ORIGINAL ARTICLE

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Comparison of Surgical Apgar Score and Time-Based Modification for Predicting Postoperative Complications in Major Abdominal and Orthopedics Surgery

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Abstract

Objective: The primary aim of this study was to compare surgical Apgar score (SAS) and time-based modification, modified SAS (mSAS), for predicting postoperative 30-day complications and mortality in major abdominal and orthopedic surgeries.

Methods: This prospective study included 308 patients who underwent major abdominal and orthopedic surgery between June and September 2017 at University of Health Sciences Turkey, Prof. Dr. Cemil Taşcıoğlu City Hospital. SAS was calculated based on estimated blood loss, lowest heart rate, and mean arterial pressure. mSAS was calculated by adding surgical duration to SAS. If the surgical duration >480 min, we added -4 points to the SAS score; 421-480 min, -3 points; 301-420 min, -2 points; 181-300 min, -1 points; and <180 min, 0 points.

Results: The comparison of area under curve (AUCs) revealed that the mSAS had a higher diagnostic accuracy for predicting ICU admission [AUC: 0.680, confidence interval (CI) 95% 0.620-0.738, p<0.001], ventilator support more than 48 h (AUC: 0.791, CI 95% 0.657-0.885, p=0.020), reintubation (AUC: 0.665, CI 95% 0.509-0.813, p=0.025), reoperation (AUC: 0.682, CI 95% 0.580-0.777, p=0.019), pneumonia (AUC: 0.626, CI 95% 0.498-0.747, p<0.001), need for albumin replacement (AUC: 0.712, CI 95% 0.648-0.772, p<0.001), and vasopressor requirement (AUC: 0.640, CI 95% 0.470-0.781, p<0.001) than the SAS.

Conclusion: We suggest that operation time should be added as a simple, objective, and practical parameter to SAS. mSAS might be more effective in predicting postoperative outcomes.

Keywords: Morbidity, mortality, perioperative care, postoperative complications, surgery

INTRODUCTION

Over the past decades, high-risk surgical procedures have become more common because of medical developments (1,2). In terms of health economics and patient safety, the rational use of limited resources with the goal of reducing mortality and postoperative complication rates is essential (2). To this end, many types of scoring systems have been developed to predict the risk of perioperative mortality and morbidity (1-4). However, surgical teams have not had a reliable tool for routine use at the end of surgery (5).

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Gawande et al. (5) defined the surgical Apgar score (SAS) in 2007. The score was based on three intraoperative parameters, including the lowest heart rate (HR), estimated blood loss (EBL), and mean arterial pressure (MAP). SAS was initially validated randomly selected patients undergoing colectomy. Subsequently, the score has been validated in various surgical procedures to predict postoperative complications and mortality (6-10). In addition, some investigators have created modified versions of SAS for patients with various diseases. Yu et al. (11) added plasma brain natriuretic peptide as a parameter to predict postoperative cardiac events. Pearson et al. (12) used the intraoperative blood transfusion volume instead of the EBL parameter. In elderly patients undergoing abdominal cancer surgery, combining the comprehensive geriatric assessment tool and SAS improved short-term outcome prediction (13). On the other hand, the effect of operation duration on postoperative complications and mortality has been demonstrated in previous studies (14,15). Iino et al. (16) reported that prolonged cross-clamping during aortic valve replacement is an independent factor for postoperative complications and mortality. A previous study also presented a modified version by adding the operation duration as a parameter to the SAS in emergency surgery (17).

Here, we presented a study analyzing patients undergoing major abdominal and orthopedic surgery using SAS for predicting postoperative complications and mortality. We also added the operation duration to the SAS as a simple parameter and determined the diagnostic accuracy of this novel modification in this cohort.

METHODS

Participants and Settings

This prospective study was approved by the local ethics committee of Prof. Dr. Cemil Taşcıoğlu City Hospital, University of Health Sciences Turkey (IRB number: 658; date: May 9th, 2017).

The study protocol was registered at clinicaltrials.gov (ID: NCT04010474). Patients who underwent major abdominal and orthopedic surgery under general or regional anesthesia between June and September 2017 were enrolled in the study. Patients <18 years were excluded. All procedures in this study were performed in accordance with the standards described in the Declaration of Helsinki, revised in 2013 (18). Written informed consent was obtained from the participants or their next of kin.

The sample size calculation revealed a minimum of 275 patients to detect an area under the receiver operator characteristics curve (AUC) value of 0.70 with a power of 90% and an α error of 0.05 (19). Finally, 313 patients were enrolled in the study to compensate for possible dropouts.

Variables

Demographic data, ASA scores, type of surgery, diagnosis, type and amount of preoperative blood product transfusions, and anesthetic methods were recorded. The Glasgow Coma Scale was calculated on the 24th hour after surgery for all patients. The SOFA score was determined on the first day of the intensive care unit (ICU) stay. The length of hospital and ICU stay were recorded.

Major events were defined as mental alterations, acute kidney injury (AKI), major bleeding, cardiopulmonary resuscitation, reoperation, deep venous thrombosis, septicemia, septic shock, acute myocardial injury, new-onset arrhythmia, reintubation, need for invasive mechanical ventilation more than 48 hours, pulmonary thromboembolism, vasopressor requirement, surgical site infection, and need for albumin replacement.

