Clinical Medicine

Use of APACHE II Classification to Evaluate Outcome of Patients Receiving Hemodialysis in an Intensive Care Unit

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We retrospectively reviewed the medical records of all patients who were admitted to the medical and surgical intensive care units of a university center (N = 100) and its affiliated veterans' hospital (N = 46) between 1982 and 1986 to receive dialysis. The APACHE II severity-of-disease classification was used to identify the cases in which the prognosis was so poor that no long-term benefit would accrue from hemodialysis treatment. A "risk of death" was calculated for each patient. At a risk of death of 70% or greater, the system correctly predicted the demise of patients with 100% specificity regardless of what interventions were carried out. Sensitivity and predicted negative value were low in all cases, however, indicating a poor predictability of those who will survive. Withholding the average of 6 dialysis treatments that this group of patients received would probably have reduced patient suffering during a lingering terminal illness and led to a savings of about $4,500 per patient.

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Changes in American medical practice in recent years have been remarkable. Each technologic advance in diagnostic or treatment capability, however, carries a cost that is also impressive. With growing competition for available health care dollars, physicians must justify expensive procedures, particularly in critically ill patients with a poor prognosis.

Toward that goal, Knaus and associates developed a severity-of-disease classification system, the Acute Physiology and Chronic Health Evaluation (APACHE), that showed strong, stable relationships between the severity of illness and the subsequent probability of death from various diseases commonly treated in intensive care units (ICUs).[1-3] The system was later revised and simplified into APACHE II, which used fewer but readily available measurements; the accuracy of the original system was maintained.[1-3]

In this study we used the APACHE II system to evaluate mortality in patients who received hemodialysis in an ICU. The purpose of our investigation was to develop a method of identifying those cases in which dialysis was unlikely to provide benefit. From an ethical perspective, a prognostic classification for excluding a patient from dialysis must approach infallibility. We found the APACHE II classification a reasonable way to discern which patients in an ICU had such a high probability of dying that hemodialysis did not improve survival. As an addendum, the cost-effectiveness of overall ICU care could also be improved.

Patients and Methods

APACHE II Classification

The APACHE II classification is largely based on 12 physiologic variables (called the Acute Physiology Score [APS]) that are weighted according to their deviation from the normal range as a measurement of the acute physiologic derangement of a patient. A final APACHE II score is calculated from the APS combined with a weighted score for the patient's age and a score based on the severity of the underlying chronic illness at the time of admission to the ICU. A prior use of the APACHE II system showed that the "risk of death" calculation was influenced by both the APACHE II score and by the disease process causing the ICU admission. Weighted scores for various diseases were empirically derived. A logistic multiple regression equation was developed using both the APACHE II score and the diagnostic category weight for predicting the risk of death in individual patients. This method was verified in an extensive multicenter study involving 13 hospitals and more than 5,800 patients.[2] The following example shows the use of this method:

Example. A 64-year-old woman with a history of diabetes mellitus, chronic obstructive pulmonary disease, and chronic renal insufficiency was admitted to the intensive care unit for treatment of respiratory failure from extensive pneumonia. None of her chronic organ disease was sufficient to warrant Chronic Health Points.[2] Her admitting APS of 18, combined with an age point value of 3, gives a total APACHE II score of 21. Her estimated risk of death is calculated by the following equation:

$$\begin{aligned} \ln(R/1-R) = &-3.517 + (\text{APACHE II score} \times 0.146) \\ &+ 0.603 \text{ (only if an emergency operation was done)} \\ &+ \text{(diagnostic category weight)} \end{aligned}$$

where R is the risk of hospital death. In this patient,

$$\begin{aligned} \ln(R/1-R) &= -3.517 + (21 \times 0.146) + 0 + 0 \\ &= -3.517 + 3.066 \\ &= -0.451 \\ R/1-R &= 0.639 \\ R &= 0.389 \text{ or } 38.9\%. \end{aligned}$$

