Original Article

Comparison of Acute Physiology and Chronic Health Evaluation (APACHE) II and American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) scoring system in predicting postoperative mortality in patients undergoing emergency laparotomy: A retrospective study

Address for correspondence:
Dr. Sukhyanti Kerai,
Room No. 413, BL Taneja Block, Maulana Azad Medical College, New Delhi, India.
E-mail: drsukhi25@gmail.com

Submitted: 12-Sep-2023
Revised: 20-Nov-2023
Accepted: 03-Dec-2023
Published: 22-Feb-2024

Access this article online

Website: https://journals.lww.com/ijaweb

DOI: 10.4103/ija.ija_888_23

Quick response code

Pallavi Doda, Sukhyanti Kerai, Kanika Chauhan, Vineet Manchanda, Kirti N. Saxena, Anurag Mishra

Department of Anaesthesiology and Intensive Care, Maulana Azad Medical College and Associated Hospitals, New Delhi, India

ABSTRACT

Background and Aims: There is paucity of studies on preoperative risk assessment tools in patients undergoing emergency surgery. The present study evaluated the performance of the Acute Physiology and Chronic Health Evaluation (APACHE) II, American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) surgical risk calculator and American Society of Anesthesiologists (ASA) physical status (PS) classification system in patients undergoing emergency exploratory laparotomy. **Methods:** This retrospective study included 60 adult patients who underwent emergency exploratory laparotomy for perforation peritonitis. The clinical details, ASA PS classification, laboratory investigations and postoperative course of patients were retrieved from their medical records. Based on these details, APACHE II and ACS-NSQIP were calculated for the patients. The study's primary outcome was the accuracy of the preoperative APACHE II, ACS-NSQIP risk calculator and ASA PS class in predicting the postoperative 30-day mortality of patients. **Results:** The area under the curve (AUC) of APACHE II, ACS-NSQIP score, and ASA PS classification for mortality 30 days after surgery was 0.737, 0.694 and 0.601, respectively. The *P* value for the Hosmer–Lemeshow (H–L) test of scoring systems was 0.05, 0.25 and 0.05, respectively. AUC for postoperative complications was 0.799 for APACHE II, 0.683 for ACS-NSQIP and 0.601 for ASA PS classification. H–L test of these scoring systems for complications after surgery revealed *P* values of 0.62, 0.36 and 0.53, respectively. **Conclusion:** Compared to the ACS-NSQIP and ASA PS classification system, the APACHE II score has a better discriminative ability for postoperative complications and mortality in adult patients undergoing emergency exploratory laparotomy.

Keywords: ACS-NSQIP, Acute Physiology and Chronic Health Evaluation, American College of Surgeons, anaesthesia, APACHE, emergencies, laparotomy, National Surgical Quality Improvement Program, risk assessment

How to cite this article: Doda P, Kerai S, Chauhan K, Manchanda V, Saxena KN, Mishra A. Comparison of Acute Physiology and Chronic Health Evaluation (APACHE) II and American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) scoring system in predicting postoperative mortality in patients undergoing emergency laparotomy: A retrospective study. Indian J Anaesth 2024;68:231-7.

INTRODUCTION

Emergency laparotomy is a common surgical procedure performed worldwide. The mortality rate following

emergency laparotomy is five times higher than that following high-risk elective procedures, and major complications as high as 50% have been reported.[1] To improve patient outcomes after emergency laparotomy, the risk stratification of patients is vital so that targeted perioperative interventions can be initiated.

Preoperative risk assessment tools aid in identifying patients at increased risk of adverse perioperative outcomes. They facilitate preoperative optimisation, inform patients and decision-making. They are also used for quality improvement and allocation of healthcare resources by predicting length of stay and postoperative complication rates.[2] The American Society of Anesthesiologists (ASA) physical status (PS) classification system is the most widely used risk score in anaesthesia practice. It is a simple tool that is used to predict morbidity and mortality in surgical patients based on their preoperative health status. However, ASA PS is associated with significant interobserver variability, and its role in predicting the outcome of emergency surgery is unclear.[3,4] Various other scoring systems have been used for risk assessment in emergency surgical patients, such as Acute Physiology and Chronic Health Evaluation (APACHE) II, Surgical Risk Scale, Mannheim Peritonitis Index, Boey Score, Portsmouth-Physiology and Operative Severity Score for the enumeration of Mortality and Morbidity (P-POSSUM) and National Emergency Laparotomy Audit (NELA).[5]