Definition of the Variables

Mental alterations were defined as a comatose state or unconsciousness for ≥24 hours. AKI was defined according to kidney disease: improving global outcomes (20). Major bleeding is defined as bleeding requiring more than 4 units of red blood cell transfusion within 72 h. The diagnosis of thromboembolic events depends on the ultrasonographic or angiographic evidence. Septicemia or septic shock was diagnosed according to the current guidelines (21). Acute myocardial injury was identified as a higher serum concentration of high-sensitive troponin I than the upper reference limit. Diagnosis of surgical site infection based on a previous study (22).

Definition of Modified SAS

The modified SAS (mSAS) score was calculated by adding the duration of surgery to the SAS parameters of the lowest HR, EBL, and MAP. If the surgical duration >480 min, we added -4 points to the SAS score; 421-480 min, -3 points; 301-420 min, -2 points; 181-300 min, -1 points; and <180 min, 0 points (Table 1). Risk categories were defined as low (8-10 points), medium (5-7 points), and high (0-4 points) for bothSAS and mSAS.

For each patient, radial artery catheterization was performed 30 min before surgery to allow real-time MAP and HR monitoring The calculation of EBL was based on the sum of the aspirated blood volume and the number of blood packs. The lowest HR and MAP values were documented from the electronic medical record. The duration of surgery was defined as the time from the induction of anesthesia to the end of surgery.

Table 1. Modified Surgical Apgar score					
mSAS parameters	**0**	**1**	**2**	**3**	**4**
Estimated blood loss (ml)	>1,000	601-1,000	101-600	≤100	-
Lowest MAP (mmHg)	<40	40-54	55-69	≥70	-
Lowest HR (/min)	>85	76-85	66-75	56-65	≤55
	-4	**-3**	**-2**	**-1**	**0**
Surgical duration (min)	>480	421-480	301-420	181-300	≤180
Risk categorization					
High	**Medium**		**Low**		
0-4 points	5-7 points		8-10 points		
The lowest score might be 0 points. MAP: Mean arterial pressure, HR: Heart rate					

Outcomes

The primary outcome of the study was to compare SAS and mSAS. Secondary outcomes are to determine the diagnostic accuracy of SAS and mSAS for postoperative mortality and major complications within 30 days after surgery and to reveal the effect of operation duration on these outcomes.

Statistical Analysis

Statistical analysis was performed using the Number Cruncher Statistical System (NCSS, Kaysville, Utah, USA) version 2007. All data are presented as mean ± standard deviation, frequency and percentage, and median with minimum and maximum values. Chi-square test and Fisher-Freeman-Halton test were used to compare the qualitative data. Spearman's correlation analysis was used to evaluate the association between variables. The intraclass correlation coefficient was used to assess the agreement between the SAS and mSAS scores and risk groups.

Predictive abilities of SAS and mSAS for each complication and death were evaluated using the AUC with the pROC library in the R statistical program (version 3.6.1, R Core Team; R Foundation for Statistical Computing, Austria) (23). Bootstrap with 10,000 replications was used for bias correction in AUC with 95% confidence interval estimations. Results based on both original data and bootstrapped samples are presented. Comparison of SAS and mSAS regarding the AUCs were performed using the DeLong and Bootstrap methods. The p-values obtained from both the De-Long and bootstrap methods are presented. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 308 patients were included in the study after excluding 5 patients because of the decision of inoperability after laparotomy or surgical plan changed to a minor procedure (Figure 1). Four patients died after hospital discharge. Thus, the analysis of major complications within 30 days after surgery was completed in 304 patients. Of the patients, 54.92% were male, and most patients were ≤65 years (Table 2). Most patients underwent abdominal surgery. The ASA II and ASA III rates were 54.5% and 26.0%, respectively. Most patients (88.6%) underwent surgery under general anesthesia. The median operation duration was 190 (140.0-269.5) min. The operation duration of most patients was 180 min. The rates of patients with operation durations of 181-300 min and 301-420 min were 33.8% and 14.3%, respectively. The median length of hospital and ICU stays was 6 (4-8) and 1 (0-1) days, respectively. The median SOFA score of the patients was 1 (0-2). The mean duration of ventilator support was 0.27±2.02.

The rates of the lowest HR during operations were 29.2% for ≤55/min, 34.4% for 56-65 in, 20.1% for 66-75 in, 10.4% for 76-85 in, and 5.8% for <85 min. The distribution of the lowest MAP was as

