Electronic Journal of General Medicine
2025, 22(5), em675
e-ISSN: 2516-3507
https://www.ejgm.co.uk/

MODESTUM

Original Article **OPEN ACCESS**

Analysis of surgical apgar score combined with ASA classification (SASA) score in ICU and non-ICU patients following intra-abdominal surgery

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Citation: Bumrungchatudom K, Chavez R, Tawanwongsri W, Puangrab S. Analysis of surgical apgar score combined with ASA classification (SASA) score in ICU and non-ICU patients following intra-abdominal surgery. Electron J Gen Med. 2025;22(5):em675. https://doi.org/10.29333/ejgm/16621

ARTICLE INFO

Received: 19 Feb. 2025
Accepted: 15 Jun. 2025

ABSTRACT

Background: Identifying high-risk patients for intensive care unit (ICU) admission after intra-abdominal surgery is crucial, especially in resource-limited settings. This study evaluates the predictive accuracy of the surgical apgar score combined with ASA classification (SASA) for ICU admission within 48 hours.

Methods: A retrospective cohort of 242 patients (24 ICU admissions, 9.9%) was analyzed, with a mean age of 58.25 years (standard deviation = 15.41) and 137 males (56.6%). The performance of SAS and SASA was assessed using ROC curve and calibration analysis.

Results: SASA outperformed SAS (area under the receiver operating characteristic [auROC]: 0.9483 vs. 0.8772). An optimal SASA cutoff score of 13 provided 83.33% sensitivity and 94.95% specificity for ICU admission. ASA classification, open abdominal surgery, operative duration, hemodynamic instability, and blood loss were significant ICU predictors ($p < 0.001$).

Conclusion: SASA demonstrates superior predictive accuracy for ICU admission and enhances perioperative risk stratification. Prospective studies are recommended to validate its role in predicting morbidity and mortality.

Keywords: ICU admission, intra-abdominal surgery, predictive model, surgical apgar score (SAS), SASA score

INTRODUCTION

Intra-abdominal surgeries carry a considerable risk of postoperative complications [1-3]. A study analyzing 9,288 cases reported intraoperative adverse events in 2% of patients, with 44% involving bowel injuries and 29% vessel injuries, leading to increased 30-day morbidity and mortality [4]. Intensive care unit (ICU) admission plays a crucial role in managing high-risk patients by reducing complications and improving survival outcomes. A systematic review highlighted that patients admitted to the ICU after developing complications experienced worse outcomes, including a higher mortality rate and prolonged length of stay, compared to those admitted preemptively, reinforcing the importance of early ICU admission strategies [5-7]. However, ICU resources, particularly in low-resource settings, remain constrained, emphasizing the need for accurate predictive tools to optimize ICU admission decisions and improve patient outcomes [8].

Several scoring systems assess postoperative risk and guide ICU admissions. The American Society of Anesthesiologists physical status (ASA-PS) classification is widely used for preoperative risk stratification, categorizing patients based on their overall health and comorbidities. While effective in evaluating baseline risk, it does not incorporate intraoperative parameters, which are essential for predicting postoperative ICU needs (ASA) . The POSSUM score integrates physiological and operative risk factors, though its mortality predictions in low-risk patients tend to be elevated by 9.3-fold, influencing its suitability for ICU triage [9]. The surgical apgar score (SAS) assesses intraoperative conditions, including blood loss, lowest heart rate, and mean arterial pressure, providing valuable insight into surgical stability [10, 11]. However, its predictive capacity for ICU admission is enhanced when combined with preoperative health assessments [12].

To address these limitations, the study in [13] developed the SAS combined with ASA classification (SASA), integrating preoperative ASA-PS with intraoperative SAS parameters. A large-scale study analyzing 32,555 surgical patients demonstrated SASA's superior predictive performance for 30-day postoperative mortality, with an AUC of 0.87, compared to 0.81 for SAS and 0.79 for ASA-PS. However, this study did not specifically assess SASA's ability to predict ICU admission.

