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# Mortality Predicting Calculators used in ICU

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**ABSTRACT**

Diseases are constantly present, like a persistent companion, and their effects serve as a reminder of their presence. We all have to address medical needs in some way or other. Disease can be classified as general illness, severe or chronic disease. General illness needs normal attention though severe or chronic disease needs much attention because critically ill patients have a potential risk of death. It happens that chronic disease may lead to patient admission in ICU.

The stay of the patient into ICU and likelihood of mortality can be predicted in many ways ranging from manual to automated prediction. Manual prediction requires experienced doctors though if supplied with right parameters, the same can be done by system i.e., application-based procedure.

Predicting the likelihood of mortality has been a cornerstone of medical decision-making for centuries. With advancements in healthcare technology and data science, we can now leverage sophisticated models to predict a patient's likelihood of mortality, length of ICU stay and usage of mechanical ventilator with increased accuracy.

Different Medical calculators like SOFA, SAPS, APACHE, MPM, GCS etc. are in use to predict the likelihood of mortality these days. Their accuracy can be calculated before manually and later automatically and now AI-assisted.

***Keywords:*** *ICU, Predicting Calculators, Mortality.*

## 1. INTRODUCTION

An intensive care unit (ICU) in the hospital are for those patients facing severe illness or injuries. Patients in intensive care unit (ICU) are mostly critically ill, so they need special attention because of presenting high mortality risk compared with other departments in the hospital. Death is the primary clinical outcome while readmission and prolonged length of stay (LOS) are common clinical outcomes that indicates patient's health conditions. So, in most of the cases patients require special attention with

medical equipment such as mechanical ventilation to ensure that the body functions normally and because of this they need to be observed continuously and thoroughly.

For thorough observation Intensive care units (ICUs) depend on scoring systems such as APACHE (Acute physiology and chronic health evaluation) and SAPS (Simplified acute physiology score) to understand patient severity of illness and basically these scoring systems predict the short-term outcomes, including fatality. These continuous evolving tools are designed for mainstream ICU use. Scoring systems have a very important position in ICU for gauging the severity of the disease and

anticipating the likelihood of mortality, Prolonged length of stays etc. These tools like APACHE and SAPS are updated regularly for common ICU use so that they can provide useful observation for patient management.

So, our objective is to identify the principal characteristics that can predict the likelihood of mortality. By using these principal characteristics, we will try to build a simplified and effective scoring system for predicting the likelihood of mortality

**Family of Evaluation Assessment Scoring System Which are Present in ICU While Taking Care of a Patient**

The main prognostic models for assessing the overall severity of illness in critically ill adults are Acute Physiology and Chronic Health Evaluation (APACHE), Sequential organ failure assessment (SOFA), Simplified Acute Physiology Score (SAPS), and Mortality Probability Model (MPM). Simplified Acute Physiology Score and Mortality Probability Model have been updated to their third versions and Acute Physiology and Chronic Health Evaluation to its fourth version as shown in Figure 1.

**Related Work**

William A. Knaus is recognized as the founder of the APACHE (Acute Physiology and Chronic Health Evaluation) system, which he developed in collaboration with Jack E. Zimmerman, Douglas P. Wagner, and Elizabeth A. Draper. APACHE was established in 1978 during Knaus's tenure as an attending physician at George Washington University

Hospital [9]. The APACHE scoring system was developed to address critical needs in managing patients in intensive care units (ICUs). One of its primary objectives was to standardize the assessment of severity, as there was no uniform method to quantify the illness severity of critically ill patients. By incorporating objective physiological data, APACHE provided a systematic approach that ensured consistent evaluations across different healthcare settings [6,9].

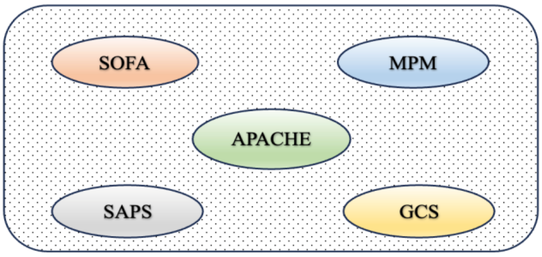


**Figure 1: Family of Evaluation Assessment Scoring System**

Additionally, APACHE played a crucial role in quality assurance and outcome monitoring. By utilizing a scoring system, healthcare providers could track patient outcomes and assess the effectiveness of treatment strategies, leading to improved clinical practices [6,9]. Another significant feature of APACHE was its ability to facilitate risk stratification, allowing clinicians to predict mortality rates and tailor treatment plans accordingly. This ensured that high-risk patients received the appropriate level of care [6]. Moreover, the system supported research and comparative analysis by enabling researchers to evaluate outcomes across different ICUs and studies. Such comparisons were essential for identifying best practices and advancing patient care in critical care environments [6,9]. Lastly, APACHE was designed to integrate clinical knowledge with modern statistical techniques, enhancing its precision and reliability. This combination allowed clinicians to make data-driven decisions rather than relying solely on anecdotal evidence, thereby improving patient outcomes and healthcare efficiency [9].

Acute Physiology Score (APS) [10]

The APS is based on 12 physiological variables assessed within the first 24 hours of ICU admission. These variables include:

Body Temperature: Measures hypothermia or hyperthermia.

Mean Arterial Pressure (MAP): Evaluates blood pressure stability.

Heart Rate: Monitors pulse rate.

Respiratory Rate: Counts breaths per minute.

Oxygenation: Assessed through arterial oxygen tension (PaO2).

Serum Sodium Level: Measures sodium concentration.

Serum Potassium Level: Evaluates potassium concentration.

Creatinine Level: Indicates kidney function, with higher levels contributing more points.