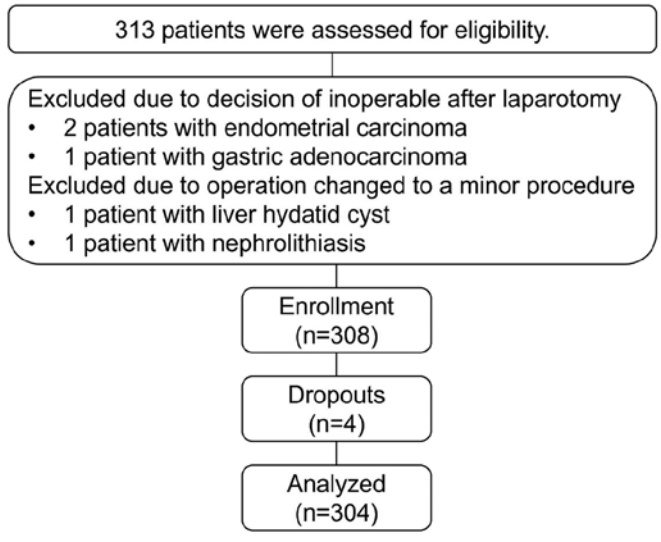

Figure 1. Flow chart of the study

follows: <40 mmHg (1.3%), 40-54 mmHg (18.8%), 55-70 mmHg (38.3%), and more than 70 mmHg (41.6%). EBL was <1,000 mL in 10.7% of the patients, 601-1,000 mL in 14.9%, 101-600 mL in 61.4%, and <100 mL in 13.0%.

The means of the SAS and mSAS risk scores were 7±2 and 6±2 points, respectively (Figure 2). Of the patients, 10.4% (n=32) were at high risk, 54.5% (n=168) at medium risk, and 35.1% (n=108) at low risk, according to the SAS. However, evaluation of the patients with mSAS revealed that 22.4% (n=69) of the patients were at high risk, 54.2% (n=167) at medium, and 23.4% (n=72) at low risk. The relationship between the SAS and mSAS risk groups and the total number of complications are presented in Figures 3 and 4. Statistical analysis determined a significant relationship between the SAS risk score and the total number of complications (p=0.002) and between the mSAS risk score and the number of complications (p=0.001). The rates of patients without a complication in the low-risk group and with one or more complications in the medium-risk group were significantly high, according to mSAS. Additionally, the rate of patients with complications ≥4 was significantly high in the high-risk group of mSAS.

The correlation analysis revealed a significant negative correlation between the SAS (r=-0.270; p=0.001) and mSAS (r=-0.389; p=0.001) scores and the total number of complications. In addition, a positive correlation was observed between the length of operation duration and the total number of complications (r=0.345; p=0.001).

Table 2. Characteristics of patients and operations

Variables	All patients (n=308)
Age, years	
≤65	191 (62.0)
66-75	70 (22.7)
75-85	35 (11.4)
>85	12 (3.9)
Gender, male	169 (54.9)
Surgical branch	
General surgery	139 (45.1)
Orthopedics	101 (32.8)
Urology	68 (22.1)
ASA score	
ASA I	60 (19.5)
ASA II	168 (54.5)
ASA III	80 (26)
Anesthesia type	
General	273 (88.6)
Regional	35 (11.4)
Glasgow coma scale	15-15 (15)
	15±1
Duration of operation, min	140-269.5 (190)
>480	9 (2.9)
421-480	3 (1.0)
301-420	44 (14.3)
181-300	104 (33.8)
≤180	148 (48.1)
Length of, days	
Hospital stay	6 (4-8)
ICU stay	1 (0-1)
SOFA score	1.0 (0.0-2.0)
	1.0±1.0
Duration of ventilatory support, days	0 (0-0)
	0.27±2.02

All values are expressed as number (percentages), median (interquartile range) and/or mean ± standard deviation.
ASA: American Society of Anesthesiologists, SOFA: Score, Sequential Organ Failure Assessment score.

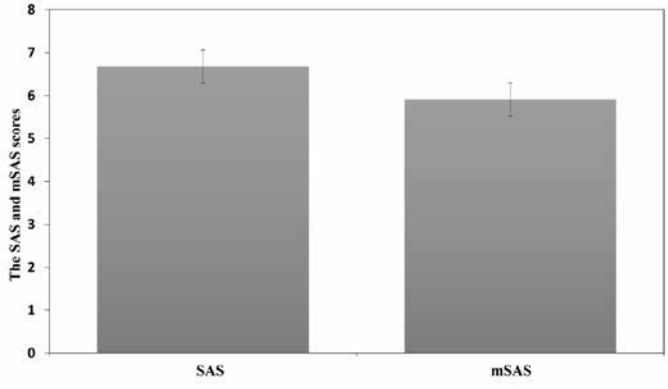

Figure 2. Distribution of SAS and mSAS scores
SAS: Surgical Apgar score

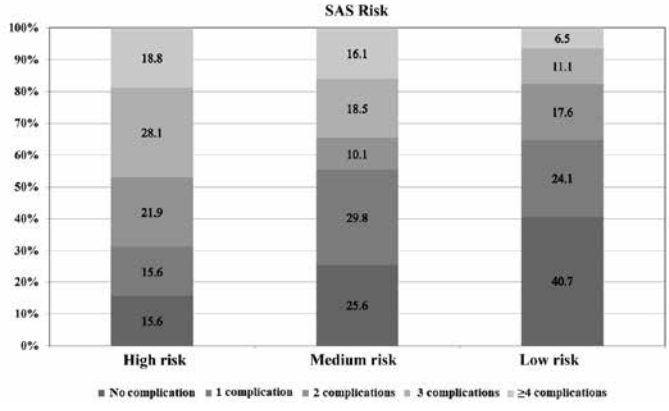

Figure 3. Relationship between SAS risk level and total number of complications
SAS: Surgical Apgar score

Thirty-two of the patients were in the high-risk group, according to SAS and mSAS. SAS revealed that 168 patients were in the medium-risk group. However, 36 of these 168 patients were in the high-risk group, according to the mSAS. Additionally, 36 of 108 patients with low risk based on the SAS were in the medium-risk group, according to the mSAS. The SAS and mSAS levels showed an agreement of 76.6%. The analysis revealed significant agreements between the SAS and mSAS risk levels (ICC=0.742, p=0.001) and scores (ICC=0.822, p=0.001).