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ABBREVIATIONS USED IN TEXT

APACHE = Acute Physiology and Chronic Health Evaluation
APS = Acute Physiology Score
ICU = intensive care unit

Study Patients

The medical records of all patients admitted to the ICU who received dialysis at the Jerry L. Pettis Memorial Veterans Administration Medical Center and the Loma Linda (California) University Medical Center between 1982 and 1986 were retrospectively reviewed. Following the technique of Chang and co-workers who evaluated the benefit from total parenteral nutrition,[4] each patient's APACHE II score was determined from the worst values over the first 24 hours of admission to the ICU and the 24 hours before the time hemodialysis was instituted. It was initially thought that one of these scores might be more predictive of death.

A total of 196 patients were identified for the study from dialysis records, but the records of 31 were not evaluated: 29 were never actually admitted to an ICU and 2 were transferred from an ICU before dialysis. Of the remaining 165 patients, 19 could not be evaluated as inadequate medical records militated against accurately determining the APACHE II scores. The results of this study were based on the records of the remaining 146 patients.

The criteria for hemodialysis did not differ in patients included in this study from those customarily used outside an ICU setting and included severe hyperkalemia, metabolic acidosis, progressive azotemia, or fluid overload. Fluid overload appeared more frequently in these patients because of attempts to administer adequate nutrition by parenteral or liquid enteral feedings.

Analysis of Data

The APACHE II data for each patient were entered into an IBM-XT computer and the risk of death calculated. Values for sensitivity, specificity, positive predictive value, and negative predictive value were calculated by standard formulas.[4] Confidence intervals for various percentages were calculated by the following techniques: For percentages between 85% and 100%, calculations were made by Poisson approximations of the binomial distribution. For percentages of less than 85%, calculations were made from a normal approximation of the binomial distribution. When a zero numerator was present (risk of death 70% or greater), an approximation based on the calculation of Hanley and Lippman-Hand was used.[5]

Results

The characteristics of the study patient population are shown in Table 1. The predicted and actual outcomes of patients at varying risk levels of death are recorded in Tables 2 and 3. Levels of the risk of death calculated from the APACHE II scores on the day of admission to the ICU are shown in Table 2, and Table 3 contains calculations based on the date of the initial hemodialysis treatment. The specificity in predicting death increased with the increasing level of risk, reaching 100% for all patients with a 70% or greater predicted risk of death. As specificity increased, however, sensitivity diminished. This pattern was similar whether using APACHE II scores from the ICU admission date or from the date that dialysis was instituted. Both identified a risk level of 70% or greater as showing 100% specificity for death. The 23 patients predicted to die at a 70% risk level using the ICU admission date did die, as did the 35 predicted from the data on the date dialysis was started. The sensitivity at this level was 25.8% and 39.3%, respectively.

In an attempt to increase the overall sensitivity for predicting hospital mortality, a combination of risk levels from information gathered on both the admitting ICU date and the dialysis date was used. The following combinations were evaluated: 70% or greater on the admission date or less than 70% on the admission date with 40% or greater on the initial dialysis date, 70% or greater on the admission date or less than 70% on the admission date with 50% or greater on the dialysis date, and 70% or greater on the admission date or less than 70% on the admission date with 60% or greater on the dialysis date. Although the sensitivities were better—75.3%, 59.6%, and 49.3%, respectively—only the last combination approached 100% specificity.

The possibility that the subgroup of patients already receiving continuous hemodialysis might have different outcomes was also evaluated (Table 4). At a 70% risk level we again showed 100% specificity, but because this subgroup was small, the 95% confidence limits were large and definitive conclusions cannot be made with these data.

Discussion

The APACHE system was developed to enable groups of patients receiving different types of therapies to be compared. The originators emphasized that it was not developed to aid decision making about treating individual patients as proposed in this study. Nonetheless, as Chang and co-workers have previously reported and as shown in this report, the accuracy of predicting death is remarkable.[4] As noted by all who use this classification system, however, it is better at predicting those who will die than those who will live (low sensitivity and low negative predictive value).