Hematocrit: Measures the proportion of blood volume occupied by red blood cells.

White Blood Cell Count: Assesses immune response.

Glasgow Coma Scale (GCS): Evaluates consciousness level; lower scores indicate more severe impairment.

Blood pH: Assesses acidity or alkalinity.

Age Points

Additional points are assigned based on the patient's age [3,10]:

0 points for ages < 44 years

2 points for ages 45–54 years

3 points for ages 55–64 years

5 points for ages 65–74 years

6 points for ages ≥ 75 years

Chronic Health Status

Points are added based on the patient's chronic health conditions before admission:

Elective postoperative patients with severe organ insufficiency or immunocompromised status receive additional points.

Nonoperative patients or emergency postoperative patients with similar conditions receive even more points.

The total APACHE score is calculated by summing the acute physiology score, age points, and chronic health status points. The overall score can range from 0 to 71, with higher scores indicating greater severity of illness and increased risk of mortality [3,13].

**Why did you develop the APACHE system?**

In the 1970s, when William began developing the APACHE system, Diagnosis-Related Groups (DRGs) were newly introduced and focused on healthcare financing. DRGs classified ICU patients using simple tests like blood lactate levels with fixed thresholds, which were ineffective for continuous measures. Bryan Jennett later developed the Glasgow Coma Scale, which was successful but limited to head injuries and emergencies. The innovation of using ICU patients' physiological data to create a comprehensive severity measure was a breakthrough and was unexpectedly well-received [4,10]. Over time, the APACHE system evolved to incorporate many variables; however, the available technology at the time could not efficiently process large-scale computations. Simple equations used in APACHE would take an entire weekend to compute, leading to strategic discussions on whether to halt and focus solely on updating the database. It became clear that classification systems do not improve over time unless continuously updated with current data. The release of APACHE II demonstrated improvements in critical care outcomes across various areas, highlighting that outdated databases fail to reflect contemporary results [4,10,11].

During this period, technology was advancing rapidly—computers became faster, and there was increasing optimism about the future of data collection and scoring systems. The vision was for computers to be easily accessible for medical consultations, much like how Google's algorithms function today. However, decades after APACHE II's release, progress in healthcare technology, particularly regarding interoperability and modern computing, has been slow. Despite ambitious goals, expected advancements have not been fully realized. While the APACHE system continues to evolve, its latest version, APACHE IV, with an improved algorithm and database, is still not widely adopted compared to APACHE II [4,10]. In hindsight, if the slow development of healthcare technology had been anticipated, a stronger focus on updating the APACHE II database rather than creating newer versions might have been preferred. Although APACHE IV is more sensitive and capable, automatic data integration remains a challenge. Thus, when utilizing APACHE, it is essential to ensure that the database—whether proprietary or external—incorporates contemporary patient data, as the relationship between scores and patient outcomes changes over time. Using the same scoring system is acceptable, but maintaining up-to-date data is critical for accuracy and relevance [4,10].

**Evolution of the APACHE Score Evaluation System**

The Acute Physiology and Chronic Health Evaluation (APACHE) scoring system has evolved significantly since its inception in 1981 to enhance the accuracy of predicting patient mortality in intensive care units (ICUs). The first version, APACHE I, consisted of 34 variables and involved complex calculations for risk assessment. To simplify the process, APACHE II was introduced in 1985 with 12 variables, incorporating the Glasgow Coma Scale (GCS) and chronic health status. Further advancements led to APACHE III (1991), which expanded to 20 variables, adding comorbidities, diagnostic categories, and refined prediction models. Finally, APACHE IV (2006) became the most comprehensive model, integrating physiological, demographic, and hospital-specific data for improved ICU mortality predictions. This evolution, as shown in Figure 2. reflects continuous efforts to enhance clinical decision-making and patient outcome assessments.

**Transition from APACHE I to APACHE II**

The transition from APACHE I (1981) to APACHE II (1985) involved simplifying the model by removing several parameters as shown in Figure 3, while enhancing mortality prediction accuracy. APACHE I originally utilized 34 physiological variables mentioned in Figure 3, making data collection time-consuming and impractical for routine ICU use. Additionally, some variables contributed minimal predictive power, rendering them redundant. To address these issues, APACHE II reduced the number of key physiological variables to 12, selecting those with the most significant impact on patient outcomes. This reduction streamlined the scoring process, making it easier and faster, which encouraged widespread adoption [6,10].

**Transition from APACHE II to APACHE III**

Further refinements were made in the transition from APACHE II (1985) to APACHE III (1991) to enhance accuracy, specificity, and usability in ICU mortality prediction. While APACHE II considered 12 physiological variables as mentioned in Figure 3, it sometimes lacked specificity for certain ICU patients and did not fully differentiate between various ICU admission types, such as medical, surgical, or trauma cases. APACHE III addressed these limitations by expanding the number of physiological parameters for improved prediction. Additionally, it incorporated the patient's admission source (e.g., Emergency Room, Operating Room) to enhance ICU-specific risk assessment, allowing for more detailed patient evaluation and outcome prediction [7,10].