While established scoring systems have been extensively studied for their role in postoperative risk stratification, their application in guiding immediate ICU admission decisions

Table 1. ASA-PS classification system and definitions [14]

ASA-PS C	Definition	Key adult examples
ASA I	Normal healthy patient	Healthy, non-smoking, no or minimal alcohol use
ASA II	Mild systemic disease	Well-controlled DM/HTN, mild lung disease, obesity (BMI = 30-40), pregnancy, social alcohol drinker, current smoker
ASA III	Severe systemic disease	Poorly controlled DM/HTN, COPD, morbid obesity (BMI ≥ 40), active hepatitis, alcohol dependence, implanted pacemaker, ESRD on dialysis, history (> 3 months) of MI, CVA, TIA, or CAD/stents
ASA IV	Severe systemic disease, constant threat to life	Recent (< 3 months) MI, CVA, TIA, CAD/stents; ongoing ischemia, severe valve dysfunction, DIC, sepsis, ARDS, ESRD not on dialysis
ASA V	Moribund patient, unlikely to survive without surgery	Ruptured aneurysm, massive trauma, intracranial bleed with mass effect, ischemic bowel, multiple organ failure
ASA VI	Brain-dead patient	Organ donor

Note. C: Classification; ESRD: End-stage renal disease; MI: Myocardial infarction; CVA: Cerebrovascular accident; TIA: Transient ischemic attack; CAD: Coronary artery disease; DIC: Disseminated intravascular coagulation; & ARDS: Acute respiratory distress syndrome

Table 2. SAS criteria

SAS	0 points	1 point	2 points	3 points	4 points
Estimated blood loss (mL)	> 1,000	601-1,000	101-600	≤ 100	-
Lowest mean arterial pressure (mmHg)	< 40	40-54	55-69	≥ 70	-
Lowest heart rate (bpm)[a]	> 85	76-85	66-75	56-65	≤ 55

Note. [a]Occurrence of pathologic bradyarrhythmia, including sinus arrest, atrioventricular block or dissociation, junctional or ventricular escape rhythms, and asystole, also receive 0 points for the lowest heart rate; mL: milliliters; mmHg: millimeters of mercury; & bpm: beats per minute

remains uncertain. Despite promising results in mortality prediction, SASA's role in predicting ICU admission within the first 48 hours after intra-abdominal surgery remains underexplored. This study aims to evaluate SASA's predictive accuracy in ICU admission, comparing it to existing ICU admission criteria. Identifying a reliable and user-friendly scoring system can optimize proper ICU allocation, support surgical decision-making, and improve patient outcomes, especially in resource-limited settings.

MATERIALS AND METHODS

Participants

This retrospective cohort study was conducted following approval from the Institutional Review Board (IRB No. S011h/67_ExPD).

The study included adult patients aged 18 to 85 years who underwent intra-abdominal surgeries, including colorectal and urological procedures, at Bamrasnaradura Infectious Diseases Institute between October 2023 and June 2024. Eligible participants were those who received either general or regional anesthesia and had complete perioperative data necessary for SASA calculation. Exclusion criteria comprised patients who had been admitted to the ICU prior to surgery, those who underwent one-day surgery or were discharged within 24 hours postoperatively, patients undergoing obstetric or gynecological procedures, and individuals with incomplete records or missing critical data required for SASA scoring or ICU admission analysis.

All cases within the study period were consecutively screened and individually assessed for eligibility based on the predefined inclusion and exclusion criteria.

The ASA-PS was determined through a review of preoperative medical records, while intraoperative parameters were obtained from anesthetic records. The SASA score was calculated according to the method described in **Table 1**.

Data Collection

Data for this retrospective study were obtained from medical records at Bamrasnaradura Infectious Diseases Institute, Thailand, from October 2023 to June 2024. A standardized case record form was utilized to ensure consistency and accuracy in data extraction. Collected variables included preoperative, intraoperative, and postoperative factors relevant to the study objectives.

Preoperative data consisted of demographic details such as age, sex, weight, height, body mass index (BMI), emergency surgical status, smoking status, and the ASA-PS to assess baseline health and comorbidities. The ASA-PS classification is a standardized system used to evaluate a patient's preoperative health, ranging from ASA I (a normal healthy patient) to ASA VI (a brain-dead patient). **Table 1** presents the ASA-PS Classification along with its corresponding definitions [14].

Intraoperative data included key parameters such as the type of surgery (urological or colorectal procedures), surgical approach (open or laparoscopic abdominal surgery), operation time (hours), anesthesia time (hours), type of anesthesia (general or regional), estimated blood loss (mL), lowest recorded heart rate (beats per minute), and lowest mean arterial pressure (mmHg). These variables were used to calculate the SAS, which assigns a score ranging from 0 to 10 based on specific thresholds, as presented in **Table 2**. Lower SAS scores indicate a higher likelihood of postoperative complications or mortality.