A comparison of SAS and mSAS risk levels and complications and mortality are shown in Table 3. The analysis revealed that ICU admission (p=0.037), ventilator support more than 48 h (p=0.042), bleeding requiring transfusion (p=0.001), and need for albumin replacement (p=0.001) were significantly higher in high-risk patients than in lower-risk, according to the SAS. However, the postoperative major events, including ICU admission (p=0.001), ventilator support more than 48 h (p=0.005), reoperation (p=0.009), bleeding requiring transfusion (p=0.001), and need for albumin replacement (p=0.001), were significantly higher in high-risk patients than in lower-risk.

The relationship between the operation duration and postoperative complications and mortality is shown in Table 4. The analysis revealed a significant difference between the duration of ICU admission (p=0.001), ventilator support >48 h (p=0.002), reintubation (p=0.014), reoperation (p=0.001), bleeding requiring transfusion (p=0.001), new-onset arrhythmia (p=0.002), pneumonia (p=0.003), sepsis or septic shock (p=0.002), cardiac arrest (p=0.049), cardiopulmonary resuscitation (p=0.049), need for albumin replacement (p=0.001), and vasopressor requirement (p=0.010). The post-hoc analysis with the Bonferroni correction test revealed that the rate of patients with bleeding requiring transfusion was higher in patients with

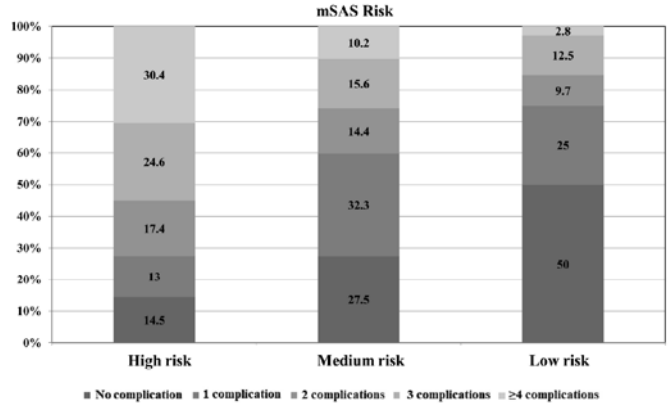

Figure 4. Relationship between mSAS risk level and total number of complications

SAS: Surgical Apgar score

operation duration >420 min than in patients with operation duration between 301 and 420 min (p=0.042). Additionally, the rate of ICU admission (p=0.006), ventilator support more than 48 h (p=0.025), bleeding requiring transfusion (p<0.001), new-onset arrhythmia (p=0.018), sepsis or septic shock (p=0.048), cardiac arrest (p=0.019), cardiopulmonary resuscitation (p=0.017), and need for albumin replacement (p=0.006) were higher in patients with operation duration >420 min than in those with operation duration between 181 and 300 min. Similarly, the rate of ICU admission (p<0.001), ventilator support more than 48 h (p<0.001), bleeding requiring transfusion (p<0.001), and need for albumin replacement (p<0.001) were higher in patients with an operation duration >420 min than in patients with operation duration ≤180 minutes. In patients with operation duration between 301 and 420 min, the rates of ICU admission (p=0.006), reoperation (p=0.006), bleeding requiring transfusion (p=0.018), new-onset arrhythmia (p<0.001), sepsis or septic shock (p=0.007), and need for albumin replacement (p<0.001) were higher than those in patients with operation duration between 181 and 300 min. Additionally, in patients with an operation duration of 301-420 min, the rates of ICU admission (p<0.001), reintubation (p=0.013), reoperation (p<0.001), new-onset arrhythmia (p=0.023), pneumonia (p<0.001), sepsis or septic shock (p=0.019), need for albumin replacement (p<0.001), and vasopressor requirement (p<0.001) were higher than those in patients with operation duration ≤180 minutes.

ROC analyzes were conducted for each complication and death to test the diagnostic accuracy of the SAS and mSAS scores (Table 5 and Figure 5). The areas under the ROC curves were compared to test whether the proposed score was more effective than the SAS score in prognosis. Similar results were obtained based on the original data and bootstrapped samples. In the bootstrapped samples, the comparison of AUCs of complications, including ICU admission (AUC: 0.680, CI 95% 0.620-0.738, p<0.001), ventilator support more than 48 h (AUC: 0.791, CI 95% 0.657-0.885, p=0.020), reintubation (AUC: 0.665, CI 95% 0.509-0.813, p=0.025), reoperation (AUC: 0.682, CI 95% 0.580-0.777, p=0.019), pneumonia (AUC: 0.626, CI 95% 0.498-0.747, p<0.001), need for albumin replacement (AUC: 0.712, CI 95% 0.648-0.772, p<0.001), and vasopressor requirement (AUC: 0.640, CI 95% 0.470-0.781, p<0.001), determined significant differences between SAS and mSAS.