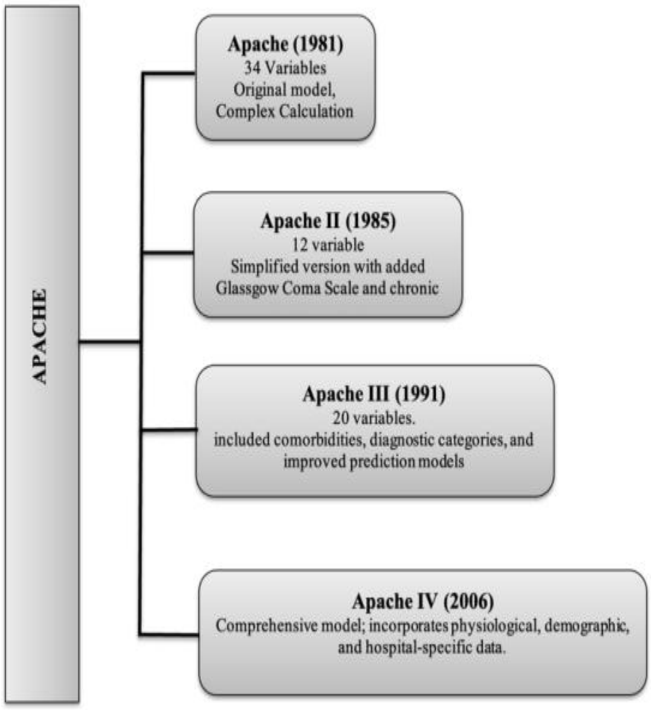


**Figure 2: Apache Version Progression and key features.**

**Transition from APACHE III to APACHE IV**

The transition from APACHE III (1991) to APACHE IV (2006) was necessary to enhance ICU mortality prediction accuracy, adjust for medical advancements, and improve ICU benchmarking. One of the key limitations of APACHE III was its reliance on outdated mortality prediction models from the early 1990s, which did not account for significant advancements in ICU treatments. Additionally, some variables used in APACHE III as mentioned below in Figure 4 became less predictive due to changes in clinical practices. To address these issues, APACHE IV introduced updated statistical models for mortality prediction, utilizing data from over 100,000 ICU patients. These improvements allowed APACHE IV to better adjust for modern ICU treatments, including advanced ventilation strategies and new sepsis protocols, thereby enhancing its predictive accuracy and clinical relevance [8,10].

**APACHE I**

1. Heart rate
2. Respiratory rate
3. Systolic blood pressure
4. Diastolic blood pressure
5. Mean arterial pressure
6. Body temperature
7. Glasgow Coma Scale (GCS) score
8. Oxygenation & Ventilation (4 variables)
9. $PaO_2$ (arterial oxygen partial pressure)
10. $PaCO_2$ (arterial carbon dioxide partial pressure)
11. pH (arterial blood acidity)
12. A-gradient (alveolar-arterial oxygen difference)
13. Sodium ($Na^+$)
14. Potassium ($K^+$)
15. Calcium ($Ca^{2+}$)
16. Magnesium ($Mg^{2+}$)
17. Bicarbonate ($HCO_3^-$)
18. Chloride ($Cl^-$)
19. Blood urea nitrogen (BUN)
20. Creatinine
21. Glucose
22. Hematocrit
23. White blood cell (WBC) count
24. Platelet count
25. Hemoglobin
26. Prothrombin time (PT) / INR
27. Bilirubin (total)
28. Albumin
29. Total protein
30. Lactate
31. Aspartate aminotransferase (AST) / Alanine aminotransferase (ALT)
32. Age
33. Presence of chronic organ failure (cardiac, pulmonary, renal, hepatic)
34. Immunosuppression status

Recent major surgery or trauma

**DIFFERENCE**

**Parameters Removed From APACHE I For APACHE II**

1. Serum Albumin (g/dL)
2. Bilirubin (mg/dL)
3. Urine Output (mL/day)
4. Sepsis Diagnosis (Yes/No)
5. Cardiac Arrest
6. Congestive Heart Failure (CHF)
7. Chronic Obstructive Pulmonary Disease (COPD)
8. Stroke
9. Hepatic Failure
10. Diabetes with Complications
11. Malignancy
12. Immunocompromised Status
13. Post-Operative Complications
14. Multiple Organ Failure
15. Trauma
16. Metabolic Acidosis

**APACHE II**

1. Temperature (°C)
2. Mean Arterial Pressure (MAP) (mmHg)
3. Heart Rate (beats per minute)
4. Respiratory Rate (breaths per minute)
5. Oxygenation ($PaO_2$ or A-a gradient, depending on $FiO_2$ levels)
6. Arterial pH
7. Serum Sodium (mEq/L)
8. Serum Potassium (mEq/L)
9. Serum Creatinine (mg/dL)
10. Hematocrit (%)
11. White Blood Cell (WBC) Count (×10³/mm³)
12. Glasgow Coma Scale (GCS) Score
13. Age in years (assigned points based on age group)
14. Chronic Health Conditions (e.g., severe organ system failure, immunosuppression)

Additional Factors

1. Type of Admission (Elective/Emergency)
2. Mechanical Ventilation Status
3. Simplified Glasgow Coma Scale (GCS Calculation in weighted form)

**Figure 3: Parameters of Apache I and Apache II**

**APACHE III**

1. Temperature (°C), 2. Mean Arterial Pressure (MAP) (mmHg), 3. Heart Rate (beats per minute), 4. Respiratory Rate (breaths per minute), 5. Oxygenation ($PaO_2$ or A-a gradient), 6. Arterial pH, 7. Serum Sodium (mEq/L), 8. Serum Potassium (mEq/L), 9. Serum Creatinine (mg/dL), 10. Blood Urea Nitrogen (BUN) (mg/dL), 11. Hematocrit (%), 12. White Blood Cell (WBC) Count (×10³/mm³), 13. Glasgow Coma Scale (GCS) Score, 14. Serum Albumin (g/dL), 15. Bilirubin (mg/dL), 16. $PaCO_2$ (arterial carbon dioxide) (mmHg), 17. Urine Output (mL/day), 18. Lactate (mmol/L), 19. Chronic Health Conditions, 20. Age (years), 21. Type of Admission (elective or emergency), 22. Mechanical Ventilation Status

**APACHE IV**

Acute Physiology Score (APS) Variables (17):