Table 2 presents the SAS, including the scoring criteria for estimated blood loss, lowest mean arterial pressure, and lowest heart rate, as adapted from Kinoshita et al [13]. To improve predictive accuracy, the SAS was integrated with the ASA-PS to formulate the SASA. The SASA score was calculated using Eq. (1) [13]:

$$SASA = SAS + (6 - ASA - PS) \times 2, \quad (1)$$

which yielding a range from 0 to 20. This composite score incorporates intraoperative variables from the SAS and preoperative risk assessment from the ASA-PS, providing a more comprehensive evaluation of perioperative risk. SASA inversely correlates with the probability of ICU admission, with lower scores indicating a higher likelihood of postoperative ICU requirement.

Postoperative data focused on ICU admission within the first 48 hours following surgery, collecting data of the timing and primary indications for ICU transfer. ICU admission was primarily determined based on six predefined clinical criteria: severe postoperative complications, persistent hypotension requiring vasopressor support, need for mechanical ventilation, high oxygen demand, ongoing significant bleeding, and major organ dysfunction (e.g., acute kidney injury requiring renal support, neurological impairment). However, the final decision for ICU admission ultimately depended on the clinical judgment of the attending surgeons and intensivists, considering the patient's overall postoperative condition. Additionally, postoperative complications—including surgical site infections, pulmonary complications, acute kidney injury not requiring renal support, and sepsis—were systematically recorded to assess their impact on ICU utilization but were not considered primary criteria for ICU admission. To maintain confidentiality, all patient identifiers were removed, and data were anonymized using unique study codes. Extracted information was securely stored in an encrypted database accessible only to authorized members of the research team. Discrepancies or missing data were addressed through secondary reviews of medical records to ensure completeness and accuracy.

Data Extraction and Validation

Clinical data were extracted by a researcher from validated case record forms maintained at Bamrasnaradura Infectious Diseases Institute. These forms have been reviewed and standardized by institutional experts to ensure completeness and consistency prior to data collection.

Data were directly transcribed into the study database. Cross-referencing against original medical records was performed where necessary to verify the accuracy of the extracted variables and to enhance the reliability of the dataset.

Sample Size

The sample size for this study was determined using the formula for sample size estimation for a single proportion. The proportion (p) was based on ICU admission rates reported for colorectal and urological surgeries, which were 17.7% and 3.8%, respectively [15].

For the calculation, the estimated population proportion ($\hat{p}$) was set at 0.18, with a z-score (Z) of 1.96, corresponding to a 95% confidence level, and a margin of error (e) of 0.05. Substituting these values into Eq (2):

$$n = \frac{Z^2 \times \hat{p} \times (1-\hat{p})}{e^2}, \tag{2}$$

which yields a minimum sample size of 227 participants. To account for potential incomplete data or other factors that could limit data collection, a 10% adjustment was added. This adjustment increased the required sample size to 253 participants, ensuring adequate statistical power for the analysis.

Statistical Analysis

Data are presented as counts (n) and percentages for categorical variables. Continuous variables are summarized as means with standard deviations (SD) for normally distributed data or medians with interquartile ranges (IQR) for non-normally distributed data. The Shapiro-Wilk test was applied to assess the normality of continuous variables.

Univariate logistic regression was performed to evaluate the association between individual variables and ICU admission within the first 48 hours postoperatively. The independent variables included demographic factors (e.g., age, sex, BMI), preoperative characteristics (e.g., ASA classification, smoking status, comorbidities), intraoperative parameters (e.g., estimated blood loss, lowest heart rate, lowest mean arterial pressure, type and duration of anesthesia), and surgical characteristics (e.g., type of surgery, emergency vs. elective surgery). The association between each variable and ICU admission was quantified using odds ratios (OR) with 95% confidence intervals (CI), and statistical significance was determined using two-tailed p-values, with values less than 0.05 considered significant. To assess the predictive performance of the SAS and the SASA, ROC curve analysis was conducted. The area under the AUC was calculated for both scoring systems to evaluate their discriminative ability in predicting ICU admission. ROC curves were compared to determine whether SASA demonstrated superior predictive accuracy over SAS alone.

All statistical analyses were conducted using Stata/BE version 18.0 (Stata Corp, College Station, TX). Data were thoroughly reviewed for completeness and accuracy, and validation procedures were performed to ensure the robustness and reliability of the results.