Admittedly, by the very nature of our basic objective, a specific subset of the general ICU patient population was selected who may have a higher risk of death because of renal failure. This probably explains why 100% specificity was

TABLE 1.—*Distribution of Patients (N=146) by Various Characteristics*

Characteristic	*Patients, Number*
Male	116
Female	30
Mean age, years (range)	61 (22-83)
Hospital location	
Loma Linda University Medical Center	100
Loma Linda Veterans' Hospital	46
Type of intensive care unit	
Coronary care unit	19
Medical	21
General surgical	18
Cardiothoracic surgical	15
Combined medical and surgical	59
Pulmonary	13
Neurosurgical	1
Clinical condition	
Receiving continuous hemodialysis	24
Postoperative	58
Severe trauma	1
After renal transplant	14
Miscellaneous conditions	49

TABLE 2.—*Actual and Predicted Outcome at Different Risk Levels of Death Using Calculations at ICU Admission Date for Patients Receiving Hemodialysis**

Level of Risk		Patients Predicted To Live	To Die	Total	Sensitivity, %†	Specificity, %†	Predictive Positive Value, %	Predictive Negative Value, %
		Number						
40%					59.5 (28.2, 90.8)	84.2 (76.6, 91.6)	85.5	57.1
	Actually alive ...	48	9	57				
	Actually dead ...	36	53	89				
	Total	84	62	146				
50%					47.2 (36.8, 57.6)	93.0 (82.0, 98.1)	91.3	53.0
	Actually alive ...	53	4	57				
	Actually dead ...	47	42	89				
	Total	100	46	146				
60%					33.7 (23.9, 43.5)	96.5 (87.3, 99.6)	93.8	48.2
	Actually alive ...	55	2	57				
	Actually dead ...	59	30	89				
	Total	114	32	146				
70%					25.8 (16.7, 34.9)	100 (94.7, 100)	100	46.3
	Actually alive ...	57	0	57				
	Actually dead ...	66	23	89				
	Total	123	23	146				
80%					11.2 (4.6, 17.8)	100 (94.7, 100)	100	42.0
	Actually alive ...	57	0	57				
	Actually dead ...	79	10	89				
	Total	136	10	146				

ICU=intensive care unit

*Patients with a risk of death greater or equal to the listed level were predicted to die.
†Values in parentheses represent the 95% confidence interval for each mean percentage.

TABLE 3.—*Actual and Predicted Outcome at Different Levels of Risk Using Calculations on the Date of Initiation of Dialysis**

Level of Risk		Patients Predicted To Live	To Die	Total	Sensitivity, %†	Specificity, %†	Predictive Positive Value, %	Predictive Negative Value, %
		Number						
40%					71.9 (62.6, 81.2)	77.2 (68.5, 85.9)	83.1	63.8
	Actually alive ...	44	13	57				
	Actually dead ...	25	64	89				
	Total	69	77	146				
50%					53.1 (42.7, 63.5)	86.0 (72.4, 93.9)	86.7	57.0
	Actually alive ...	49	8	57				
	Actually dead ...	37	52	89				
	Total	86	60	146				
60%					48.3 (37.9, 58.7)	93.0 (82.0, 98.1)	91.5	53.5
	Actually alive ...	53	4	57				
	Actually dead ...	46	43	89				
	Total	99	47	146				
70%					39.3 (29.2, 49.4)	100 (94.7, 100)	100	51.4
	Actually alive ...	57	0	57				
	Actually dead ...	54	35	89				
	Total	111	35	146				
80%					15.7 (8.1, 23.3)	100 (94.7, 100)	100	43.2
	Actually alive ...	57	0	57				
	Actually dead ...	75	14	89				
	Total	132	14	146				

*Patients with a risk of death greater or equal to the listed level were predicted to die.
†Values in parentheses represent the 95% confidence interval for each mean percentage.