1. Temperature (°C), 2. Mean Arterial Pressure (MAP) (mmHg), 3. Heart Rate (beats per minute), 4. Respiratory Rate (breaths per minute), 5. $PaO_2$, 6. A-a Gradient, 7. Arterial pH, 8. Serum Sodium (mEq/L), 9. Serum Potassium (mEq/L), 10. Serum Creatinine (mg/dL), 11. Blood Urea Nitrogen (BUN) (mg/dL), 12. Hematocrit (%), 13. White Blood Cell (WBC) Count (×10³/mm³), 14. Glasgow Coma Scale (GCS) Score, 15. Serum Albumin (g/dL), 16. Bilirubin (mg/dL), 17. $PaCO_2$ (mmHg)

Chronic Health Conditions (4):

18. Severe Chronic Organ Failure (Cardiac, Pulmonary, Renal, Hepatic), 19. Immunosuppression Status, 20. Recent Major Surgery or Trauma, 21. History of Severe Sepsis or Septic Shock

ICU Admission Details (4):

22. Type of Admission, 23. Source of Admission, 24. Time in Hospital Before ICU Admission, 25. Primary ICU Admission Diagnosis

Mechanical Ventilation and Oxygen Support (3):

26. Need for Mechanical Ventilation, 27. Use of Non-Invasive Ventilation (NIV), 28. Duration of Mechanical Ventilation Before ICU Admission

Laboratory and Biochemical Parameters (8):

29. Serum Lactate (mmol/L), 30. C-reactive Protein (CRP) (mg/L), 31. Procalcitonin (ng/mL), 32. INR, 33. Prothrombin Time (PT), 34. Activated Partial Thromboplastin Time (aPTT), 35. Fibrinogen (g/L), 36. Platelet Count (×10³/mm³)

Organ Dysfunction Variables (6):

37. Acute Kidney Injury (AKI), 38. Liver Dysfunction Markers, 39. Need for Renal Replacement Therapy (Dialysis), 40. Acute Respiratory Distress Syndrome (ARDS), 41. Cardiac Arrest Before ICU, 42. Multi-Organ Failure

Age and Demographics (2):

43. Age (years), 44. Gender

ICU Procedures and Treatments (6):

45. Use of Vasopressors, 46. Need for ECMO, 47. Use of Neuromuscular Blockers, 48. Total Parenteral Nutrition (TPN), 49. Blood Transfusion Requirement, 50. Need for Invasive Monitoring

ICU Performance and Outcomes (5):

51. Length of ICU Stay, 52. Length of Hospital Stay, 53. ICU Discharge Status, 54. Hospital Discharge Status, 55. ICU Readmission Within 72 Hours

ICU Admission Diagnoses (Examples from 115 categories):

56. Acute Myocardial Infarction (AMI), 57. Sepsis and Septic Shock, 58. Stroke, 59. Traumatic Brain Injury (TBI), 60. Gastrointestinal Bleeding, 61. Acute Pancreatitis, 62. Pneumonia / ARDS, 63. Drug Overdose / Poisoning, 64. Acute Kidney Injury (AKI), 65. Postoperative Complications

**Figure 4: Parameters of Apache III and Apache IV**

## 2. APACHE SCORE CALCULATION [6,8,10]

Apache II Score = [APS (12 physiological parameter) + AGE POINTS + CHRONIC HEALTH POINT]

This is taken in Initial 24 hours of the patient admission

Temperature

In this we Measures hypothermia or hyperthermia 0 being the normal score and +4 being the highest and risky score of a patient in both the cases either it is increasing or decreasing as mentioned below in Table 1.

**Table 1: Apache II Score on The Basis of Temperature**

| POINTS: | +4 | +3 | +1 | 0 | +1 | +2 | +3 | +4 |
|---|---|---|---|---|---|---|---|---|
| TEMP: | >41 | 39-40.9 | 38.5-38.9 | 36-38.4 | 34-35.9 | 32-33.9 | 30-31.9 | <29.9 |

Mean Arterial Pressure (mm Hg)

In this we Evaluates blood pressure stability of a patient. 0 being the normal score and +4 being the highest and risky score of a patient in both the cases either it is increasing or decreasing as mentioned below in Table 2.

**Table 2: Apache II Score on The Basis of MAP**

| POINTS: | +4 | +3 | +2 | 0 | +2 | +3 | +4 |
|---|---|---|---|---|---|---|---|
| MAP: | >160 | 130-159 | 110-129 | 70-109 | 50-69 | 30-31.9 | <49 |

**Heart Rate**

In this we Monitors pulse rate of a patient. 0 being the normal score and +4 being the highest and risky score of a patient in both the cases either it is increasing or decreasing as mentioned below in Table 3

**Table 3: Apache-2 Score on The Basis of Heart Rate**

| POINTS: | +4 | +3 | +2 | 0 | +2 | +3 | +4 |
|---|---|---|---|---|---|---|---|
| HEART RATE: | >180 | 190-179 | 110-139 | 70-109 | 55-69 | 40-54 | <39 |

**Respiratory Rate**

In this we count breaths per minute a patient. 0 being the normal score and +4 being the highest and risky score of a patient in both the cases either it is increasing or decreasing as mentioned below in Table 4.

**Table 4: Apache II Score on The Basis of Respiratory Rate**

| POINTS: | +4 | +3 | +1 | 0 | +1 | +2 | +4 |
|---|---|---|---|---|---|---|---|
| RESPIRATORY RATE: | >50 | 35-49 | 25-34 | 10-24 | 10-11 | 6-9 | <5 |

Oxygenation if FIO2 > 50% then A-ADO2 / PIO2 < 50PAO2

In this we Assessed through arterial oxygen tension (PaO2). 0 being the normal score and +4 being the highest and risky score of a patient in both the cases either it is increasing or decreasing as mentioned below in Table 5.