RESULTS

Demographic Data

A total of 242 patients who underwent intra-abdominal surgeries were included in the study, with 24 patients (9.9%) requiring ICU admission within the first 48 hours postoperatively. The mean age was 58.25 (SD = 15.41) years, and 137 patients (56.6%) were male. All perioperative variables analyzed, including age, sex, weight, height, BMI, ASA classification, emergency surgery status, smoking status and ICU admission status, were completely recorded without missing data. Comparisons between ICU and non-ICU patients identified several factors significantly associated with ICU admission. Sex was not significantly associated with ICU admission, with 66.67% of ICU-admitted patients being male compared to 55.50% in the non-ICU group (OR = 1.60, p = 0.298, area under the receiver operating characteristic [auROC] = 0.56). Age was higher in ICU-admitted patients, with a mean of 66.96 years compared to 59 years in the non-ICU group, and each additional year was associated with a 5% increase in ICU admission odds (OR = 1.05, p = 0.005, auROC = 0.68). Weight, height, and BMI showed no significant differences between groups (p > 0.05). ASA classification showed no ICU admissions among ASA I patients, while ASA III and ASA IV patients accounted for 66.67% and 25.00% of ICU admissions, respectively (OR = 36.5 and 219, p < 0.001). Emergency surgery was performed in 37.50% of ICU-admitted patients and 22.48% of non-ICU patients (OR = 2.07, p = 0.107, auROC = 0.58).

Table 3. Preoperative demographic and clinical characteristics of ICU and non-ICU patients

Variable		ICU admission (n = 24)	No ICU admission (n = 218)	OR	p-value	auROC
Sex (male), n (%)		16 (66.67%)	121 (55.50%)	1.60 (0.66-3.90)	0.298	0.56
Age, mean (SD)		66.96 (8.07)	57.30 (15.74)	1.05 (1.02-1.09)	0.005	0.68
Weight (kg), median (IQR range)		62.5 (56.5, 68.5)	64.50 (57.73)	0.99 (0.96-1.02)	0.494	0.54
Height (cm), mean (SD)		161.26 (7.44)	162.35 (8.56)	0.98 (0.94-1.04)	0.550	0.55
BMI (kg/m²), mean (SD)		24.23 (3.80)	24.21 (21.95)	0.97 (0.88-1.07)	0.527	0.51
ASA classification, n (%)	ASA I	0.00 (0.00%)	38 (17.43%)	Not applicable		0.90
	ASA II	2 (16.00%)	146 (66.97%)	Reference		
	ASA III	16 (66.67%)	32 (14.68%)	36.50 (7.99-166.71)	< 0.001	
	ASA IV	6 (25.00%)	2 (0.92%)	219.00 (26.20-1,830.38)	< 0.001	
Emergency surgery, n (%)		9 (37.50%)	49 (22.48%)	2.07 (0.85-5.02)	0.107	0.58
Smoking, n (%)		4 (16.67%)	37 (16.97%)	0.98 (0.32-3.03)	0.970	0.50

Table 4. Intraoperative characteristics and surgical details of ICU and non-ICU patients

Variable		ICU admission (n = 24)	No ICU admission (n = 218)	OR	p-value	auROC
Type of surgery: Urological surgery, n (%)		6 (8.82%)	62 (91.18%)	0.84 (0.32-2.21)	0.722	0.52
Open abdominal surgery, n (%)		20 (83.33%)	79 (36.24%)	8.80 (2.90-26.65)	< 0.001	0.74
Operation time (hr), median (IQR)		2.70 (1.17, 5.75)	0.76 (0.58, 1.17)	2.53 (1.82-3.50)	< 0.001	0.86
General anesthesia, n (%)		23 (10.70%)	192 (89.30%)	3.11 (0.40-24.03)	0.276	0.54
Anesthesia time (hr), median (IQR)		3.08 (1.75, 6.83)	1.17 (0.92, 1.58)	2.35 (1.74-3.18)	< 0.001	0.86
Lowest heart rate (beats/min)	> 85	7 (29.17%)	15 (6.88%)	43.40 (4.98-378.25)	0.001	0.74
	76-85	3 (12.50%)	16 (7.34%)	17.44 (1.71-178.24)	0.016	
	66-75	3 (12.50%)	28 (12.84%)	9.96 (1.00-99.61)	0.050	
	56-65	10 (41.67%)	66 (30.28%)	14.09 (1.76-112.76)	0.013	
	< 55	1 (4.17%)	93 (42.66%)	Reference		
Lowest mean arterial pressure (mmHg)	< 40	0 (0.00%)	0 (0.00%)	Not applicable		0.79
	40-54	4 (16.67%)	3 (1.38%)	43.47 (7.62-248.01)	< 0.001	
	55-69	15 (62.50%)	52 (23.85%)	9.40 (3.26-27.12)	< 0.001	
	> 70	5 (20.83%)	163 (74.77%)	Reference		
Estimated blood loss (ml)	> 1,000	4 (16.67%)	1 (0.46%)	113.71 (11.21-1154.01)	< 0.001	0.82
	600-1,000	5 (20.83%)	1 (0.46%)	142.14 (14.60-1383.43)	< 0.001	
	101-600	8 (33.33%)	17 (7.80%)	13.38 (4.33-41.37)	< 0.001	
	< 100	7 (29.17%)	199 (91.28%)	Reference		

