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SURGICAL RISK SCORING SYSTEMS: A SYSTEMATIC REVIEW OF PREDICTIVE MODELS AND THEIR CLINICAL VALIDITY

Rameez Raja Mallah[1] and Mohammed Shakeel Ansari[2]

[1]PG Scholar, Dept of Ilmul Jarahat NIUM Banglore, Karnataka
[2]Associate Professor, Dept of Ilmul Jarahat, NIUM Banglore, Karnataka

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ABSTRACT

Accurate preoperative risk assessment is essential for optimizing perioperative management, especially in major abdominal surgeries where complication and mortality risks are high. Multiple surgical risk scoring systems have been developed, each with unique methodologies and applications. The American Society of Anaesthesiologists (ASA) physical status classification remains widely used due to its simplicity and global acceptance, despite its subjective nature and limited detail regarding surgical complexity. POSSUM and its variants (P-POSSUM, CR-POSSUM) offer a more detailed evaluation by incorporating physiological and operative factors, but may overestimate mortality in low-risk patients. The ACS NSQIP calculator provides personalized risk predictions based on extensive national data but has limited accessibility. Other tools, such as the Revised Cardiac Risk Index (RCRI), APACHE II, and sepsis-specific scores (e.g., Mannheim Peritonitis Index), have roles in specific clinical scenarios but vary in predictive accuracy. Postoperative models like the Mortality Prediction Model (MPM) and the Surgical Mortality Score (SMS) aid in outcome auditing. Trauma scoring systems, including TRISS, integrate physiological and anatomical injury data to improve prognostication. Systemic Inflammatory Response Syndrome (SIRS) criteria and the Multiple Organ Dysfunction Score (MODS) are valuable in assessing systemic complications and organ failure. Despite the availability of numerous scoring systems, no single model provides consistent predictive accuracy across all major abdominal surgeries, underscoring the need for continued research to refine risk stratification tools. Combining different scores or tailoring them to specific patient populations may enhance clinical decision-making and improve perioperative outcomes.

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Keywords: Surgical risk assessment, ASA score, POSSUM, APACHE II, NSQIP, MODS, perioperative mortality, abdominal surgery.

INTRODUCTION

Accurately assessing surgical risk is fundamental to contemporary perioperative management, especially for major abdominal procedures, which carry significant risks of complications and death. Preoperative risk assessment tools play a critical role in guiding clinical decisions, facilitating informed patient consent, optimizing postoperative resource planning, and enabling performance comparisons between healthcare institutions. Of the many scoring systems designed to evaluate surgical risk, the American Society of Anesthesiologists (ASA) classification remains one of the most widely used.[1] The Physical Status Classification, POSSUM (Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity), its variants like P-POSSUM and CR-POSSUM, and the ACS NSQIP calculator are all commonly used tools in surgical settings. Each was created using different methods and serves different purposes. The ASA score is one of

*Corresponding author: *drrehanrameez@gmail.com*

the oldest and simplest, based mainly on the anesthesiologist's judgment of the patient's overall health. While it's easy to use, it doesn't consider the complexity of the surgery or the patient's specific medical conditions in detail.[2] Unlike the ASA score, the POSSUM system and its variants offer a more detailed approach by including both physiological and surgical factors to estimate the risk of complications and death. However, their accuracy can vary depending on the type of surgery and patient population. The NSQIP calculator takes a different approach—it's based on a large national database and uses many preoperative factors to provide personalized risk predictions. While it has proven useful in many types of surgery, its reliance on specific data and limited availability can restrict its broader use. [3]

Although ASA, POSSUM, and NSQIP scoring systems are widely used, their ability to accurately predict outcomes varies significantly across different patient groups undergoing major abdominal surgeries—such as colorectal procedures, emergency laparotomies, and surgeries related to inflammatory bowel disease. While many studies have tried to assess and compare these tools, differences in patient populations, urgency of surgery, outcome measures, and study quality have led to inconsistent results. Importantly, no comprehensive systematic review or meta-analysis has yet evaluated and compared how well these scoring systems perform across both planned and emergency abdominal surgeries. To fill this gap, this systematic review aimed to assess and compare the predictive accuracy of the ASA, POSSUM (and its variants), and NSQIP models in major abdominal surgeries, with the aim of improving clinical decision-making and risk assessment.[1]