**Table 5: Apache II Score on The Basis of Oxygenation**

| POINTS: | +4 | +3 | +2 | 0 | +1 | +3 | +4 |
|---|---|---|---|---|---|---|---|
| OXYGENATION: | >500 | 350-499 | 200-349 | 400-70 | 61-70 | 55-60 | <55 |

To Calculate the AaDO2: AaDO2 ((FIO2 * 713) - PaO2) - PaCO2

**Arterial PH**

Measure of the acidity of the blood in the arteries. 0 being the normal score and +4 being the highest and risky score of a patient in both the cases either it is increasing or decreasing as mentioned below in Table 6.

**Table 6: Apache II Score on The Basis of Arterial PH**

| POINTS: | +4 | +3 | +1 | 0 | +2 | +3 | +4 |
|---|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ARTERIAL PH: | >7.7 | 7.6-7.69 | 7.5-7.59 | 7.33-7.49 | 7.25-7.32 | 7.15-7.24 | <7.15 |

**Bicarbonate in Venous Blood**

Measure of the amount of the bicarbonate in the blood. 0 being the normal score and +4 being the highest and risky score of a patient in both the cases either it is increasing or decreasing as mentioned below in Table 7.

**Table 7: Apache II Score on The Basis of Bicarbonate in Venous Blood**

| POINTS: | +4 | +3 | +1 | 0 | +2 | +3 | +4 |
|---|---|---|---|---|---|---|---|
| BVB: | > 52 | 41-51.9 | 32-40.9 | 22-31.9 | 18-21.9 | 15-17.9 | < 15 |

If ABG is not available we can send venous blood

Potassium (MEQ / L)

Potassium levels are measured in millie equivalents per liter (mEq/L). A normal potassium level for adults is between 3.5 and 5.2 mEq/L. Low-level termed as hypokalemia and high-level potassium termed as hyperkalemia. 0 being the normal score and +4 being the highest and risky score of a patient in both the cases either it is increasing or decreasing as mentioned below in Table 8.

**Table 8: Apache II Score on The Basis of Potassium**

| POINTS: | +4 | +3 | +1 | 0 | +1 | +2 | +4 |
|---|---|---|---|---|---|---|---|
| POTASSIUM: | >7 | 6-6.9 | 5.5-5.9 | 3.5-5.4 | 3-3.4 | 2.5-2.9 | <2.5 |

Sodium (MEQ / L)

Sodium levels are measured in milliequivalents per liter (mEq/L). A level below 135 mEq/L is called hyponatremia. 0 being the normal score and +4 being the highest and risky score of a patient in both the cases either it is increasing or decreasing as mentioned below in Table 9.

**Table 9: Apache II Score on The Basis of Sodium**

| POINTS: | +4 | +3 | +2 | +1 | 0 | +2 | +3 | +4 |
|---|---|---|---|---|---|---|---|---|
| SODIUM: | >180 | 160-170 | 155-159 | 150-154 | 130-149 | 120-129 | 111-119 | <110 |

Serum Creatinine (MG / DL)

In this Indicates kidney function, with higher levels contributing more points. 0 being the normal score and +4 being the highest and risky score of a patient in both the cases either it is increasing or decreasing as mentioned below in Table 10.

**Table 10: Apache II Score on The Basis of Serum Creatinine**

| POINTS: | +4 | +3 | +2 | 0 | +2 |
|---|---|---|---|---|---|
| SERUM CREATININE: | >3.5 | 2-3.4 | 1.5-1.9 | 0.6-1.4 | <0.6 |

Hematocrit (%)

In this we measure the proportion of blood volume occupied by red blood cells. 0 being the normal score and +4 being the highest and risky score of a patient in both the cases either it is increasing or decreasing as mentioned below in Table 11.

**Table 11: Apache II Score on The Basis of Hematocrit**

| POINTS: | +4 | +3 | +2 | +1 | 0 | +2 | +4 |
|---|---|---|---|---|---|---|---|
| Hematocrit (%): | >60 | 59.1-59.9 | 50-59 | 46-49.9 | 30-45.9 | 20-29.9 | <20 |

TLC (IN 1000)

(TOTAL LEUKOCYTE COUNT)

GCS (Glasgow Coma Scale):

It is a neurological scale designed to assess a patient's level of consciousness following a traumatic brain injury or other condition affecting the brain.

The GCS is a score based on three components:

Eye Opening €

Verbal Response (V)

Motor Response(M)

The total GCS score is the sum of these three components.

Ranging from 3(Deep unconsciousness) to 15 (fully alert person) as mentioned below in Table 12.

In this we Evaluates consciousness level; lower scores indicate more severe impairment.

**Table 12: Apache-2 Score on The Basis of GCS**

| GCS SCORE | SEVERITY INDICATOR |
|---|---|
| 15 | 0 |
| 14 | 1 |
| 13 | 2 |
| 12 | 3 |
| 11 | 4 |
| 10 | 5 |
| 9 | 6 |
| 8 | 7 |
| 7 | 8 |
| 6 | 9 |
| 5 | 10 |
| 4 | 11 |
| 3 | 12 |

**3. AGE CHRONIC HEALTH POINTS:**

2 Points if an elective postoperative patient with immunocompromised or a history of severe organ insufficiency as mentioned below in Table 13.

5 Points for non-operative patient emergency postoperative patients with immunocompromised or severe organ insufficiency as mentioned below in Table 13.

**Table 13: Apache-2 Score on The Basis of Age**

| POINTS: | 0 | 2 | 3 | 5 | 6 |
|---|---|---|---|---|---|
| AGE: | <44 | 45-54 | 55-64 | 65-74 | >75 |

**Mortality Prediction:**

If the overall score of a patient is according to the range given in the table 14 then the chances of mortality in percentage written in percentage respectively.

