primary service (*Table 5*). In this hospital, the patients admitted from Vascular Surgery and Urology share characteristics which place them at low mortality risk (the majority of Urology SICU admissions were for renovascular surgery). Likewise, both general surgery and colorectal surgery patients are at high risk, and both of these groups have abdominal pathology. A review of these four groups showed that, for a 3-month period, 55% of the general surgery/colorectal surgery patients had sepsis and 28% had neoplasm as part of the admitting diagnosis. For the vascular surgery/urology group, 3% involved sepsis and 4% involved neoplasm. Nineteen percent of the general surgery/colorectal surgery patients had both sepsis and neoplasm on admission, while none of the vascular surgery/urology patients had that combination.

Other comparisons can be made which reveal differences among departments and their populations. Characteristics such as age, severity of illness, and length of stay in the ICU can be compared for survivors and nonsurvivors within departments (*Table 6*). In the Urology Department, the patients who died

TABLE 4
DIAGNOSTIC CATEGORIES

	No. of patients	No. of deaths (%)
Nonoperative patients		
Respiratory failure or insufficiency from		
Asthma/allergy	1	0
Cardiopulmonary disease	1	0
Pulmonary edema (noncardiogenic)	2	0
Postrespiratory arrest	2	1 (50)
Aspirations/poisoning/toxic	5	4 (80)
Pulmonary embolus	2	0
Infection	4	1 (25)
Neoplasm	1	0
Cardiovascular failure or insufficiency from		
Hypertension	3	0
Rhythm disturbance	–	–
Congestive heart failure	17	1 (7)
Hemorrhagic shock/hypovolemia	7	1
Coronary artery disease	2	1 (50)
Sepsis	36	14 (39)
Postcardiac arrest	7	5 (62)
Cardiogenic shock	3	3 (100)
Dissecting thoracic/abdominal aneurysm	8	4 (50)
Trauma		
Multiple trauma	2	0
Head trauma	–	–
Neurologic		
Seizure disorder	3	1 (33)
Intracranial hemorrhage/SDH/SAH	–	–
Other		
Drug overdose	2	0
Diabetic ketoacidosis	1	0
Gastrointestinal bleeding	16	5 (31)
If none of the above, organ system resp. for ICU admission		
Cardiovascular	11	2
Respiratory	2	27
Gastrointestinal	8	2
Metabolic/renal	5	0
Neurologic	2	0
Postoperative patients		
Multiple trauma	1	0
Surgery for chronic cardiovascular disease	19	0
Peripheral vascular surgery	244	15 (6)
Heart valve surgery	–	–
Thoracic surgery for neoplasm	4	0
Craniotomy for neoplasm	–	–
Head trauma	1	0
Renal surgery for neoplasm	9	1 (11)
Renal transplant	22	0
Craniotomy for intracranial hemorrhage/ SDH/SAH	–	–
Laminectomy and other spinal cord surgery	–	–
Hemorrhagic shock/hypovolemia	8	1 (12)
Gastrointestinal bleeding	8	2 (25)
Gastrointestinal surgery for neoplasm	12	1 (8)
Respiratory insufficiency after surgery	3	0
Gastrointestinal perforation/obstruction	17	7 (39)
Sepsis	26	13 (50)
Post respiratory arrest	1	0
Post cardiac arrest	9	1
If none of above, organ system resp. for ICU admission		
Cardiovascular	23	1 (4)
Respiratory	13	0
Gastrointestinal	13	2 (15)
Metabolic/renal	5	0
Neurologic	2	0
Total	613	96 (15.7)

SDH = subdural hematoma; SAH = subarachnoid hemorrhage

TABLE 5
MORTALITY RATIO BY SERVICE

Hospital service	n	Expected deaths	Actual deaths	Mortality ratio
Colorectal surgery	50	18.1	18	.99
General surgery	79	30.5	27	.88
Others	94	28.5	20	.70
Pediatrics	19	5.5	1	.18
Urology	78	15.3	4	.26
Vascular surgery	293	42.1	26	.61
All patients	613	140.0	95	.68