The performance of the APACHE II score is consistent across patient subgroups undergoing emergency surgery and is promoted for their individualised risk assessment.[6] The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) surgical risk calculator is an open-access online tool that estimates surgical procedure-specific outcomes using 20 patient variables.[7] There is paucity of studies on the utility of ACS-NSQIP score on preoperative risk assessment of patients undergoing emergency exploratory laparotomy. We planned the present study to assess the performance of APACHE II and ACS-NSQIP risk scores in preoperative risk assessment of patients undergoing exploratory laparotomy following hollow viscus perforation.

METHODS

This retrospective observational study was conducted in a tertiary care urban centre after approval from the institutional ethics committee (vide approval number F.1/IEC/MAMC/95/01/2023/No55, dated 5 April 2023). Because of the retrospective nature of the study, a waiver of consent was granted by the Institutional Ethical Committee. The study was registered with the Clinical Trials Registry- India (vide registration number CTRI/2023/04/051840). This study was done as per the Declaration of Helsinki 2013 and its later amendments and following principles of good clincial practice.

In this study, we included adult (18–80 years of age) patients who underwent emergency exploratory laparotomy for peritonitis following perforated hollow viscus from July 2022 to December 2022. The patients undergoing repeat exploratory laparotomy, those with human immunodeficiency virus (HIV) infection, and those receiving immunosuppressive medications such as long-term steroids and chemotherapeutic drugs were excluded.

The list of eligible patients was obtained from the data register of the emergency operating rooms, and their case records were retrieved from the Medical Record Department. The preoperative details, anaesthesia records and the postoperative course of patients during their hospital stay were reviewed. The data collected included a demographic profile of patients, diagnosis, comorbidities, ASA PS classification and history of smoking and alcohol intake. The preoperative clinical condition of the patient including the Glasgow Coma Scale, temperature, requirement of supplemental oxygen, respiratory rate, heart rate and mean arterial pressure were recorded. The preoperative haematological investigations, haematocrit, total leucocyte count, serum creatinine, serum sodium, serum potassium and partial pressure of oxygen in the blood from the arterial blood gas analysis report were noted. Intraoperative details consisted of the site of perforation, type of surgical procedure, type of anaesthesia provided and intraoperative blood loss. In the postoperative period, the need for intensive care unit (ICU) admission, duration of hospital admission, postoperative complications, and patient outcomes were noted. The APACHE II and ACS-NSQIP scores were calculated by entering the relevant preoperative variables into open-access online tools.[8,9]

The study's primary outcome was the accuracy of the preoperative APACHE II, ACS-NSQIP risk calculator and ASA PS class in predicting the postoperative 30-day mortality of patients in patients undergoing emergency laparotomy surgeries for peritonitis

following perforated hollow viscus. The patient's mortality was defined as the death within 30 days of surgery, irrespective of patient's geographical location, even if the patient had been discharged from the hospital. Cases discharged home before the postoperative 30 days were contacted telephonically for follow-up. The secondary outcome included the predictive ability of APACHE II, NSQIP risk calculator and ASA PS class for postoperative complications. Both surgery-related and medical complications in the postoperative period were noted. The surgery-related complications included anastomotic leaks, bleeding, fascial rupture, seroma formation, surgical site infection and the need for repeat surgery during the same hospital stay. Medical complications included postoperative pulmonary complications, acute myocardial infarction, heart failure, cardiac arrhythmia, deep vein thrombosis, acute kidney injury and acute liver complications.