**Table 14: Apache-2 Score on The Basis of Mortality Prediction**

| SCORE RANGE | MORTALITY PERCENTAGE (%) |
|---|---|
| 0-4 | 4% |
| 5-9 | 8% |
| 10-14 | 15% |
| 15-19 | 25% |
| 20-24 | 40% |
| 25-29 | 55% |
| 30-24 | 75% |
| >34 | 85% |

**Patient 1 Input Parameters in APACHE Scoring System**

The APACHE (Acute Physiology and Chronic Health Evaluation) scoring system utilizes multiple physiological parameters to assess the severity of a patient's illness and predict ICU mortality. As shown in Figure 5: Patient with Different Input Parameters of APACHE Scoring System, key variables such as temperature (38.2°C), heart rate (110 bpm), respiratory rate (22 breaths/min), mean arterial pressure (85 mmHg), oxygenation level (250 mmHg), and Glasgow Coma Scale (GCS = 14) are used in the calculation. Additionally, serum potassium (4.2 mEq/L), serum sodium (140 mEq/L), hematocrit (42%), and serum creatinine (1.2 mg/dL) play a crucial role in evaluating organ function and overall patient status. These input parameters help clinicians determine the severity of illness and guide critical care decisions.

Patient with different input parameters of APACHE scoring system

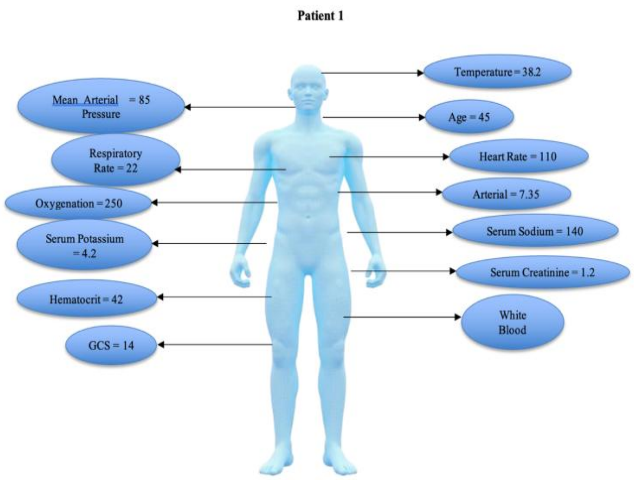


**Figure 5: Patient-1 Stats of 45 year old male with pneumonia and chronic heart disease**

Total APACHE score is 9, predicted Low ICU mortality risk (~5-10%)

**Patient 2 Parameters in APACHE Scoring System**

The APACHE (Acute Physiology and Chronic Health Evaluation) scoring system considers multiple physiological factors to assess the severity of illness in critically ill patients. As illustrated in Figure: 6 Patient with Different Input Parameters of APACHE Scoring System, the patient's vital signs include temperature (36°C), heart rate (130 bpm), respiratory rate (30 breaths/min), and mean arterial pressure

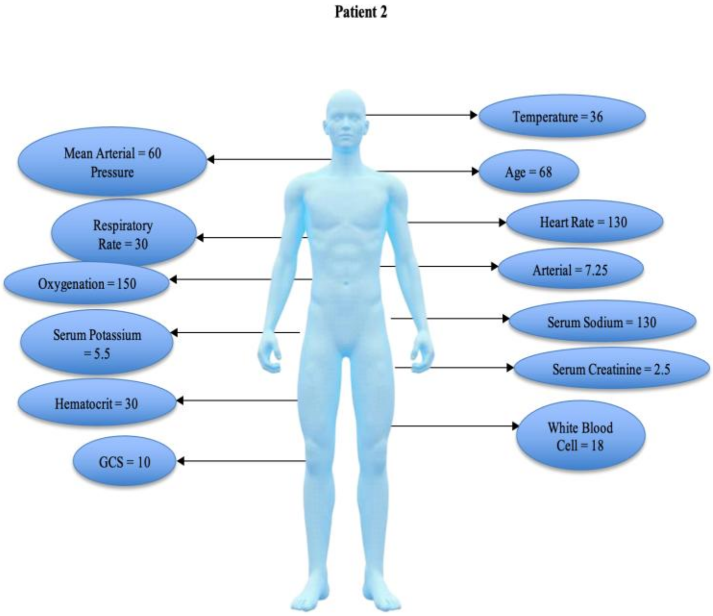


**Figure 6: Patient-2 (A 68 year old patient with sepsis and no chronic health condition)**

Total APACHE score is 50, Very high ICU mortality risk (>80%)

(60 mmHg). Additionally, blood chemistry parameters such as serum potassium (5.5 mEq/L), serum sodium (130 mEq/L), serum creatinine (2.5 mg/dL), and hematocrit (30%) play a role in determining organ function. The Glasgow Coma Scale (GCS = 10) and oxygenation level (150 mmHg) further contribute to assessing neurological status and respiratory function. These parameters collectively aid in determining the severity of illness and guiding ICU management.