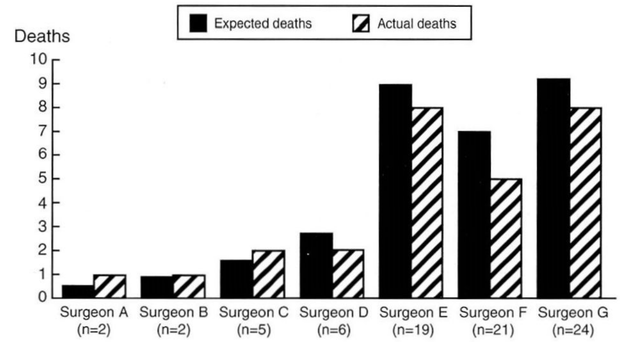

FIGURE 3. Mortality comparisons for patients of individual surgeons in one department. All surgeons who admitted more than 5 patients to the ICU had fewer deaths than predicted by the APACHE II system.

while in the hospital had markedly higher severity of illness on admission to the ICU than those who survived. The patients in the General Surgery Department showed a similar difference, and their illness was more severe even for the survivors, as compared with the survivors in the urology group.

APACHE II does not take the actual surgical procedure into account. For example, the APACHE II diagnosis "peripheral vascular surgery" may lead to underestimating severity of illness for the population of vascular surgery patients utilizing our ICU. In other ICUs, this diagnosis might include many patients who, having had carotid artery or femoral-popliteal bypass surgery, are being monitored for graft patency, or because of significant heart disease or for other reasons. However, in this institution, these patients are routinely monitored in the post-anesthesia care unit, so that 68% of our ICU patients with the APACHE diagnosis of peripheral vascular surgery have had major aortic or thoraco-abdominal surgery.

Analysis by primary physician

Comparing mortality ratio to a "norm" can indicate the quality of care in a global sense to reflect medical care, nursing care, and supportive services, but it is not a tool to evaluate surgical practice specifically. However, consistently poor surgical judgment and technique will eventually be revealed as poor outcome in critically ill patients. APACHE could be used to trigger departmental review by peers if a major, consistent difference in outcome among surgeons is found.

A comparison (*Figure 3*) in this institution shows that, in one department, all surgeons who admitted more than five patients to the SICU were associated with lower than expected mortality. Analysis of this kind makes it possible for a department to set benchmarks: for example, if individual surgeons with adequate case experience were associated with a mortality ratio substantially above a chosen value, whether a national norm like APACHE or a locally defined standard, they would be considered outliers, and review of their practice would ensue. The APACHE system could be used to uncover possible differences in medical practice, although more specific analysis would be necessary to determine whether such differences really exist, and if so, what steps should be taken to modify performance.

Patients with unexpected outcomes

One use of a severity of illness indicator is to direct attention to patients whose outcome is different than expected. It is now standard practice in our ICU to carefully review those patients who were estimated to be at low risk but did not survive hospitalization, as well as those who survive despite being at high risk. In the study population, five patients with estimated mortality risk of 15% or less expired during hospitalization, and three survived despite risk greater than 85%. A review of the cases showed that, of the five patients who died despite being at low risk, four had coronary artery disease and underwent extensive vascular surgical procedures. The fifth patient had relatively little physiologic impairment, yet had an incurable malignancy.

Two of the three patients who survived hospitalization in the face of severely abnormal physiology experienced cardiorespiratory arrest, and so had values abnormal enough to generate high APACHE scores; but the duration of the abnormalities before resuscitation is not recorded. Patients who are promptly brought back to homeostasis undoubtedly have improved outcome. Nevertheless, the APACHE system accurately predicted mortality in the high-risk (>85%)

group: 5 of the 22 patients in this group survived, for a mortality ratio of 0.84. The third high-risk patient was indeed severely ill (in septic shock), but the focus was drained and the process reversed relatively quickly, as reflected by an ICU length of stay of only 4 days.