DISCUSSION

In the present study, we aimed to develop a novel SAS by adding operation duration as a simple parameter to the lowest HR, EBL, and MAP. The new modification, mSAS, showed high diagnostic

accuracy for predicting postoperative complications such as ICU admission, ventilator support >48 h, reoperation, and bleeding requiring transfusion in patients in the high-risk group. However, in this study, both SAS and mSAS were insufficient to predict 30-day mortality. AUC analysis showed that mSAS has higher diagnostic accuracy than SAS for predicting reintubation, ICU admission, albumin replacement, vasopressor requirement, reoperation, pneumonia, and ventilator support more than 48 hours. However, SAS is more effective than mSAS in predicting the risk of deep venous thrombosis.

Many diagnostic tools have been developed to predict postoperative complications and mortality (2). How intraoperative variables affect the risk factors associated with postoperative complications and mortality is still debated. Although a quantitative measure of intraoperative care has not been established, optimal management of intraoperative procedures improves postoperative outcomes. Researchers have developed various diagnostic tools that assess measurable intraoperative parameters such as arterial blood pressure, body temperature, heart rate, and blood loss to predict postoperative complications and mortality (3,4,24,25).

SAS has been validated in various surgical subgroups such as abdominal, vascular, urologic, gynecologic, orthopedic, and neurosurgical procedures (10,26-29). Perioperative measures should be monitored early to allow optimal timing of decisions regarding the need for intensive care in the postoperative period (1). Standard tools for predicting postoperative complications and mortality focused on preoperative risk assessment (19,30,31). In addition, intraoperative hemodynamic instability and bleeding volume were rarely included in diagnostic tools (32). Although SAS does not reveal the specific mechanisms that put patients at high risk for postoperative complications and mortality, it determines which patients require intensive care in the early postoperative period (5).

SAS is effective in various surgical subgroups but plays a limited role in orthopedic and elective surgical procedures (33). Similarly, Nair et al. (34) showed that SAS has variability in predicting postoperative complications and mortality in different surgical

Table 3. Comparison of complications and mortality based on SAS and mSAS risk levels

Complications	SAS risk levels				mSAS risk levels			
	High (n=32)	Medium (n=168)	Low (n=108)	p-value	High (n=68)	Medium (n=168)	Low (n=72)	p-value
Unconsciousness	0 (0.0)	5 (3.0)	2 (1.9)	*0.87	0 (0.0)	7 (4.2)	0 (0.0)	*0.07
ICU admission	23 (71.9)	91 (54.2)	50 (46.3)	†**0.037**	49 (72.1)	89 (53.0)	26 (36.1)	†**0.001**
Ventilator support more than 48 h	3 (9.4)	9 (5.4)	1 (0.9)	***0.042**	8 (11.8)	4 (2.4)	1 (1.4)	***0.005**
Reintubation	2 (6.3)	4 (2.4)	3 (2.8)	*0.40	3 (4.4)	6 (3.6)	0 (0.0)	*0.18
Reoperation	3 (9.4)	13 (7.7)	4 (3.7)	†0.33	7 (10.3)	13 (7.7)	0 (0.0)	***0.009**
Bleeding requiring transfusion	20 (62.5)	81 (48.2)	32 (29.6)	†0.001	45 (66.2)	70 (41.7)	18 (25.0)	†**0.001**
Surgical site infection	2 (6.5)	9 (5.4)	9 (8.4)	†0.62	5 (7.5)	10 (6.0)	5 (7.0)	*0.86
New-onset arrhythmia	0 (0.0)	7 (4.2)	2 (1.9)	*0.52	1 (1.5)	7 (4.2)	1 (1.4)	*0.47
Myocardial injury	0 (0.0)	2 (1.2)	0 (0.0)	*0.61	1 (1.5)	1 (0.6)	0 (0.0)	*0.45
Pneumonia	1 (3.2)	10 (6.0)	5 (4.7)	†0.77	6 (9.0)	9 (5.4)	1 (1.4)	*0.14
Sepsis or septic shock	1 (3.2)	8 (4.8)	7 (6.5)	†0.71	3 (4.5)	11 (6.6)	2 (2.8)	*0.48
Bacteraemia	2 (6.5)	5 (3.0)	5 (4.7)	*0.46	5 (7.5)	4 (2.4)	3 (4.2)	*0.19
Acute kidney injury	1 (3.2)	3 (1.8)	0 (0.0)	*0.15	1 (1.5)	3 (1.8)	0 (0.0)	*0.66
Deep venous thrombosis	0 (0.0)	2 (1.2)	0 (0.0)	*0.61	0 (0.0)	2 (1.2)	0 (0.0)	*1.00
Pulmonary embolism	0 (0.0)	1 (0.6)	0 (0.0)	*1.00	0 (0.0)	1 (0.6)	0 (0.0)	*1.00
Cardiac arrest	1 (3.2)	2 (1.2)	0 (0.0)	*0.21	1 (1.5)	2 (1.2)	0 (0.0)	*0.79
Cardiopulmonary resuscitation	1 (3.2)	2 (1.2)	0 (0.0)	*0.21	1 (1.5)	2 (1.2)	0 (0.0)	*0.79
Need for albumin replacement	18 (56.3)	56 (33.3)	22 (20.4)	†**0.001**	41 (60.3)	46 (27.4)	9 (12.5)	†**0.001**
Vasopressor requirement	0 (0.0)	7 (4.2)	2 (1.9)	*0.52	4 (6.0)	4 (2.4)	1 (1.4)	*0.34
Death	1 (3.1)	4 (2.4)	1 (0.9)	*0.47	1 (1.5)	4 (2.4)	1 (1.4)	*1.00