TABLE 4.—*Actual and Predicted Outcome at Different Levels of Risk for Those Patients Already Receiving Continuous Dialysis**

Level of Risk		Patients Predicted To Live (Number)	To Die (Number)	Total (Number)	Sensitivity, %†	Specificity, %†	Predictive Positive Value, %	Predictive Negative Value, %
40%					66.6 (28.9, 100)	94.4 (69.1, 99.9)	80.0	89.5
	Actually alive	17	1	18				
	Actually dead	2	4	6				
	Total	19	5	24				
50%					66.6 (28.9, 100)	94.4 (69.1, 99.9)	80.0	89.5
	Actually alive	17	1	18				
	Actually dead	2	4	6				
	Total	19	5	24				
60%					66.6 (28.9, 100)	94.4 (69.1, 99.9)	80.0	89.5
	Actually alive	17	1	18				
	Actually dead	2	4	6				
	Total	19	5	24				
70%					16.6 (0.0, 46.4)	100 (83.3, 100)	100	78.3
	Actually alive	18	0	18				
	Actually dead	5	1	6				
	Total	23	1	24				

*Patients with a risk of death greater or equal to the listed level were predicted to die.
†Values in parentheses represent the 95% confidence interval for each mean percentage.

seen at a lower level than that in the previous reports.[3,4] Therefore, the absolute accuracy of the APACHE II system as previously determined may not be directly related to our particular patient subset. Nevertheless, we feel these results have revalidated the usefulness of the APACHE II system as a highly specific predictor of mortality in an ICU even in this subset of patients. At a calculated risk level of 70% or greater, death was predicted correctly in all cases. Like the study of Chang and colleagues who used the APACHE II classification to identify ICU cases for which total parenteral nutrition would not provide a benefit, this study showed an improvement in sensitivity in predicting death by using combinations of risk levels on ICU admission and the initial dialysis date. As noted, we were never able to achieve the 100% specificity that was achieved using data from the admitting or dialysis date alone. The usefulness of this type of evaluation depends on its near infallibility; therefore, using combinations of risk levels did not add to its usefulness.

Using an average cost of $750 per hemodialysis treatment, withholding one treatment from the 23 patients correctly predicted to die (Table 2) would have saved about $17,250. Because patients received 1 to 20 or more dialysis treatments, it is obvious that a substantial cost is involved. With 6 as the average number of hemodialysis sessions per patient, about $103,500 would have been saved.

The withholding of therapy from terminally ill patients has received considerable discussion in both the medical and lay literature in recent years. Well-publicized cases such as those of Karen Quinlan, Elizabeth Bouvia, Clarence Herbert, and others have led to an outpouring of both legal and ethical comments on the subject.[6,7] Wanzer and associates attempted to outline a reasonable approach to the level of care that should be given to a hopelessly ill patient.[8] Yet, even in their proposal, no standard of care can be applied to all situations.

The desires of a patient when known, the desires of the family when the patient's wishes are unknown, and the varied experiences of different clinicians must all be considered before making decisions. Yet, as experience grows with a probabilistic system such as APACHE II, physicians can have a strong, objective indicator of patients for whom various forms of acute intervention may serve no useful purpose.[9] In such cases, dialysis becomes extraordinary treatment because it is medically impossible or futile, it provides no benefits in terms of prolonging life or alleviating suffering, or the resulting burdens on the patients are excessive in relation to the benefits gained.[10] It is hoped that this will help physicians practice more humane and, in the end, more cost-effective critical care medicine. A caveat from a *Lancet* editorial, however, should be remembered: "probability is only one factor to be taken into account when making a clinical decision. Statistics should be used as the drunken man uses the lamppost—for support rather than illumination."[11]

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