TABLE 6
COMPARISON OF TWO DEPARTMENTS

	General surgery			Urology		
	S	N	All patients	S	N	All patients
Predicted mortality (%)	30.7	53.9	38.6	17.1	66.7	19.6
Mean LOS (days)	5.0	20.8	10.4	2.5	9.2	2.8
Mean age (years)	54.0	53.5	54.0	62.0	62.0	62.0

S = survivors N = nonsurvivors

Several points can be made about these patients. First, the APACHE system deals with statistics that apply to groups of patients, and care must be made in applying prognostic data to individuals. Even though the estimated risk for an individual is low, in a sufficiently large group of such patients a certain number will inevitably have poor outcomes. It is important to monitor the number of such events to verify that they are not more frequent than the APACHE score would predict.

Second, the system measures physiologic abnormalities but not the level of care required to maintain physiologic parameters. In one of our patients with postoperative hemorrhage, the APACHE score was kept low, despite the need for reoperation, volume resuscitation, and use of vasopressors. The APACHE score, taken alone, underestimates severity of illness in such cases.

DISCUSSION

Advantages

The concept of APACHE is appealing in its simplicity: when a patient is well, basic physiologic parameters are normal, and the farther from normal these parameters are, the greater the severity of illness. This cuts across diagnostic categories and eliminates the need for specific scoring systems for each illness. Such systems, perhaps with weighting for the variables which affect mortality, might be accurate, but they would be cumbersome to use.

The APACHE II system has been validated in a multi-institutional study and has been reported useful in assessing severity of illness in critically ill patients in a number of settings throughout the world.[6–12] Kruse[13] reported that APACHE was highly predictive and as good as, but not better than, the clinical assessment of physicians in predicting mortality. While this may at first glance be considered negatively, it is actually quite an endorsement: one would have to be skeptical of a system that runs counter to clinical experience. Additionally, APACHE II is reproducible and quantifiable in a way that stands up to scrutiny. It is inexpensive in terms of initial cost compared to other severity of illness quantification systems, takes relatively little time to acquire data (approximately 20 minutes per patient to collect the data and enter it into a personal computer, in our experience), and allows meaningful analysis of patient populations.

Comparisons are at the heart of quality assessment. Comparing outcomes from different hospitals, ICUs, departments, practitioners, levels of nursing staffing, and therapy protocols is necessary to establish standards of care. For example, it is meaningless to report raw mortality data from ICUs. In a landmark study by Knaus,[14] in which he rated mortality ratios in 13 major medical center ICUs, the fourth best performing hospital had a mortality rate of 38%. Seen superficially, it would seem undesirable to refer patients to that hospital, but after adjusting for severity of illness, a 42% mortality rate would have been expected. Conversely, the hospital that ranked last had a 26% mortality rate, but only 17% mortality was predicted by APACHE II.

These data become meaningful when they are correlated to show variation in mortality ratios. *Table 7* updates the ranking of 13 hospitals according to mortality ratio by Knaus, inserting our data and data reported by Jacobs from Riyadh Armed Forces Hospitals (RAFH).[15]

While the mortality ratio varies 2.7-fold among the hospitals, it is also interesting that the mortality risk varies 4.3-fold (from 0.10 to 0.43), indicating dramatically different use of the ICU in different settings. In order to maintain confidentiality, Knaus's study did not present complete characterizations of medical and surgical ICUs; however, in general, it would seem fair to expect surgical ICUs to have a lower mortality risk in their populations, since they often monitor patients after surgery who are not critically ill at the time. The predicted mortality rate for our surgical ICU, however, was 0.23, ranking fifth highest among the 15 ICUs.