Note. hr: Hour; mmHg: Millimeters of mercury; & ml: Milliliters

Smoking status was reported in 16.67% of ICU patients and 16.97% of non-ICU patients, with no significant difference (OR = 0.98, p = 0.970, auROC = 0.50). Additional details on variable distributions and statistical measures are provided in **Table 3**.

Among the 24 ICU patients, the most common comorbidities were hypertension (HT) in 14 patients (58.3%), dyslipidemia (DLP) in 10 (41.7%), chronic kidney disease (CKD) in 9 (37.5%), and diabetes mellitus (DM) in 8 (33.3%). Other conditions included sepsis in 3 patients (12.5%), ischemic and hemorrhagic strokes in 2 each (8.3%), ischemic heart disease (IHD) and arrhythmia in 2 each (8.3%), with asthma, hypothyroidism, cirrhosis, and HIV observed in 1-2 patients (4.2%-8.3%).

Among the 218 non-ICU patients, HT was reported in 88 individuals (40.4%), DLP in 102 (46.8%), and CKD stage 3 in 44 (20.2%). DM was present in 43 (19.7%), while obesity was noted in 18 patients (8.3%) and HIV in 15 (6.9%). Ischemic stroke was recorded in 8 patients (3.7%), while valvular heart disease (VHD), chronic obstructive pulmonary disease (COPD), and obstructive sleep apnea (OSA) were observed in 2 patients each (0.9%). Less frequent conditions included asthma, hyperthyroidism, hypothyroidism, hemorrhagic stroke, and seizures, each affecting 1-3 patients (0.5%-1.4%).

Operative and Intraoperative Characteristics

ICU admission rates varied by surgical type and anesthesia type. Urological surgery accounted for 8.82% of ICU admissions compared to 91.18% in the non-ICU group (OR = 0.84, p = 0.722, auROC = 0.52). Open abdominal surgery was more frequent among ICU patients (83.33%) than non-ICU patients (36.24%), with an OR of 8.80 (p < 0.001, auROC = 0.74). The median operation time was longer in ICU patients (2.70 vs. 0.76 hours, OR = 2.53, p < 0.001, auROC = 0.86). Regarding anesthesia type, general anesthesia was used in 10.70% of ICU patients and 89.30% of non-ICU patients (OR = 3.11, p = 0.276, auROC = 0.54), with longer anesthesia duration among ICU admissions (3.08 vs. 1.17 hours, OR = 2.35, p < 0.001, auROC = 0.86).

Several intraoperative factors were associated with ICU admission. The lowest heart rate was lower in ICU patients, with 41.67% having heart rates of 56-65 bpm compared to 30.28% in the non-ICU group (OR = 14.09, p = 0.013). Heart rates >85 bpm were associated with higher ICU admission (29.17% vs. 6.88%, OR = 43.40, p = 0.001, auROC = 0.74). Lowest mean arterial pressure (MAP) was < 55 mmHg in 16.67% of ICU patients compared to 1.38% in the non-ICU group (OR = 43.47, p < 0.001, auROC = 0.79).

Estimated blood loss was significantly different between groups. Blood loss exceeding 1,000 mL occurred in 16.67% of ICU patients compared to 0.46% in non-ICU patients (OR = 113.71, p < 0.001, auROC = 0.82). Blood loss between 600-1,000 mL accounted for 20.83% of ICU admissions (OR = 142.14, p < 0.001), while 33.33% of ICU patients had blood loss between 101-600 mL compared to 7.80% of non-ICU patients (OR = 13.38, p < 0.001).

Table 4 provides more details on intraoperative parameters and how they relate to ICU admission.