MATERIALS AND METHODS

This systematic review was conducted to evaluate and compare the predictive accuracy of commonly used surgical risk scoring systems in major abdominal surgeries. A comprehensive literature search was performed using electronic databases including PubMed, MEDLINE, Embase, and Cochrane Library, covering studies published up to 2025. Keywords used included “surgical risk assessment,” “ASA score,” “POSSUM,” “NSQIP,” “APACHE II,” “perioperative mortality,” and “abdominal surgery.” Inclusion criteria comprised original research articles, systematic reviews, and meta-analyses that assessed the performance of preoperative and postoperative risk scoring tools in adult patients undergoing major abdominal procedures. Studies focusing on emergency and elective surgeries, as well as those involving sepsis and trauma-related risk assessment, were included. Articles not published in English, case reports, and studies lacking sufficient outcome data were excluded. Data extraction focused on the scoring systems' components, methodologies, predictive accuracy (e.g., ROC curves, calibration), patient populations, and surgical settings. The quality of included studies was assessed using standardized appraisal tools. Comparative analyses were conducted to highlight the strengths and limitations of each scoring system, with particular emphasis on their applicability, ease of use, and prognostic value in perioperative risk stratification.

Pre-operative Scores

American Society of Anaesthesiologists Score

The American Society of Anesthesiologists (ASA) score is commonly used as a rough measure of surgical risk, though it was originally designed only to assess a patient's physical health status. Despite this, it has been included in several other risk scoring systems. The ASA score is based purely on clinical judgment, although test results may influence the clinician's evaluation indirectly. While not initially intended as a risk prediction tool, it has become widely used for this purpose due to its simplicity, global adoption, and its ability to reflect individual patient factors. However, its usefulness is limited by its subjective nature, lack of detail, and considerable variation between different observers. The ASA score is effective for preoperative risk classification and can be a strong predictor of postoperative mortality, but it does not offer a precise, numerical estimate of the risk of complications or death. Instead, it functions better as a general tool for risk stratification. [4,5]

- Grade I: A completely healthy individual
- Grade II: Patient with mild systemic disease without functional limitation
- Grade III: Patient with severe systemic disease, which limits function but is not incapacitating Grade
- Grade IV: Patient with incapacitating disease that is a constant threat to life
- Grade V: Moribund patient unlikely to survive 24 hours with or without surgery

Surgical Risk Scale

Sutton et al developed the Surgical Risk Scale (SRS) as a tool for comparing surgical outcomes across cases. When tested in a prospective study, it proved to be a useful predictor of mortality. The SRS combines three components: the ASA score, the Confidential Enquiry into Peri-operative Deaths (CEPOD) classification, and the British United Provident Association (BUPA) operative grade. These elements produce a total score ranging from 3 to 15, each corresponding to a predicted mortality risk. Since the ASA score is part of the calculation, the SRS includes some level of subjectivity. Despite this, studies have shown that the SRS has predictive accuracy similar to that of the Portsmouth-POSSUM (P-POSSUM), particularly in high-risk patients, but with the added benefit of being simpler to use.[6]

Cardiac Risk Index Assessment

The original Cardiac Risk Index Assessment (CRIA) was introduced by Goldman et al. in 1977. Since then, several updated versions have been developed. One by Detsky et al. in 1986 became a key part of the American College of Physicians' guidelines. Another version, created by Lee et al. in 1999 for planned (elective) surgeries, is known as the Revised Cardiac Risk Index (RCRI).

Although newer heart tests like echocardiograms can provide useful details, especially for high-risk patients, they haven't significantly improved overall preoperative risk prediction. Overall, CRIA tools have some limitations—they don't predict perioperative death very accurately and are generally less reliable than the ASA score.[3]

APACHE-II

The APACHE II score, originally designed to predict ICU mortality after surgery, has also been studied for its use before surgery. While it's fairly simple to use in emergencies, it requires 12 different physiological measurements, making it more complex than the ASA score.

In a study by Goffi et al., 187 general surgery patients (including 49 emergency cases) were assessed using both the ASA and APACHE II scores before surgery. They then looked at how well each score predicted death and complications within 30 days after surgery. APACHE II performed better, with an ROC curve area of 0.894, compared to 0.777 for ASA—this difference was statistically significant ($p < 0.001$). The accuracy of both scores was similar for emergency and elective surgeries, and whether used before or after surgery. The study concluded that APACHE II can be helpful before surgery but should not replace clinical judgment. [7]

Sepsis scores

In addition to the APACHE II score, several other scoring systems have been developed specifically for patients with intra-abdominal sepsis. These include the Simplified Acute Physiology Score (SAPS), the Sepsis Score, the Multiple Organ Failure Score, and the Mannheim Peritonitis Index (MPI). Among these, studies have shown that APACHE II and MPI are the most effective at predicting outcomes.