The data acquired was analysed using Statistical Package for Social Sciences (SPSS) version 25.0 (IBM SPSS Statistics, International Business Machines Corporation, Armonk, New York, USA). Categorical variables (gender, smoking status, history of alcohol intake, presence of comorbidities, functional status, history of use of steroids for a chronic condition, history of ascites, congestive heart failure, diabetes, chronic obstructive pulmonary disease, dialysis, ventilator dependency, disseminated cancer, hypertension) were expressed in number. Continuous variables were presented as mean (standard deviation [SD]). The normality of data was assessed by the Kolmogorov–Smirnov test. A P value of < 0.05 was considered statistically significant. Quantitative variables (age, body mass index, mean arterial pressure, heart rate, respiratory rate, arterial partial pressure of oxygen [PaO_2], serum sodium, serum potassium, serum creatinine, haematocrit, total leucocyte count, mean APACHE II score, mean ACS score) were compared using the independent *t*-test and the Mann–Whitney test. The predictive accuracy of APACHE II, ACS-NSQIP score and ASA PS was assessed using the area under the receiver operating characteristic curve (AUC). For interpretation of AUC, more than 0.9 was considered outstanding, 0.8–0.9 as excellent, 0.7–0.8 as acceptable and less than 0.7 as poor.[10] Logistic regression models were used to assess APACHE II, ACS-NSQIP score and ASA PS as independent variables using the mortality of patients or the occurrence of postoperative complications as dependent variables. The calibration of models was evaluated with Hosmer–Lemeshow goodness-of-fit tests. For this test, $P > 0.05$ means no statistical difference exists in the incidence of expected and observed outcomes.[9]

The *post hoc* power analysis of the study was calculated using G* power version 3.1.9.2 software (Heinrich Heine Universität Düsseldorf, Düsseldorf, Germany). Assuming a sample size of 60 with an effect size of 0.50 and alpha of 0.05, the *post hoc* power of the study was found to be 86.6%.

RESULTS

A total of 486 patients underwent emergency exploratory laparotomy. Out of them, peritonitis following perforation of hollow viscus was found in 60 patients. The mean (SD) age of patients was 40.4 (15.1) years, and the majority of the patients were males [Table 1]. There was no significant delay from hospital admission of patients to exploratory laparotomy, with a mean (SD) of 0.87 (1.14) days. The most common site of perforation in the present cohort of patients was the small bowel (32/60), followed by the stomach (12/60), appendix (9/60) and large bowel (7/60).

All cases were conducted under general anaesthesia. At our centre, generally, multimodal analgesia comprising parenteral analgesic medications is used for postoperative analgesia after emergency exploratory laparotomy. In 10 cases, epidural analgesia was used, while in seven patients, transversus abdominis plane (TAP) block was utilised. The mean (SD) intraoperative blood loss recorded in the patients was 447.9 (234.4) ml. The predominant surgical procedure was bowel resection and stoma formation in 24 cases and primary repair in 18 cases. The patients' mean (SD) duration of hospital stay was 14.5 (10.7) days. Postoperatively, 21 out of 60 patients required ICU admission and mechanical ventilation. The majority of patients who were shifted to the ICU had features of septicaemia with poor preoperative chest conditions (19 out of 21; five patients among them had preoperative acute kidney injury). Two patients were shifted to the ICU in view of the requirement for ionotropic support. Postoperative complications were noted in 25/60 cases. The complications comprised septicaemia (13/60), surgical site infection (5/60), acute kidney injury (4/60), burst abdomen (4/60), multiple organ dysfunction syndrome (MODS; 3/60), pulmonary complications (2/60) and others. At the