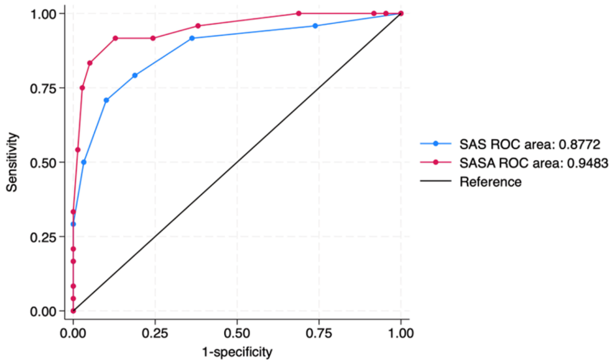

Figure 1. ROC curve comparison of SASA and SAS for ICU admission prediction (Source: Authors' own elaboration)

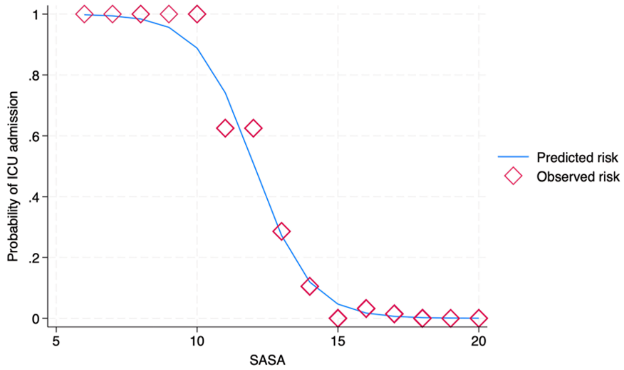

Figure 2. Calibration plot of predicted vs. observed risk of ICU admission on SASA scores (Source: Authors' own elaboration)

All ICU admissions (100%) were associated with acute clinical conditions requiring intensive care. The most common reasons for ICU admission were hemodynamic instability (n = 16, 66.7%) and hypovolemic shock (n = 4, 16.7%). Other conditions included opioid overdose, pulmonary embolism, septic shock, and asthmatic attack (4.2% each, n = 1).

Complications during ICU stays occurred in 15 patients (62.5%), underscoring the complexity of managing critically ill surgical patients. The most frequent ICU complications were sepsis with septic shock (n = 4, 26.7%), death (n = 4, 26.7%), and anastomotic leakage (n = 2, 13.3%). Other complications included atrial fibrillation, alcohol withdrawal, pulmonary embolism, small bowel obstruction, and unstable bradycardia, each occurring in 1 patient (6.7%).

Predictive Role of SASA

The SAS and the SASA demonstrated strong predictive capabilities for ICU admission. ICU patients had significantly lower SAS scores (mean 5.58 ± 2.10) compared to non-ICU patients (median 9, IQR 8-10; OR = 0.37, p < 0.001), with an initial auROC curve of 0.8772. Similarly, SASA scores were significantly lower in ICU patients (mean 11.25 ± 2.61) compared to non-ICU patients (median 17, IQR 16-18; OR = 0.36, p < 0.001), with an initial auROC of 0.9483.

Figure 1 illustrates the ROC curves for both models, with the blue line representing SASA and the red line representing SAS. The ROC curve for SASA demonstrates higher sensitivity and specificity across the risk spectrum, confirming its enhanced predictive accuracy. A Chi-squared test (χ^2 = 7.24, p = 0.007) confirmed the statistically significant improvement in predictive performance by SASA over SAS. These findings support SASA as a more reliable tool for identifying patients at higher risk of ICU admission.

Both scoring systems exhibited an inverse relationship with ICU admission risk, with lower scores indicating a higher likelihood of ICU admission. To enhance the accuracy of predictive performance interpretation, the auROC values were adjusted by subtracting the initial values from 1, resulting in corrected auROC values of 0.8772 for SAS and 0.9483 for SASA. This adjustment underscores SASA's superior predictive performance compared to SAS. Based on the ROC curve analysis, an optimal SASA cutoff score of 13 was determined, yielding a sensitivity of 83.33% and a specificity of 94.95% for predicting ICU admission (auROC = 0.9483).