**Table 15: Apache-2 Score of Patient-1 And Patient-2**

| | PATIENT 1 | | PATIENT 2 | |
|---|---|---|---|---|
| CONDITION: | A 45-year-old male with pneumonia and chronic heart disease | | A 68-year-old male with sepsis and no chronic health conditions | |
| PARAMETERS | | | | |
| Parameters | Value (Patient one) | APACHE-2 POINT | Value (Patient two) | APACHE-2 POINT |
| Age: | 45 | 3 | 68 | 9 |
| Temperature: | 38.2 | 0 | 36.0 | 1 |
| Mean Arterial Pressure: | 85 | 0 | 60 | 10 |
| Heart Rate (bpm): | 110 | 2 | 130 | 5 |
| Respiratory Rate (bpm): | 22 | 1 | 30 | 4 |
| Oxygenation: | 250 | 2 | 150 | 5 |
| Arterial PH: | 7.35 | 0 | 7.25 | 3 |

| | | | | |
|---|---|---|---|---|
| Serum Sodium (mEq/L): | 140 | 0 | 130 | 2 |
| Serum Creatinine (mg/dL): | 1.2 | 0 | 2.5 | 4 |
| Hematocrit (%): | 42 | 0 | 30 | 2 |
| White Blood Cell Count: | 12 | 1 | 18 | 2 |
| Glasgow Coma Scale (GCS): | 14 | 1 | 10 | 6 |
| Total APACHE II Score: | Low Risk | 9 | Very High Risk | 50 |

**Overview**

Patient-1, with an APACHE II score of 9, is at low risk with a favorable prognosis. Patient-2, with a score of 50, is at very high risk due to advanced age, severe physiological disturbances, and sepsis. Immediate intensive care is required for Patient-2. The APACHE II scoring system accurately differentiates patient severity an assists in clinical decision-making.

How APACHE IV Calculates Mortality Risk

APACHE IV (2006) is the most advanced version of the APACHE scoring system, using 142 variables to provide the most accurate ICU mortality predictions. It uses a logistic regression model that incorporates multiple patient factors.

Steps in APACHE IV Mortality Calculation[12]:

Acute Physiology Score (APS) Calculation

17 key physiological variables are assessed within the first 24 hours of ICU admission.

Each variable is assigned a weighted score based on how much it deviates from normal values.

Example variables:

Heart Rate

Respiratory Rate

Blood Pressure

Glasgow Coma Scale (GCS)

Serum Sodium, Potassium, Creatinine

Arterial pH, $PaO_2$, $PaCO_2$

Higher deviations = Higher APS Score (worse condition).

Chronic Health Condition Adjustment

APACHE IV considers whether the patient has a severe chronic illness (e.g., liver failure, COPD, immunosuppression).

Patients with pre-existing chronic diseases receive additional risk points.

ICU Admission Diagnosis (115 Categories)

APACHE IV includes 115 different ICU admission diagnoses, each with its own mortality risk weight.

Examples:

Acute Myocardial Infarction (AMI)

Sepsis or Septic Shock

Pneumonia or Acute Respiratory Distress Syndrome (ARDS)

Acute Kidney Injury (AKI)

More severe conditions = Higher base mortality risk.

Time Before ICU Admission & Length of Stay Before ICU

Unlike APACHE III, APACHE IV considers how long a patient was in the hospital before ICU admission.

If a patient was in the hospital for several days before ICU transfer, their risk increases.

**Mechanical Ventilation Status**

If a patient requires mechanical ventilation, their mortality risk is significantly higher.

The impact of ventilation is adjusted based on the patient's other conditions.

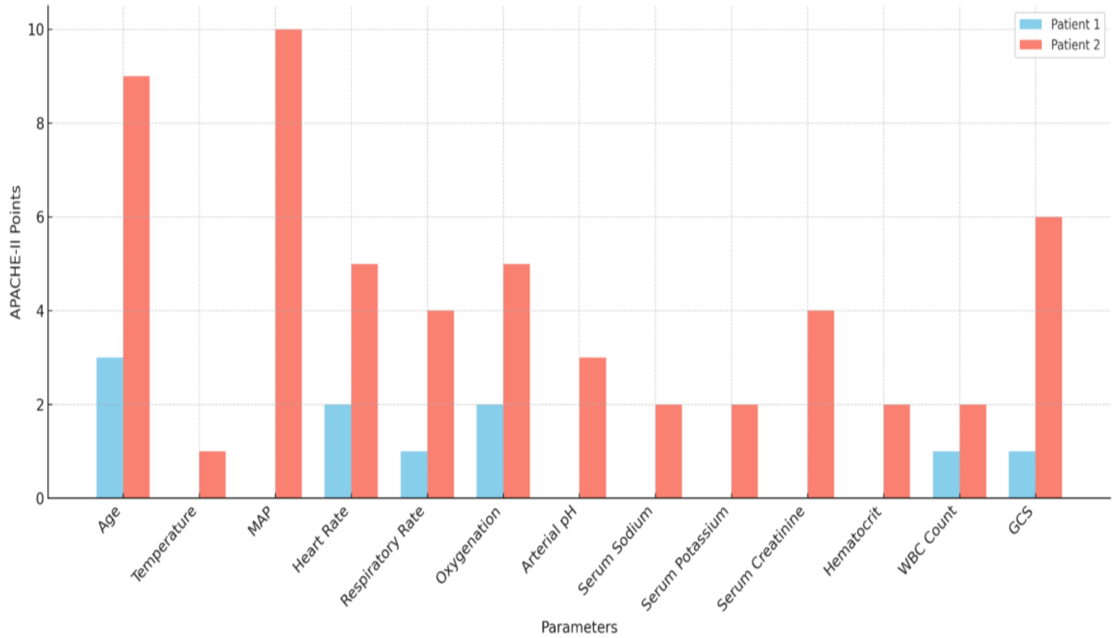


**Figure 7: Apache-2 Score of Patient-1 And Patient-2.**

Final APACHE IV Mortality Calculation (Logistic Regression Model) as mentioned below in Figure 8.