In Wagner's report of 5,790 ICU admissions from 13 hospitals, 24% were for monitored low-risk patients,

TABLE 7
ACTUAL AND PREDICTED DEATHS IN 15 HOSPITALS

Performance rank	Total patients	Mortality rate	Mortality risk	Predicted deaths	Actual deaths	Mortality ratio
1	365	11.2	.19	69	41	.59
CCF-SICU	613	15.7	.23	140	96	.68
2	201	20.4	.24	49	41	.84
3	159	18.9	.21	34	30	.88
4	201	38.3	.43	86	77	.90
5	500	9.8	.11	53	49	.92
6	426	8.9	.10	41	38	.93
7	412	17.2	.18	74	71	.96
8	198	19.7	.20	39	39	1.00
9	1657	24.1	.23	383	400	1.04
10	366	14.8	.13	49	54	1.10
11	170	26.5	.24	40	45	1.13
RAFH	608	30.8	.26	156	187	1.20
12	178	26.4	.25	44	56	1.27
13	197	26.4	.17	33	52	1.58

with the numbers for individual hospitals ranging from 7% to 42%. However, only 3.6% of the admissions to our ICU were in this category. One reason for the rather high predicted mortality and the low rate of monitored admissions is that our hospital has a post-anesthesia care unit capable of overnight monitoring and ventilation for up to 15 patients per night. This allows us to reserve use of the SICU for patients who truly need active treatment, or who have special problems requiring ICU monitoring.

Another indication of severity of illness is the percentage of patients with chronic failing health (by APACHE II definition). In the 13 hospitals of the validation study, the percentage of patients with chronic health points varied from 5% to 29%; our incidence was 24%, and Jacobs[15] reported 37%. In these two hospitals, of the patients who died, 55% in the RAFH and 38% at the CCF had chronic ill health. The reasons for assigning chronic health points are quite different in the two reports and may in part explain the difference in outcome: our incidence of renal failure, for which there is treatment (hemodialysis), was twice as high as at RAFH, while the frequency of liver failure, for which no real treatment exists, was 2.5 times higher among admissions at RAFH than at CCF.

One important reason for reporting ICU experience by APACHE II is so that other hospitals may have a basis for analyzing appropriate use of resources. A hospital may ask, "Are we providing expensive care in our ICU for patients who could be safely monitored elsewhere in the hospital?" "Does severity of illness indexing indicate that a great many of our patients are so ill that they are unlikely to benefit from ICU care?" If many ICUs of different types and representing a variety of geographical distributions and organizational structures, were to report their experiences in a similar format, it would allow for evaluations that could improve the quality of health care and assure its delivery in a rational and planned atmosphere.

Problems with APACHE II

APACHE II is a tool which can be used effectively to explain many aspects of care, but the system is not perfect. Its results are based on comparison with the experience of 13 hospitals voluntarily collecting data from 1979 to 1982, and therefore cannot be presumed to reflect the current state of nationwide care. Its data are still useful, however, and each hospital can monitor its own performance over time and set its own standards. But a representative, ongoing reference database of ICU care is needed.

As discussed earlier, APACHE II is based on presentation physiology, the worst value for each parameter documented in the first 24 hours of ICU admission. The score is meant to reflect the state of the patient and to be independent of the care received in the ICU. However, patients arrive in the ICU after varying amounts of care received elsewhere. Some patients are admitted after extensive resuscitation in the Emergency Department, some come directly from the street, and others transfer in after long, complicated courses in other hospitals' ICUs. In our experience, the latter patients are often stabilized by the time they are admitted to the ICU, so that physiological the derangements measured by APACHE underestimate severity of illness. We are in the process of reviewing this group of patients.

There is a fear that excellent care before ICU admission (such as rigorous maintenance of homeostasis by anesthesiologists during surgery) can cause severity of illness to be underestimated, leading to false indications of poor ICU performance. Conversely, apparently excellent ICU performance might be attributed to poor anesthesia care. Although data were not collected to document anesthesia-related physiology, our experience indicates that aggressive intraoperative care does not lead to underestimation of severity of illness, but probably contributes to improved survival.