The calibration plot comparing predicted and observed risks of ICU admission based on SASA scores demonstrated strong agreement across the risk spectrum. As shown in **Figure 1**, the predicted risk (blue line) closely aligns with the observed risk (red diamonds), particularly at lower and intermediate SASA scores. At higher SASA scores (above 15), the predicted risk stabilizes near zero, reflecting the minimal likelihood of ICU admission in this range. The calibration curve in **Figure 2** indicates that the SASA model reliably estimates ICU admission risk, with no significant over- or underestimation observed. **Appendix A** shows patient flow chart, ROC analysis for predictive performance of SASA and SAS, and comparison of predictive accuracy between SASA and SAS.

DISCUSSION

SAS primarily evaluates intraoperative risk factors, with lower scores associated with increased ICU admissions and prolonged ICU stays. Additionally, poor SAS scores have been linked to delayed ICU transfers for patients initially managed on the general ward [16]. Conversely, the ASA-PS assesses preoperative health status, with increasing ASA-PS scores correlating with higher mortality risks [17-19]. Meta-analysis in [18] confirmed that mortality rises exponentially beyond ASA-PS III. The integration of these two systems within SASA provides a more comprehensive assessment of both preoperative physiological reserves (ASA-PS) and intraoperative events (SAS), enhancing risk prediction accuracy. In resource-constrained settings, ICU availability is often limited, making effective patient selection crucial for optimizing outcomes and reducing mortality rates [5]. Our study aimed to develop a promising tool for predicting ICU admission within the first 48 hours after intra-abdominal surgery. The findings indicate that SASA is a highly accurate model, demonstrating superior performance over SAS alone in identifying patients who require critical care.

Several studies support the combined use of SAS and ASA-PS for improving postoperative risk stratification, particularly in high-risk surgeries [13, 17, 20]. The SASA model enhances risk assessment by integrating comorbidities and intraoperative stability markers, refining postoperative risk prediction [20]. Notably, previous research has demonstrated that while SAS and ASA-PS individually predict complications and mortality, their combined use improves specificity and overall predictive performance [17]. Our study found that SASA exhibited superior predictive accuracy for ICU admission, with an adjusted auROC of 0.95, significantly higher than SAS alone (auROC 0.88). These findings align with previous studies emphasizing the importance of multifactorial risk assessment models in postoperative outcome prediction.

Previous research has shown that the auROC of SAS for predicting major postoperative complications ranges from 0.63 to 0.73, indicating moderate discriminatory ability [21-23]. However, SASA demonstrated superior performance, particularly in predicting ICU admission. Our findings confirmed a strong correlation between predicted and observed ICU admission risks, reinforcing the model's reliability. Additionally, the results revealed an inverse relationship between SASA scores and ICU admission probability, further validating its clinical applicability. A statistically significant Chi-squared test ($p = 0.007$) confirmed SASA's superior predictive ability compared to SAS.

One explanation for the superior utility of SASA over SAS lies in its inclusion of comorbidities, which are a significant determinant of ICU admission risk. Patients requiring ICU admission exhibited higher rates of chronic conditions such as HT, DLP, and CKD, as well as acute conditions like sepsis and cerebrovascular events [24]. The inclusion of ASA classification in SASA systematically integrates these comorbidities, enhancing predictive accuracy. Intraoperative factors such as prolonged operative time, significant blood loss, and hemodynamic instability were strongly associated with ICU admission. Persistent intraoperative tachycardia and hypotension have been independently linked to increased postoperative morbidity, ICU admission rates, and prolonged hospital stays [12, 25-27]. In addition, patients undergoing open abdominal surgery had significantly higher ICU admission rates than those undergoing laparoscopic surgery. Open procedures were associated with greater blood loss, increased transfusion requirements, and higher postoperative ventilation rates [28]. Laparoscopic techniques, particularly in high-risk patients, have been associated with shorter ICU stays, reduced hospital stays, and lower mortality rates [29, 30]. These findings underscore the technical and clinical benefits of laparoscopic surgery in optimizing postoperative outcomes.

The SASA scoring system enables rapid and comprehensive postoperative risk assessment, serving as an objective tool for prioritizing high-risk patients who require intensive monitoring. By quantifying perioperative risk, SASA also facilitates more precise ICU resource allocation, particularly in settings with limited capacity. Furthermore, it can support shared decision-making by providing anesthesiologists, surgeons, ICU teams, patients, and families with a clearer understanding of postoperative risks and ICU admission likelihood.