Table 1: Demographic characteristics of the study cohort

Baseline parameters	Value (*n*=60)
Age (years)	40.38 (15.14)
Gender (Male: female)	43:17
Body mass index (kg/m^2)	22.58 (0.29)
Smoking status (Yes: no)	20:40
Alcohol intake (Yes: no)	19:41
Comorbidities (Yes: no)	19:41
Temperature (°C) (>37.8°C: <37.8°C)	23:37
Mean arterial pressure (mmHg)	85.62 (12.06)
Heart rate (beats per minute)	98.98 (18.91)
Respiratory rate (rate per minute)	21.80 (4.59)
Oxygenation (mmHg)	98.66 (62.18)
Arterial pH	7.35 (0.05)
Sodium (mEq/l)	136.65 (4.36)
Potassium (mEq/l)	4.06 (0.50)
Serum creatinine (mg/dl)	1.01 (0.80)
Haematocrit	36.95 (7.54)
Total leucocyte count (WBCs per microlitre)	14,342.03 (7391.922)
Glasgow Coma Scale	15 (0.00)
Functional status (Good: poor)	44:16
Steroid use for chronic condition (Yes: no)	0:60
Ascites within 30 days before surgery (Yes: no)	19:41
Systemic sepsis within 48 h before surgery (Yes: no)	17: 43
Ventilator dependent (Yes: no)	0:60
Disseminated cancer (Yes: no)	1:59
Diabetes (Yes: no)	1 :59
Hypertension requiring medications (Yes: no)	4:56
Congestive heart failure in 30 days before surgery (Yes: no)	0:60
Dyspnoea (Yes: no)	19:41
History of severe Chronic Obstructive Pulmonary Disease (Yes: no)	0:60
Dialysis (Yes: no)	1:59
Acute renal failure (Yes: no)	4:56

Data expressed as mean (standard deviation) or numbers. *n*=number of patients, WBCs= white blood cells

end of 30 days after surgery, mortality was observed in 23/60 of patients (13 of these patients died due to septicaemia, which was present during the preoperative period; the rest of the patients developed complications in the postoperative period).

A total of 29 patients belonged to ASA emergency (E) I, 20 to ASA EII and 11 to ASA EIII. Of these ASA E classes, mortality was seen in 10, 5 and 8 patients, respectively. There was a significant difference in patients' mortality between different ASA classes ($P = 0.027$). The AUC of the receiver operating characteristic (ROC) curve between ASA grading and the outcome of patients was 0.601.

Postoperative complications were noted in a higher proportion of patients belonging to ASA EIII (7/11) compared to ASA EI (10/29) or ASA EII (8/20). However, the difference in the postoperative complications between different ASA classes was not statistically significant ($P = 0.24$).

The mean (SD) APACHE score for survivors was 5.24 (4.68), whereas for nonsurvivors, it was 9.13 (4.93) ($P = 0.002$). The AUC for ROC for APACHE and outcome of patients was 0.737 [Table 2]. The best cut-off point was 5.50, with sensitivity and specificity of 78.3% and 29.7%, respectively [Table 3]. The mean (SD) APACHE score for patients who experienced postoperative complications was 9.80 (5.24) compared to 4.54 (3.74) in uneventful cases ($P < 0.001$). The predictive ability of the APACHE score for postoperative complications was found to be good, with 0.799 AUC for ROC. The best cut-off point for the APACHE score for postoperative complications was 5.50, with a sensitivity of 76% and a specificity of 28.6%.

The mean (SD) ACS-NSQIP score in survivors was 1.00 (2.28) in comparison to 9.00 (17.94) in nonsurvivors ($P = 0.002$). In patients who subsequently developed postoperative complications, the mean (SD) ACS-NSQIP score based on preoperative

values was 8.76 (3.45) compared to 0.71 (0.25) in those who had not experienced any postoperative complications ($P = 0.008$). The AUC for ROC between the ACS-NSQIP score and the outcome of patients was 0.694, suggesting fair accuracy [Figure 1]. Similarly, the AUC for ACS-NSQIP score and postoperative complications was 0.683.

Logistic regression analysis was carried out with the APACHE score as an independent variable and the outcome of the patient (dead or alive) as the dependent variable. The Hosmer and Lemeshow test of the goodness of fit suggested that the model fits the data well with $P = 0.059$ [Table 4]. This model was observed to correctly classify the outcome for 68.3% of cases. It was found that the APACHE score had a significant overall effect ($P = 0.007$). An increase in APACHE score is associated with an increased likelihood of a patient's nonsurvival. Unit increase in APACHE score was associated with a mortality rate of 1.177 times. Similarly, a logistic regression model was created for the ACS-NSQIP score and ASA PS. The Hosmer and Lemeshow goodness of fit for the predictive model using the ACS score was found to fit well ($P = 0.25$), whereas, for ASA grading, it was not found to have good fitting ($P = 0.04$).