To improve the accuracy of prediction, the APACHE II system incorporates a diagnosis- and organ-specific modifier that takes into account the effects of specific disease processes on physiology and outcome. For example, a patient with diabetic ketoacidosis may have markedly abnormal physiology with altered levels of sodium, potassium, and pH, but would be expected to have a low hospital mortality. This situation differs from that of a patient with a dissecting thoracic aneurysm, who may not yet have altered physiology, but merely with the diagnosis is expected to have a high mortality. The diagnosis-specific modifier adjusts for these differences and allows accurate predictions in both cases.

The number of categories for which a modifier is available is limited by the number of patients in the database on which the system was developed. Many of our patients have peripheral vascular surgery. This was the largest category of patients in the developmental database, and we therefore have confidence that the system reflects the care given to our patients. But each ICU's population is determined by the nature of the practice that refer patients to it, and it is possible that in some ICUs a high percentage of patients will fall into categories defined by only a small number of patients in the developmental database, or for which no diagnostic category is available. In these cases, a general modifier for the organ system involved is used. A patient in the ICU after liver transplantation, for example, would have a predicted mortality based on the modifier for gastrointestinal involvement, and therefore would be grouped with patients having had colon resection, and vagotomy, although this patient would clearly have a higher expected hospital mortality. The more diagnostic categories with large numbers of patients used to develop them, the more accurate the system would be.

A multi-institutional comparison of the effects of weighting medical and surgical ICU mortality data for age would be of value, and might show that mortality data for patients older than 85 admitted to medical ICUs for organ failure are quite different from those undergoing elective surgery. We had 79 patients over age 85 in our surgical ICU, and experienced only about 30% of the deaths predicted. It may be that APACHE II overestimates severity of illness in elderly surgical patients.

Other uses

Whenever it is desired to grade for severity of illness in an ICU population, APACHE II may be useful. We use the mortality prediction as part of a randomization plan to assign patients to arms of clinical studies. This ensures that each group is comprised of patients with roughly equal severity of illness.

Analysis of our nosocomial infections as part of a quality assurance program has shown that our patients who become infected in the ICU are more severely ill as a group than those who do not. Consequently, we have instituted a review of the care of patients who develop infections despite having low mortality risk in the hopes of identifying opportunities to improve care. We also use severity of illness to help identify patients at risk for developing nosocomial pneumonia and are developing a protocol aimed at reducing the rate of infection in that population. Quantifying severity of illness allows targeting of a population at risk and accomplishing study objectives with fewer patients.

The APACHE II system could also be used to identify patients who are not expected to benefit from therapy, and to justify withholding therapy. This approach must be taken with great caution, since once undertaken this method becomes self-fulfilling: patients not expected to survive are not treated and therefore survival is precluded. Chang,[16] recognizing that there were no survivors among patients in his hospital with greater than 60% expected mortality, suggested that parenteral nutrition could reasonably be withheld from that group. While in theory this tactic has merit, it should be based on a reliable sample, and unfortunately his conclusion was based on only eight patients. Further, as our report and other reports show, outcome is to some extent hospital specific, and results from one hospital cannot be directly applied to all other hospitals. In our 1-year experience, we had 55 patients with expected mortality > 60% and of them, 17 survived. In fact, the mortality was somewhat less than the score predicted (mortality ratio was 0.9). Clearly, the outcome from Chang's eight high-risk patients should not be used as a criterion to withhold therapy in other hospitals.

The future

APACHE II is a useful tool for analyzing ICU population and performance, and for identifying areas in which care can be improved. We highly encourage its use in medical and surgical ICUs in many applications. The problems identified above are being addressed in the development of APACHE III, which is in progress. A database will be established representing ICU care from all geographic areas, from hospitals of various sizes and organizational structures. The database will be ongoing, so that hospitals will be able to compare their performance to what is occurring concurrently at similar hospitals, not just in major medical centers at some time in the past. Attempts are being made to improve predictive accuracy, include more specific diagnoses, and show the effect of temporal changes in physiology rather than just describing the severity of illness on presentation to the ICU. The publication of APACHE III and the development of the associated database promise to be very helpful in setting national standards for ICU care. In the meantime, however, the simplicity, low cost, and explanatory power of APACHE II more than justify its broad application.

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