Integration of SASA into clinical workflows could enhance interdisciplinary collaboration between surgical and critical care teams, improving planning for postoperative management and ICU triage. However, despite its promising predictive performance, several practical barriers to the clinical adoption of SASA must be considered. These include limited clinician awareness, unfamiliarity with the scoring system, challenges in integrating it into time-constrained clinical workflows, and variability in data documentation practices across institutions. Integrating SASA into electronic medical record (EMR) systems with automated calculation features may help address these challenges and promote wider clinical implementation. Integrating scoring systems and clinical calculators into EMRs provides numerous advantages for healthcare providers and patients. Integration enhances accuracy by minimizing manual errors and increasing compliance with clinical guidelines, as shown by the early-onset sepsis risk calculator, which reduced miscalculations from 52% to 19% and improved compliance from 93% to 98% [31]. Efficiency also improves, with faster clinical interventions—such as reducing intervention time from 24 hours to within one working shift after integrating a pharmacokinetics scoring module and more streamlined workflows that prioritize high-risk patients [32, 33]. Integration standardizes clinical services across multiple hospitals and supports the automatic prioritization of patient care [33].

Despite these strengths, this study has several limitations. First, its retrospective study design may introduce selection bias, which we attempted to minimize through comprehensive data collection and statistical adjustments; however, future prospective studies are necessary to confirm these findings. Second, the single-center setting may limit external generalizability, emphasizing the need for multicenter studies to validate SASA's predictive accuracy across diverse healthcare settings. Third, the short-term follow-up period, focusing only on ICU admission within the first 48 hours, prevents assessment of long-term outcomes such as 30-day mortality and overall hospital length of stay. Future large prospective studies should incorporate extended follow-up to determine whether using SASA to guide admission setting (ICU or non-ICU) improves survival and reduces complications. Fourth, the study was limited to intra-abdominal surgeries without balancing the number of cases between surgical specialties, due to its retrospective design. This limitation restricts the ability to directly compare the efficacy of the scoring system across different surgical fields. We acknowledge that future studies are needed to balance subgroup sizes across various surgical specialties and techniques—such as different surgical scopes and robot-assisted surgeries—and to expand the investigation to a broader range of high-risk procedures, including thoracic, craniofacial, and spine surgeries, to more comprehensively assess the clinical utility of SASA.

CONCLUSION

This study highlights SASA as a superior predictive tool for ICU admission following intra-abdominal surgery. By integrating preoperative and intraoperative risk factors, SASA provides a comprehensive risk assessment, allowing for better ICU resource allocation, improved risk stratification, and enhanced patient outcomes. The findings emphasize the clinical utility of SASA in both high-resource and resource-limited settings, reinforcing its potential as a standard risk assessment tool in perioperative care.

Author contributions: KB: conceptualization, methodology, project administration, data analysis, writing–original draft preparation, and supervision; **RC:** writing–original draft preparation; **WT:** critical revision of the manuscript and final approval; & **SP:** Research concept and design, data analysis and interpretation, critical revision of the article, and final approval. All authors have agreed with the results and conclusions.

Funding: This study was funded by Bamrasnaradura Infectious Diseases Institute, Bangkok, Thailand.

Ethical statement: The authors stated that the study was approved by the Bamrasnaradura Infectious Diseases Institute Ethics Committee on 24 May 2024 with approval number S011h/67_ExPD. Written informed consents were obtained from the participants.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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APPENDIX A

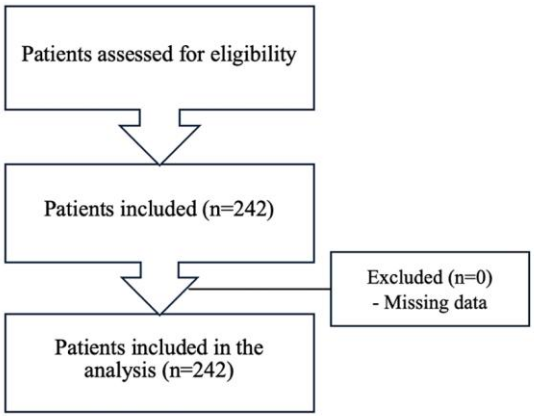

Figure A1. Patient flow chart (Source: Authors' own elaboration)

Table A1. ROC analysis for predictive performance of SASA and SAS models

Model	Observations (n)	ROC area	Standard error	95% CI
SASA	242	0.9483	0.0255	0.89837-0.99822
SAS	242	0.8772	0.0433	0.79232-0.99822

Table A2. Comparison of predictive accuracy between SASA and SAS models

Comparison	Chi-square (χ^2)	p-value
SASA vs. SAS	7.24	0.007