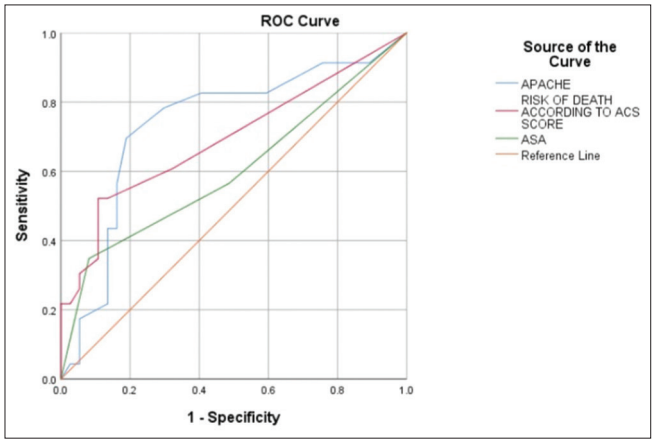

Figure 1: Receiver operating curves (ROC) for Acute Physiology and Chronic Health Evaluation (APACHE) II, American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) score and American Society of Anesthesiologists (ASA) physical status classification

DISCUSSION

The present study found that the AUC for APACHE II for predicting 30-day mortality of patients undergoing emergency laparotomy was 0.737.

In another study from India, the AUC from ROC for APACHE II was reported as 0.984, which is better than ours.[11] Lack of details on preoperative optimisation of patients, such as antibiotic administration, fluid resuscitation, surgical details and surgeons' experience, could be plausible explanations for the varied results between the studies. The accuracy of the APACHE II score in predicting postoperative complications was observed to be moderately good, with an AUC of 0.799.

The performance of the ACS-NSQIP surgical risk calculator in our study was fair, with an AUC of 0.694 for mortality and 0.683 for postoperative complications. There are inherent differences in the spectrum of the Indian surgical cohort compared to Western cohorts

Table 2: Discrimination and calibration of scoring systems in predicting postoperative mortality

Scoring system	Area under the curve (95% confidence interval)	Hosmer–Lemeshow test *P*
Postoperative mortality at 30 days after surgery		
APACHE II	0.737 (0.599–0.876)	0.059
ACS-NSQIP score	0.694 (0.549–0.840)	0.250
ASA	0.601 (0.445–0.757)	0.045
Postoperative complications		
APACHE II	0.799 (0.684–0.913)	0.628
ACS-NSQIP score	0.683 (0.536–0.830)	0.367
ASA grade	0.601 (0.453–0.749)	0.534

ACS-NSQIP=American College of Surgeons National Surgical Quality Improvement Program, APACHE II=Acute Physiology and Chronic Health Evaluation II, ASA=American Society of Anesthesiologists physical status

Table 3: Sensitivity, specificity, positive predictive value, negative predictive value, accuracy and relative risk of the cut-off points based on the receiving operating curve for scoring systems

	Sensitivity	Specificity	PPV	NPV	Accuracy	RR (95% CI)
APACHE II (Cut-off point 6)	73.8	75.7	65.4	82.4	75	8.815 (2.666–29.147)
ACS-NSQIP score (Cut-off point 1)	52.2	86.5	70.6	74.4	73.3	6.982 (2.004–24.322)
ASA (ASA EII or ASA EIII)	41.9	51.4	56.5	65.5	53.45	1.372 (0.482–3.90)

ACS-NSQIP=American College of Surgeons National Surgical Quality Improvement Program, APACHE II=Acute Physiology and Chronic Health Evaluation II, ASA=American Society of Anesthesiologists physical status, CI=confidence interval, NPV=negative prediction value, PPV=positive predictive value, RR=relative risk, E=emergency surgery

Table 4: Logistic regression analysis using postoperative mortality or occurrence of postoperative complications as dependent variables and APACHE II*, ACS-NSQIP¥ score and ASA® grading as independent variables