Once all factors are collected, a logistic regression formula is used:

$$\text{Mortality Probability} = \frac{e^{(b_0+b_1X_1+b_2X_2+\ldots+b_nX_n)}}{1+e^{(b_0+b_1X_1+b_2X_2+\ldots+b_nX_n)}}$$

**Figure 8: Formula of Mortality Probability**

Where:

X1,X2,...XnX_1, X_2, ... X_nX1,X2,...Xn = Patient-specific factors (APS score, chronic disease, ICU admission reason, etc.)

b0,b1,b2,...bnb_0, b_1, b_2, ... b_nb0,b1,b2,...bn = Predefined coefficients from APACHE IV research.

The output is the predicted probability of in-hospital mortality (% chance of death).

The output is the predicted probability of in-hospital mortality (% chance of death) as mentioned below in Table 16.

**Table 16: APACHE IV Mortality Score Calculation**

| Variable | Patient Value | Score Contribution |
|---|---|---|
| Age | 70 years | +5 points |
| Heart Rate | 120 bpm | +4 points |
| Mean Arterial Pressure | 60 mmHg | 6 points |

| | | |
|---|---|---|
| Glasgow Coma Scale (GCS) | 10 | +10 points |
| Serum Creatinine | 2.5 mg/dL | +7 points |
| Mechanical Ventilation | Yes | +8 points |
| Primary ICU Diagnosis | Septic Shock | High Risk |
| Total Score (APS + Adjustments) | 87 | |
| Mortality Risk (%) | 52% | (Based On APACHE IV Formula) |

**Table 17: Literature Review**

| S.No. | Author/Publication/Year | Research Aim | Methodology | Significant Finding | Limitation or Recommendation |
|---|---|---|---|---|---|
| 1 | W. A. Knaus, Archives of Surgery, 2002 | Discuss the development of the APACHE system from 1978 to 2001 | Review of system evolution and application | APACHE impacted ICU care quality and outcome prediction | Retrospective review; lacks new empirical data |
| 2 | Wong & Knaus, Can J Anaesth, 1991 | Evaluate APACHE system accuracy in outcome prediction | Comparative review with other ICU systems | APACHE II was reliable for ICU mortality prediction | Recommends ongoing updates and validation |
| 3 | Rapsang & Shyam, IJCCM, 2014 | Summarize ICU scoring systems including APACHE | Narrative review and compendium | Strengths and weaknesses of ICU scores outlined | Contextual use based on local ICU settings advised |
| 4 | W. Knaus, MDCalc, accessed 2023 | Provide an online APACHE II calculator | Web-based implementation from algorithm | Enables standardized bedside score calculations | Manual input required; not real-time |
| 5 | Dimensions of Critical Care Nursing, 1986 | Introduce APACHE II to nursing professionals | Educational summary article | Raised awareness of APACHE II in nursing community | Lacks technical and validation data |
| 6 | Knaus et al., Crit Care Med, 1985 | Present the APACHE II scoring system | Empirical multicenter study | Established APACHE II as a validated model | Needs further population validation |
| 7 | Knaus et al., Chest, 1991 | Introduce and validate APACHE III | Development using large ICU dataset | Improved predictive accuracy over APACHE II | Complex and proprietary system |
| 8 | Zimmerman et al., Crit Care Med, 2006 | Develop the APACHE IV model | Multicenter dataset with updated regression modeling | Enhanced predictive performance over APACHE III | Needs regular updates; hospital-specific performance varies |

| | | | | | |
|---|---|---|---|---|---|
| 9 | Knaus et al., Crit Care Med, 1981 | Introduce original APACHE system | Developed from physiological ICU data | First model using physiological variables for ICU classification | Limited by available data and technology of the time |
| 10 | Knaus et al., Chest, 1991 (Duplicate Listing) | Discuss APACHE III system development | Empirical study with extensive data | Confirmed robust hospital mortality prediction | Duplicated in citation; reflects importance but may confuse citation tracking |
| 11 | Wang Z et al., Heart Lung, 2023 | Develop an explainable ML model to predict mechanical ventilation duration in ARDS patients | Machine learning with SHAP explainability on ICU dataset | ML model accurately predicted ventilation duration with interpretability | Requires external validation; limited to ARDS cases |
| 12 | Aczon MD et al., Pediatr Crit Care Med, 2021 | Continuous mortality prediction in PICU using RNN | Recurrent neural network on pediatric ICU dataset | Continuous model outperformed traditional static models | Single-center data limits generalizability |
| 13 | Kim JH et al., J Clin Med, 2021 | Predict 30-day mortality in mechanically ventilated patients using ML | Comparative analysis of ML algorithms (RF, SVM, XGBoost) | XGBoost achieved highest predictive accuracy | Small dataset; lacked prospective validation |

## 4. FUTURE SCOPE

The future of the APACHE scoring system lies in integrating AI and machine learning to improve predictive accuracy and automate real-time data collection. IoT-enabled ICU devices can further streamline patient monitoring by feeding live physiological data into the system, reducing manual errors and improving decision-making. The integration with electronic health records (EHRs) will enable automated scoring and remote access for healthcare professionals. Additionally, expanding APACHE to emergency rooms and general wards can help in the early identification of high-risk patients. Future versions, such as APACHE V, may incorporate genetic markers and AI-driven risk assessments to further refine predictions and improve patient outcomes.

## 5. CONCLUSION

The APACHE scoring system has revolutionized critical care by providing a standardized method for assessing the severity of illness and predicting patient outcomes in ICUs. Over the years, its evolution has led to improved accuracy in mortality prediction, aiding healthcare professionals in making informed decisions. By integrating physiological parameters, chronic health conditions, and demographic factors, APACHE helps optimize treatment plans, resource allocation, and patient monitoring. With advancements in AI, automation, and real-time data integration, its predictive capabilities will continue to improve, ensuring more precise risk assessment. As technology progresses, APACHE will remain a crucial tool in ICU management, adapting to new medical innovations and enhancing overall patient care

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