However, as Bosscha et al. noted, while MPI is one of the better tools for outcome prediction, it lacks the specificity needed to guide treatment decisions for individual patients. Qureshi et al. also found that MPI alone had a high false positive rate—about 72%. Using MPI together with APACHE II improves accuracy, but even then, these scoring systems are more suitable for evaluating outcomes in groups of surgical ICU patients rather than guiding individual care.[4, 8]

NSQIP score

National Surgical Quality Improvement Program is a risk assessment tool developed by the American College of Surgeons that predicts the likelihood of postoperative complications and mortality based on a large national surgical database. It uses multiple preoperative factors such as patient demographics, comorbidities, functional status, lab values, and surgery type to provide personalized risk estimates. Widely used for guiding clinical decisions and improving surgical outcomes, NSQIP offers data-driven, evidence-based predictions but requires access to its database and accurate input, limiting its use in some settings.[9]

Peri-operative Physiological Scores

POSSUM, P-POSSUM, and O-POSSUM systems [Physiological and Operative Severity Score for enUmeration of Mortality and morbidity]

The POSSUM (Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity) was specifically designed to predict outcomes in surgical patients. It uses 12 physiological and 6 surgical factors to estimate the risk of complications and death. POSSUM is mainly used as an audit tool, allowing hospitals to compare predicted risks with actual outcomes by calculating an observed-to-expected (O:E) mortality ratio.[10]

It has proven useful for general surgical audits and for specific patient groups like those with vascular or colorectal conditions. However, it tends to overestimate the risk of death in patients who are at low risk. In studies comparing it with the APACHE II score in high-dependency surgical units, POSSUM was found to be more useful.Because the scoring system includes details about the surgery itself, it can only be used for patients who actually undergo an operation—making it unsuitable for about one-third of surgical patients who are managed without surgery.[11]

The Physiological Score (PS) in the POSSUM system includes factors such as heart signs, chest X-ray results, breathing signs, blood pressure, heart rate, Glasgow Coma Scale score, hemoglobin level, white blood cell count, blood urea nitrogen, potassium and sodium levels, and ECG findings.

The Operative Severity (OS) score considers aspects like the size of the surgery, whether it was an emergency or planned, amount of blood loss, level of contamination in the abdominal cavity, presence of cancer, and the total number of previous operations.These PS and OS scores are then used in specific POSSUM formulas to calculate the predicted percentage risk of complications, as well as morbidity and mortality.[12]

Acute Physiology And Chronic Health Evaluation

The APACHE (Acute Physiology And Chronic Health Evaluation) score is one of the most commonly used tools in intensive care units (ICUs) to assess how sick a patient is. The original version, APACHE I, used 34 different body measurements taken during the first 24 hours in the ICU. It also included a basic check of the patient's overall health before they got sick, similar to the ASA grading system. Patients were placed into one of four groups, A to D, based on their chronic health condition. The main goal of APACHE was to help group patients by how seriously ill they were, so doctors could better compare outcomes and assess new treatments. APACHE II is a newer version that simplified things by reducing the number of body measurements from 34 to 12. It also includes points for age and chronic health problems. The total score can range from 0 to 71. To estimate a patient's risk of dying, the APACHE system uses the score along with other factors, such as what type of illness the patient has and whether they had emergency surgery.[13,14]

APACHE II has been tested and found useful for both general and surgical ICU patients. Survivors usually score between 9 and 15, while those who die often score between 19 and 25. However, it doesn't always accurately predict outcomes. For example, one study found it didn't work well in patients likely to develop multiple organ failure. Another study showed it wasn't reliable in trauma patients without head injuries, likely because the score relies heavily on the Glasgow Coma Scale, which measures brain function. Many trauma patients are young and otherwise healthy, which can also affect the score's accuracy. Some research suggests APACHE II works best for emergency surgery patients compared to those having planned surgery or non-surgical patients. Still, it can sometimes underestimate or overestimate the risk of death, depending on the type of patient.[15]

APACHE II has been specifically tested in surgical patients with intra-abdominal sepsis, a condition with a high risk of death. In these cases, there was a strong link between higher APACHE II scores and the likelihood of dying.