	B	SE	Wald	df	*P*	OR=Exp (*B*)	95% CI for OR
Postoperative mortality at 30 days after surgery							
APACHE II	0.163	0.060	7.309	1	0.007	1.177	1.046–1.324
ACS-NSQIP Score	0.208	0.096	4.684	1	0.030	1.231	1.020–1.485
ASA	0.602	0.357	2.838	1	0.092	1.825	0.906–3.675
Postoperative complications							
APACHE	0.254	0.073	12.078	1	0.001	1.289	1.117–1.488
ACS-NSQIP Score	0.371	0.128	6.164	1	0.013	1.373	1.069–1.764
ASA grading	0.539	0.352	2.344	1	0.126	1.715	0.860–0.421

®ACS-NSQIP=American College of Surgeons National Surgical Quality Improvement Program, *APACHE II=Acute Physiology and Chronic Health Evaluation II, ¥ASA=American Society of Anesthesiologists physical status, CI=confidence interval, OR=odds ratio, df=degrees of freedom

presenting for emergency laparotomy. Previous studies have found that the majority of cases in low- to middle-income countries present late to the hospital with well-established peritonitis and variable degrees of septicaemia. In contrast to developed countries, the perforations of the proximal gastrointestinal tract are six times as common as the distal perforations. The predominant aetiology for perforation is infectious causes such as typhoid and tuberculosis, whereas, in Western countries, appendicitis, peptic ulceration and trauma are the major causes.[12]

Patients requiring emergency laparotomy are markedly heterogeneous, consisting of diverse surgical pathology, age, preexisting health conditions, the presence of sepsis and acute organ failure. In this retrospective analysis, only those patients who required emergency laparotomy for hollow viscus perforation were included. This subgroup of patients commonly comprises surgical emergencies worldwide. Preoperative risk assessment in these patients will allow the identification of high-risk patients, and it has been shown that a 53% reduction in mortality and morbidity can be achieved through the augmented pathway of care for these patients.[1]

APACHE II score consisted of points for age, chronic health status and 12 physiological variables measured within the last 24 h. It was initially designed to assess the disease severity in patients admitted to ICU. This scoring system has demonstrated accuracy across various patient cohorts undergoing emergency laparotomy. The discrimination ability for predicting mortality measured as AUC of APACHE has been observed to be 0.76–0.98.[6] This reflects the association of derangement in physiological variables due to disease-related sepsis, age, and comorbidities with patient outcomes.

ACS-NSQIP surgical risk calculator is based on 21 preoperative variables derived from a large database of hospitals in the USA. This scoring system has a provision for modifying scores based on their clinical judgement. It has been investigated for different surgical subgroups and found to be reasonably accurate for predicting mortality and postoperative complications.[13,14] However, it is yet to be evaluated across geographical locations, and there is paucity of studies on patients undergoing emergency laparotomy. Previous studies have shown that it underestimates the risk of overall complications, serious complications, surgical site infections and length of stay in patients presenting for acute care.[15,16] The prediction of mortality of patients was observed to be accurate. The variability in the clinical presentation of patients presenting for acute care and the limited time available for preoperative optimisation have been attributed to differences in the accuracy of the calculator's performance.

The present study is the first study to compare the APACHE II score with the ACS-NSQIP surgical risk calculator in the Indian surgical population. However, there are certain limitations to the current research. It was a retrospective analysis done on a small number of patients. Although our study was only observational and aimed at improving the quality of care provided to the patients undergoing emergency surgery, there are inherent difficulties in undertaking a prospective study in the emergency care setting. These patients are usually frightened and are often in pain and distress due to underlying pathologies. Sometimes, cognition is altered due to septicaemia and electrolyte imbalances in this cohort of patients, which affect their ability to give consent for participation. Second, we included only patients with hollow viscus organ perforation. Patients presenting for emergency laparotomy with other aetiologies, such as intestinal obstruction and trauma, were not taken up. The study was conducted in a single centre located in an urban area of India and may not reflect the rest of the parts of the country.

CONCLUSION

For patients undergoing emergency exploratory laparotomy, the Acute Physiology and Chronic Health Evaluation (APACHE) II score has better discrimination ability for mortality and occurrence of postoperative complications compared to the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) surgical risk calculator and American Society of Anesthesiologists (ASA) physical status (PS) classification.