*Fisher-Freeman-Halton test. †Pearson chi-square test. All values are expressed as a number (percentage).
SAS: Surgical Apgar score, mSAS: Modified surgical Apgar score, ICU: Intensive care unit

subgroups. In two different esophagectomy cohorts, SAS suggested a high diagnostic accuracy for postoperative outcomes. In addition, preoperative chemotherapy, intraoperative bleeding volume, and organ reconstruction were other factors associated with postoperative complications and mortality (33,35). A previous retrospective study including patients undergoing arthroplasty revealed that SAS is insufficient for postoperative risk assessment (28). In addition, a prospective study showed that a SAS score of 4 was not considered sufficient for 30-day or 6-month mortality, but the SAS effectively predicted 30-day postoperative complications (36). In the present study, the diagnostic accuracies of SAS and mSAS were statistically significant for predicting ICU admission, ventilator support >48 h, bleeding requiring transfusion, and albumin replacement. Furthermore, mSAS also significantly predicted reoperation.

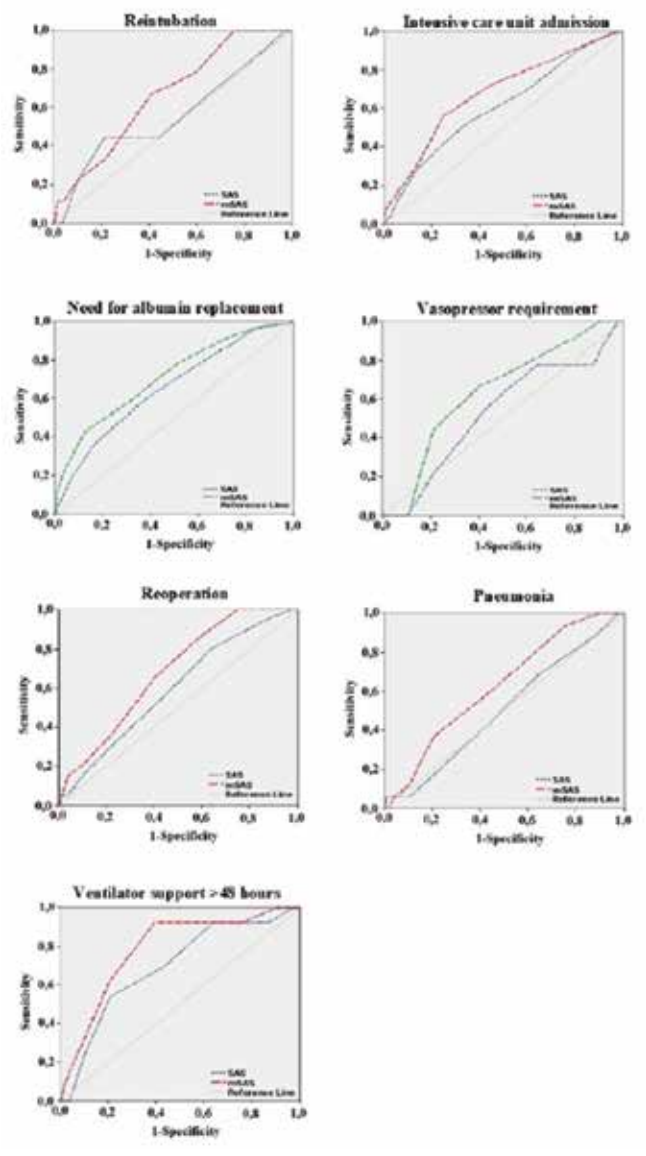

Figure 5. Comparison of the ROC curves

The modification of the SAS in this study is based on the addition of operation duration as a novel parameter. Studies defining the relationship between the duration of operation and postoperative outcomes are limited in the literature. Reich et al. (24) analyzed the physiological parameters of the POSSUM (Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity) score such as HR, systolic blood pressure, and MAP like the SAS in noncardiac surgery, and found that increased HR, systolic blood pressure, and operation duration longer than 220 min were related to postoperative complications. Another study analyzing 8501 patients who underwent abdominal surgery revealed that 24.4% of the patients with an operation duration longer than 6 h were admitted to the ICU. The rate of intensive care admission was 3.5% in patients with an operation duration between 2 and 6 h and 0.7% in those with a duration of less than 2 h (37). Another study on cardiac surgery determined that a cross-clamp duration longer than 150 min was associated with postoperative mortality and morbidity (16). Lee et al. (14) showed that the number of lymph nodes, age, intraoperative bleeding volume, and operation duration were risk factors associated with postoperative complications in radical hysterectomy procedures for cervix neoplasm. Shim et al. (38) also defined operation duration as a risk factor related to postoperative 30-day outcomes in addition to urinary complications, wound infection, blood transfusion >4 units, Charlson comorbidity index ≥2, and bleeding in patients who underwent hysterectomy for benign diseases. In the present study, subgroup analysis based on the duration of surgery showed that the rates of complications such as ventilator support more than 48 h, bleeding requiring transfusion, new-onset arrhythmia, need for albumin replacement, ICU admission, sepsis or septic shock, and pneumonia were higher in patients with longer duration of surgery than in those with shorter duration.