A researcher named Poenaru and his team improved the prediction by combining the APACHE II score with a test that measured immune system strength. This test involved injecting small amounts of five antigens under the skin to see how the body reacted. When both the APACHE II score and the immune response test were used together, the predictions were more accurate than with APACHE II alone.Later studies compared different scoring systems and found that both the APACHE II score and the Mannheim Peritonitis Index were good at predicting death in patients with intra-abdominal sepsis. Using both scores together gave the best results.[16]

APACHE III is a newer version that uses 18 body measurements and also considers chronic health. It's been used in ICUs to track how patients are doing each day. Its accuracy is similar to APACHE II and other scoring systems. However, it hasn't been widely used because the formula to calculate the predicted death rate is not publicly available—it must be bought from the company that owns it. In the UK, APACHE III has been used in intensive care databases in areas like South-West Thames and Scotland.[17]

Simplified Acute Physiology Score

The Simplified Acute Physiology Score (SAPS) is another system based on the original APACHE score. It uses 14 out of the original 34 variables to estimate the risk of death and has shown similar performance to APACHE II. SAPS II is an updated version that uses 13 physiological measurements, along with information about the type of hospital admission (whether it was planned or an emergency, surgical or medical), and certain serious health conditions like AIDS, widespread cancer, or blood cancers.

When SAPS II was compared to APACHE II, it gave a slightly better prediction of death risk in ICU patients. However, neither scoring system was accurate enough to be considered fully reliable for predicting outcomes.

Some common scoring systems and their components [18]

	APACHE II	APACHE III	SAPS	POSSUM
Temperature	+	+	+	
Blood pressure	+	+	+	+
Pulse rate	+	+	+	+
Respiratory rate	+	+	+	
Respiratory effort				
P_{aO_2}	+	+		
pH	+	+		
Bicarbonate			+	
Haemoglobin				+
Haematocrit	+	+	+	
White blood count	+	+	+	+
Sodium	+	+	+	+
Potassium	+		+	+
Creatinine	+	+		
Albumin		+		
Bilirubin		+		
Glucose		+	+	
BUN/urea		+	+	+
Urine output		+	+	
Glasgow Coma Score	+	+	+	+
ECG				+
Capillary refill				
Cardiac sign				+
Respiratory signs				+
Age	+		+	+
Chronic health	+	+		

APACHE, Acute Physiology And Chronic Health Evaluation; SAPS, Simplified Acute Physiology Score; POSSUM, Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity

Apgar score for surgery
This is a 10-point scoring system that looks at three things during surgery: the estimated blood loss, the lowest heart rate, and the lowest mean arterial pressure. A score of 4 or below is linked to a much higher risk of death. However, this score can only be calculated after the surgery is finished. Despite that, it has been shown to predict death very accurately (with strong statistical results). Here's how the scores relate to the risk of death:

- Scores of 9–10: 0% chance of death
- Scores of 7–8: 0.3% chance
- Scores of 5–6: 4.9% chance
- Scores of 0–4: 13.8% chance [19]

Post-Operative Scores

Mortality Prediction Model

The Mortality Prediction Model (MPM) is usually used when a patient first arrives in the ICU or HDU, using information from the first hour (this version is called MPM0). Older versions used data from the first 24 or 48 hours (MPM24 and MPM48). It doesn't take long to collect the required information, which includes things like: whether it was an emergency admission, if the patient had resuscitation, cancer, kidney problems, heart rate, blood pressure, infection, recent ICU admission, surgery, age, and level of consciousness (GCS). If a measurement isn't taken, the model assumes it's normal, which helps keep the data consistent and complete.[20,21]

Unlike models like APACHE, which use the worst values from the first 24 hours, MPM only uses data from the beginning. This makes it easier to compare patients between different ICUs. The latest version, MPM0-III, is available online and has been shown to predict ICU outcomes better than APACHE II, especially after some adjustments. However, MPM has some downsides. It doesn't include certain patients (like those who had heart surgery or heart attacks, or who are readmitted to the ICU). Also, even though it was recently updated, other models like APACHE IV and SAPS III are still more accurate. This may be because MPM uses fewer variables—just 16.[22]

Surgical Mortality Score

The Surgical Mortality Score (SMS) was developed mainly as a tool for auditing and comparing surgical outcomes, rather than for evaluating how sick a patient is or deciding if they need to be admitted to a High Dependency Unit (HDU) or Intensive Care Unit (ICU). It works by calculating an odds ratio for mortality. At the lowest risk level, the predicted death rate is just 0.08%, which matches well with other scoring systems.

Hadjianastassiou et al. simplified the original data to create a user-friendly, stratified system for predicting in-hospital death, which is easier to use than complex mathematical formulas used in other models. Unlike other scoring systems, the SMS isn't affected by differences in when clinical measurements are taken or how treatment is given. The SMS also accounts for the type of surgery performed—similar to P-POSSUM—but it depends on the length of the operation. A list of reference times for 652 different procedures is available online. However, this makes the score harder to calculate and assumes that surgical practices are the same in all hospitals. [23]

Trauma Scoring

The original Trauma Score (TS) was created by Champion et al. in 1981 to quickly assess injured patients in the field. It used four basic signs: systolic blood pressure, capillary refill, breathing rate (and effort), and the Glasgow Coma Scale (GCS). The more severe the injury, the lower the survival chance. This score helped decide how and where patients should be transported and supported the creation of trauma centers. However, it had some weaknesses: it used only a few measures, often overestimated how badly someone was hurt, and didn't consider where the injuries were on the body.