Study data availability

De-identified data may be requested with reasonable justification from the authors (email to the corresponding author) and shall be shared after approval as per the authors' institution policy.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

ORCID

Pallavi Doda: https://orcid.org/0000-0002-9602-7886
Sukhyanti Kerai: https://orcid.org/0000-0002-7771-0786
Kanika Chauhan: https://orcid.org/0009-0001-0588-404X
Vineet Manchanda: https://orcid.org/0000-0002-3850-5958
Kirti N Saxena: https://orcid.org/0000-0002-2045-243X
Anurag Mishra: https://orcid.org/0000-0002-2302-0632

REFERENCES

1. Oumer KE, Ahmed SA, Tawuye HY, Ferede YA. Outcomes and associated factors among patients undergoing emergency laparotomy: A retrospective study. Int J Surg Open 2021;36:100413. doi: 10.1016/j.ijso. 2021.100413.
2. Horvath B, Kloesel B, Todd MM, Cole DJ, Prielipp RC. The evolution, current value, and future of the American Society of Anesthesiologists physical status classification system. Anesthesiology 2021;135:904-19.
3. Sankar A, Johnson SR, Beattie WS, Tait G, Wijeysundera DN. Reliability of the American Society of Anesthesiologists physical status scale in clinical practice. Br J Anaesth 2014;113:424–32.
4. Havens JM, Columbus AB, Seshadri AJ, Brown CVR, Tominaga GT, Mowery NT, *et al*. Risk stratification tools in emergency general surgery. Trauma Surg Acute Care Open 2018;3:e000160. doi: 10.1136/tasco-2017-000160.
5. Nag DS. Assessing the risk: Scoring systems for outcome prediction in emergency laparotomies. Biomedicine (Taipei) 2015;5:20. doi: 10.7603/s40681-015-0020-y.
6. Oliver CM, Walker E, Ginnaris S, Grocott MPW, Moonesinghe SR. Risk assessment tools validated for patients undergoing emergency laparotomy: A systematic review. Br J Anaesth 2015;115:849-60.
7. Turner PL, Ilano AG, Zhu Y, Johnson SB, Hanna N. ACS-NSQIP criteria are associated with APACHE severity and outcomes in critically ill surgical patients. J Am Coll Surg 2011;212:287-94.
8. APACHE II Score. Available from: https://www.mdcalc.com/calc/1868/apache-ii-score. [Last accessed on 2023 15 November].
9. ACS Risk Calculator. Available from: https://riskcalculator.facs.org/RiskCalculator/. [Last accessed on 2023 15 November].
10. Mandrekar JN. Receiver operating characteristic curve in diagnostic test assessment. J Thorac Oncol 2010;5:1315-6.
11. Kulkarni SV, Naik AS, Subramanian N Jr. APACHE-II scoring system in perforative peritonitis. Am J Surg 2007;194:549–52.
12. Jhotba RS, Attri AK, Kaushik R, Sharma R, Jhotba A. Spectrum of perforation peritonitis in India-review of 506 consecutive cases. World J Emerg Surg 2006;1:26. doi: 10.1186/1749-7922-1-26.
13. Burgess JR, Smith B, Britt R, Weireter L, Polk T. Predicting postoperative complications for acute care surgery patients using the ACS NSQIP surgical risk calculator. Am Surg 2017;83:733–8.
14. Haskins IN, Maluso PJ, Schroeder ME, Amdur RL, Vaziri K, Agarwal S, *et al*. A calculator for mortality following emergency general surgery based on the American College of Surgeons National surgical quality improvement program database. J Trauma Acute Care Surg 2017;82:1094–9.
15. Golden DL, Ata A, Kusupati V, Jenkel T, Khakoo NS, Taguma K, *et al*. Predicting postoperative complications after acute care surgery: How accurate is the ACS NSQIP surgical risk calculator? Am Surg 2019;85:335-41.
16. Parkin CJ, Moritz P, Kirkland O, Doanet M, Glover A. Utility of the American College of Surgeons National surgical quality improvement program surgical risk calculator in predicting mortality in an Australian acute surgical unit. ANZ J Surg 2020;90:746-51.