In the present study, the analysis of AUCs for predicting reintubation, ICU admission, need for albumin replacement, need for vasopressor requirement, reoperation, pneumonia, and ventilatory support more than 48 h revealed improved diagnostic accuracy of mSAS compared with SAS. However, SAS showed higher diagnostic accuracy in predicting the risk of deep venous thrombosis than mSAS. The abovementioned findings suggest that adding operation duration as a simple intraoperative parameter to SAS may predict postoperative outcomes at the end of the intraoperative period.

This study has several limitations. First, the study was conducted in a single center with a limited sample size. New studies with larger sample sizes are required to generalize the results. The number of patients with surgical duration longer than 480 min,

Table 4. Relationship between complications, mortality, and operation duration					
Complications	**Operation duration**				**p-value**
	>420 min	**301-420 min**	**181-300 min**	**≤180 min**	
Unconsciousness	0 (0.0)	2 (4.5)	3 (2.9)	2 (1.4)	*0.45
ICU admission	12 (100.0)	36 (81.8)	56 (53.8)	60 (40.5)	***0.001**
Ventilator support more than 48 h	3 (25.0)	4 (9.1)	4 (3.8)	2 (1.4)	***0.002**
Reintubation	1 (8.3)	4 (9.1)	3 (2.9)	1 (0.7)	***0.014**
Reoperation	2 (16.7)	9 (20.5)	4 (3.8)	5 (3.4)	***0.001**
Bleeding requiring transfusion	12 (100.0)	26 (59.1)	34 (32.7)	61 (41.2)	†**0.001**
Surgical site infection	1 (8.3)	6 (13.6)	4 (3.8)	9 (6.3)	*0.15
New-onset arrhythmia	1 (8.3)	5 (11.4)	0 (0.0)	3 (2.1)	***0.002**
Myocardial injury	0 (0.0)	1 (2.3)	0 (0.0)	1 (0.7)	*0.45
Pneumonia	1 (8.3)	7 (15.9)	6 (5.8)	2 (1.4)	***0.003**
Sepsis or septic shock	2 (16.7)	7 (15.9)	2 (1.9)	5 (3.5)	***0.002**
Bacteremia	1 (8.3)	3 (6.8)	2 (1.9)	6 (4.2)	*0.24
Acute kidney injury	0 (0.0)	1 (2.3)	0 (0.0)	3 (2.1)	*0.39
Deep venous thrombosis	0 (0.0)	0 (0.0)	0 (0.0)	2 (1.4)	*0.67
Pulmonary embolism	0 (0.0)	1 (2.3)	0 (0.0)	0 (0.0)	*0.18
Cardiac arrest	1 (8.3)	1 (2.3)	0 (0.0)	1 (0.7)	***0.049**
Cardiopulmonary resuscitation	1 (8.3)	1 (2.3)	0 (0.0)	1 (0.7)	***0.049**
Need for albumin replacement	9 (75.0)	27 (61.4)	28 (26.9)	32 (21.6)	†**0.001**
Vasopressor requirement	0 (0.0)	5 (11.4)	3 (2.9)	1 (0.7)	***0.010**
Death	0 (0.0)	1 (2.3)	0 (0.0)	5 (3.4)	*0.23

*Fisher-Freeman-Halton test. †Pearson chi-square test. All values are expressed as a number (percentage).
SAS: Surgical Apgar score, mSAS: Modified surgical Apgar score, ICU: Intensive care unit