Before that, in 1970, the American Medical Association created the Abbreviated Injury Scale (AIS). It rated injuries from minor to fatal across five body areas. Later, Baker et al. improved on this by developing the Injury Severity Score (ISS). This method looked at six body regions, took the three worst injury scores, squared them, and added them together. ISS worked well for blunt injuries, but not as well for penetrating injuries. Eventually, a better system called the Revised Trauma Score (RTS) was created. It kept three key signs: GCS, systolic blood pressure, and breathing rate, and used statistical methods based on data from a large U.S. study (the Major Trauma Outcome Study). Later, the RTS and ISS were combined, and age was added as a factor, resulting in the Trauma Injury Severity Score (TRISS)—a more accurate tool for predicting trauma outcomes.[24]

A Z statistic was used to compare the actual number of deaths in a hospital unit to the predicted death risk for each patient. In this system, negative Z values indicate deaths, while positive Z values indicate survival. To spot unexpected differences, an additional M statistic was applied to compare the characteristics of the patient group being studied to a baseline group. The M value ranges from 0 to 1, with values closer to 1 showing a better match between the groups.

Using these statistics, a tool called "TRISSCAN" was created. This tool visually shows differences in patient outcomes by plotting trauma scores against the Injury Severity Score (ISS) for each patient. It calculates the chance of survival in a clear graph, helping identify unexpected deaths for quality review and team discussions.The TRISS method is found to predict death rates as accurately as other systems. Later improvements include validating this approach for injured children, adjusting for risk in pediatric ICUs, updating the TRISS calculations, creating a revised model called ASCOT, and developing regional TRISS standards to help set local care benchmarks.[25]

Other scoring systems

Systemic Inflammatory Response Syndrome (SIRS)

SIRS is a widespread inflammatory reaction in the body that can occur due to various causes like infection, injury, pancreatitis, reduced blood flow (ischemia), or bleeding. It represents a general inflammatory response.[26]

SIRS Diagnosis Criteria (from 1992 ACCP/SCCM Consensus Conference): A patient is considered to have SIRS if they meet two or more of the following conditions: Criteria Thresholds Temperature Above 38°C or below 36°CHeart rate Over 90 beats per minute Respiratory rate More than 20 breaths per minute or arterial CO_2 ($PaCO_2$) less than 32 mmHg White blood cells (WBC)Above 12,000/mm³, below 4,000/mm³, or more than 10% immature white cells (bands)

Multiple Organ Dysfunction Score (MODS)

MODS refers to the gradual failure of two or more organ systems after a serious illness or injury. The MODS score was created to measure how badly organs are affected and to help predict the risk of death.[27]

MODS Scoring System (Marshall et al., 1995)Organ SystemParameter MeasuredScore 4 (Severe Dysfunction) RespiratoryPaO₂ /FiO₂ ratio< 100RenalSerum creatinine or urine outputCreatinine > 440 μmol/LHepaticSerum bilirubin> 12.0 mg/dLCardiovascularPressure-adjusted heart rate (PAR)PAR > 30HematologicPlatelet count< 20,000/mm³NeurologicGlasgow Coma Scale (GCS) ≤ 6

- Each organ system is scored from 0 (normal) to 4 (severe dysfunction).
- Daily scoring can track progression of organ failure.
- Higher total scores indicate worse organ dysfunction and higher risk of mortality.

Conclusion

Surgical scoring systems are vital tools that enhance perioperative risk assessment by integrating patient health status, surgical complexity, and physiological data to predict outcomes in major abdominal surgeries. The ASA score, valued for its simplicity and widespread use, provides a quick but subjective assessment of patient physical status, while more detailed models like POSSUM and its variants offer comprehensive evaluations by including operative factors, although sometimes at the cost of complexity and limited applicability. Advanced tools such as the NSQIP calculator leverage large databases to deliver personalized risk predictions but require access to extensive data inputs. Scores like APACHE II and SAPS II, originally developed for critical care, have demonstrated strong predictive power, especially in emergency and septic patients, yet still depend on clinical context and judgment for interpretation. While each system has strengths and limitations, none alone provides a perfect prediction across all patient populations and surgical scenarios. Therefore, combining these scoring systems, alongside clinical expertise, is essential for improving individualized risk stratification, guiding surgical decisions, and optimizing patient outcomes.

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