Table 5. Comparison of the predictive ability of SAS and mSAS			
Complications	**SAS**	**mSAS**	**p-value**
	AUC (95% CI)	**AUC (95% CI)**	
Unconsciousness	0.510 (0.452-0.567)	0.552 (0.495-0.609)	0.50
	0.512 (0.310-0.705)	0.555 (0.422-0.671)	0.46
ICU admission	0.610 (0.553-0.665)	0.680 (0.625-0.732)	**<0.001**
	0.610 (0.548-0.670)	0.680 (0.620-0.738)	**<0.001**
Ventilator support more than 48 h	0.694 (0.639-0.745)	0.786 (0.735-0.830)	**0.024**
	0.698 (0.547-0.823)	0.791 (0.657-0.885)	**0.020**
Reintubation	0.557 (0.499-0.613)	0.664 (0.608-0.716)	**0.031**
	0.557 (0.343-0.765)	0.665 (0.509-0.813)	**0.025**
Reoperation	0.595 (0.538-0.650)	0.681 (0.626-0.733)	**0.023**
	0.596 (0.476-0.711)	0.682 (0.580-0.777)	**0.019**
Bleeding requiring transfusion	0.645 (0.589-0.699)	0.669 (0.613-0.721)	0.12
	0.645 (0.584-0.704)	0.669 (0.609-0.728)	0.12
Surgical site infection	0.530 (0.472-0.587)	0.510 (0.453-0.568)	0.88
	0.531 (0.398-0.659)	0.510 (0.377-0.645)	0.88
New-onset arrhythmia	0.525 (0.467-0.582)	0.605 (0.547-0.660)	0.58
	0.525 (0.367-0.676)	0.608 (0.457-0.730)	0.56

Table 5. Continued

Complications	SAS	mSAS	p-value
	AUC (95% CI)	AUC (95% CI)	
Myocardial injury	0.758 (0.706-0.805)	0.762 (0.710-0.808)	0.98
	0.758 (0.646-0.866)	0.762 (0.656-0.863)	0.98
Pneumonia	0.504 (0.447-0.562)	0.625 (0.568-0.680)	**<0.001**
	0.504 (0.369-0.643)	0.626 (0.498-0.747)	**<0.001**
Sepsis or septic shock	0.511 (0.453-0.568)	0.594 (0.536-0.649)	0.55
	0.510 (0.358-0.660)	0.596 (0.462-0.712)	0.54
Bacteraemia	0.537 (0.479-0.594)	0.560 (0.502-0.616)	0.56
	0.538 (0.343-0.727)	0.563 (0.363-0.752)	0.55
Acute kidney injury	0.674 (0.618-0.726)	0.632 (0.575-0.686)	0.65
	0.673 (0.455-0.896)	0.637 (0.419-0.795)	0.60
Deep venous thrombosis	0.650 (0.593-0.703)	0.501 (0.443-0.558)	**<0.001**
	0.650 (0.425-0.864)	0.501 (0.288-0.710)	**<0.001**
Cardiac arrest	0.745 (0.692-0.793)	0.788 (0.738-0.833)	0.70
	0.749 (0.473-0.930)	0.787 (0.653-0.992)	0.64
Cardiopulmonary resuscitation	0.745 (0.692-0.793)	0.788 (0.738-0.833)	0.70
	0.749 (0.473-0.930)	0.787 (0.653-0.992)	0.64
Need for albumin replacement	0.653 (0.597-0.706)	0.711 (0.657-0.761)	**<0.001**
	0.654 (0.586-0.718)	0.712 (0.648-0.772)	**<0.001**
Vasopressor requirement	0.530 (0.473-0.588)	0.636 (0.580-0.691)	**0.014**
	0.533 (0.334-0.701)	0.640 (0.47-0.781)	**0.010**
Death	0.664 (0.609-0.717)	0.592 (0.534-0.647)	0.24
	0.669 (0.455-0.847)	0.600 (0.400-0.748)	0.21

The first row shows areas under the ROC curve and its 95% CI based on the original data, and those based on bootstrapped samples are shown in the second row.
SAS: Surgical Apgar score, mSAS: Modified surgical Apgar score, ICU: Intensive care unit

between 421 and 480 min, and between 301 and 420 min is limited. A larger sample size in these groups may provide more reliable results than the present. In addition, another limitation is the heterogeneous characteristics of the sample size, which includes different disciplines. Therefore, our study has some strengths. The prospective nature of this study provides reliable data. This study is the first on this topic. Beyond the effect of mSAS, the analysis revealed the importance of operation duration for postoperative outcomes.

CONCLUSION

Depending on the results of this study, operation duration should be added to the SAS as a simple, objective, and practical parameter for predicting postoperative outcomes in major abdominal and orthopedic surgeries. This study demonstrated that this novel modification has high diagnostic accuracy for predicting postoperative complications. The combination of electronic medical records, mSAS, and the assessment of preoperative risk factors may help improve postoperative outcomes. Future studies may focus on using undefined intraoperative objective parameters that facilitate the achievement of postoperative care goals.

Ethics

Ethics Committee Approval: This prospective study was approved by the local ethics committee of Prof. Dr. Cemil Taşcıoğlu City Hospital, University of Health Sciences Turkey (IRB number: 658; date: May 9th, 2017).

Informed Consent: Written informed consent was obtained from patients or their next of kin.

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Authorship Contributions

Surgical and Medical Practices: M.N.Y., N.D.Y., A.C.Ö., E.A.T., N.T., Concept: M.N.Y., N.D.Y., A.C.Ö., E.A.T., N.T., Design: M.N.Y.,

N.T., Data Collection or Processing: M.N.Y., N.D.Y., A.C.Ö., E.A.T., Analysis or Interpretation: M.N.Y., N.D.Y., A.C.Ö., E.A.T., N.T., Literature Search: M.N.Y., N.D.Y., Writing: M.N.Y., N.D.Y., A.C.Ö., E.A.T., N.T.

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