

Validation of the Surgical Apgar Score After Laparotomy at a Tertiary Referral Hospital in Rwanda

Christian Ngarambe¹ · Blair J. Smart² · Neeraja Nagarajan³ · Jennifer Rickard^{4,5}

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Abstract

Background The surgical Apgar score (SAS) has demonstrated utility in predicting postoperative outcomes in a variety of surgical disciplines. However, there has not been a study validating the utility of the SAS in surgical patients in low-income countries. We conducted a prospective, observational study of patients undergoing laparotomy at a tertiary referral hospital in Rwanda and determined the ability of SAS to predict inpatient major complications and mortality.

Methods All adult patients undergoing laparotomy in a tertiary referral hospital in Rwanda from October 2014 to January 2015 were included. Data were collected on patient and operative characteristics. SAS was calculated and patients were divided into four SAS categories. Primary outcomes were in-hospital mortality and major complications. Rates and odds of in-hospital mortality and major complications were examined across the four SAS categories. Logistic regression modeling and calculation of c-statistics was used to determine the discriminative ability of SAS.

Results 218 patients underwent laparotomy during the study period. One hundred and forty-three (65.6%) were male, and the median age was 34 years (IQR 27–51 years). The most common diagnosis was intestinal obstruction (97 [44.5%]). A high proportion of patients (170 [78%]) underwent emergency surgery. Thirty-nine (18.3%) patients died, and 61 (28.6%) patients had a major complication. In-hospital mortality occurred in 25 (50%) patients in the high-risk group, 12 (16%) in the moderate-risk group, 2 (3%) in the mild-risk group and there were no deaths in the low-risk group. Major complications occurred in 32 (64%) patients in the high-risk group, 22 (29%) in the moderate-risk group, 7 (11%) in the mild-risk group and there were no complications in the low-risk group. SAS was a good predictor of postoperative mortality (c-statistic 0.79) and major complications (c-statistic 0.75).

Conclusions SAS can be used to predict in-hospital mortality and major complications after laparotomy in a Rwandan tertiary referral hospital.

✉ Jennifer Rickard
gehr0059@umn.edu

¹ Department of Surgery, University Teaching Hospital of Butare, Butare, Rwanda

² Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

³ Department of Surgery, Johns Hopkins University School of Medicine, Baltimore, MD, USA

⁴ Department of Surgery, University Teaching Hospital of Kigali, Kigali, Rwanda

⁵ Department of Surgery, University of Minnesota, 516 Delaware St SE, 11-145E, Minneapolis, MN 55455, USA

Introduction

Laparotomy is a common procedure used for a variety of diagnoses with elective and emergent indications. In addition to cesarean section and open fracture treatment, laparotomy is one of the Bellwether procedures [1]. These procedures are so-called because of their ability to serve as proxy for a functioning healthcare system with sufficient material resources and human skills to treat a broad range of essential surgical conditions [1]. Identifying patients at high risk for morbidity and mortality after laparotomy could lead to changes in management, thereby improving outcomes.

In 1953, Virginia Apgar, an anesthesiologist, created a tool to assess newborns [2]. The Apgar test has been used to identify high-risk infants, intervene and ultimately improve neonatal outcomes. Influenced by the effectiveness and simplicity of the Apgar, Gawande and colleagues developed a Surgical Apgar Score (SAS) to provide surgeons with feedback on operative outcomes [3]. The SAS is a 10-point score comprised of 3 intraoperative variables (heart rate, mean arterial pressure and estimated blood loss) [3]. Much like the Apgar, each variable in the SAS is individually scored and summed to create a score ranging from 0 to 10, with lower scores indicating worse outcomes.

Since introduction of the SAS, the tool has been validated in multiple databases and various countries [4–6]. The SAS has utility in various surgical disciplines including orthopedic surgery, colorectal surgery, neurosurgery, gynecology and emergency general surgery [7–13]. Initially, the tool was used to predict 30-day mortality and major complications [3], but now the utility of the SAS has been expanded to predict interventions in surgical step down units, readmissions and intensive care unit (ICU) admissions [13–16].

Most validation studies for the SAS have included patients from high-income countries (HICs) with limited analysis of patients in low-income countries (LICs). Haynes et al. [5] validated the SAS in eight countries, including low- and middle-income countries (LMICs): Tanzania (LIC), India (LMIC), Philippines (LMIC) and Jordan (upper middle-income country). Given the variables used to compute the SAS, this tool could be used in low-resource settings to assist clinicians in risk stratifying postoperative patients.

Rwanda is a LIC in East Africa. It is the most densely populated country in sub-Saharan Africa with a population of 11.34 million [17]. The health system is tiered where patients initially present to a health center before being referred to a district hospital then a referral hospital. More than 90% of the population has some form of health

insurance with the majority having government sponsored, community-based health insurance [18]. There is an overall shortage of physicians, including surgeons. Most surgeons live in urban centers, practicing in one of the four tertiary referral hospitals [19, 20]. Postgraduate surgical training has increased with the ultimate goal of staffing a trained surgeon at each district hospital [21].

University Teaching Hospital of Kigali (Centre Hospitalier Universitaire de Kigali, CHUK) is a tertiary referral hospital in Rwanda with a large burden of emergency surgical disease [22]. There are 565 hospital beds, and 2800 operations performed annually by surgical residents [22]. Laparotomy is a common procedure performed with over 500 cases performed annually, and more than half performed for emergency indications [22, 23]. This study aims to characterize the utility of SAS to identify patients at high risk for morbidity or mortality after laparotomy at a referral hospital in Rwanda. We hypothesize that low SAS scores will be associated with high morbidity and mortality.

Methods

All adult patients undergoing exploratory laparotomy at CHUK between October 2014 and January 2015 were included in this study. Pediatric patients (less than 12 years of age) were excluded as vital signs for infants and children differ from adolescent and adult patients. The SAS is not validated in pediatric patients. Patients were excluded if they had metastatic cancer, unresectable abdominal tumors, non-abdominal operations or poly-trauma patients as these patients were expected to have complex outcomes due to the underlying disease. Emergent gynecological cases conducted by the general surgery teams were included. Elective gynecologic surgeries were excluded as they were conducted in a separate operating facility. Patients were identified by the surgical team and followed through hospitalization. The lead investigator cross-checked operating and recovery room logbooks to ensure patient identification. Data were collected on demographics, past medical and surgical history, diagnosis, operative procedure and complications. The lead investigator followed patients and confirmed details with the operating surgeon to ensure complete data collection.

Operations were classified as emergent or elective. Emergent cases included patients requiring urgent or emergent operation prior to hospital discharge. These patients often presented to the emergency department. Elective operations included patients who presented for a scheduled elective operation.

Diagnoses were classified as intestinal obstruction, appendicitis, perforation, trauma, typhoid, cholecystitis or other. Intestinal obstruction included cases of hernia,

Table 1 Ten-point surgical Apgar score

	0	1	2	3	4
Lowest heart rate (beats/min)	>85	76–85	66–75	56–65	≤55
Lowest mean arterial pressure (mmHg)	<40	40–54	55–69	≥70	
Estimated blood loss (mL)	>1000	601–1000	101–600	≤100	

intestinal volvulus, intussusception, adhesions, obstructing bands or peritoneal tuberculosis. Appendicitis included patients with appendicular inflammation including early appendicitis, perforated appendicitis or gangrenous appendicitis. Peptic ulcer disease included all patients with gastric or duodenal perforation associated with an ulcer. Trauma included all blunt or penetrating trauma. Typhoid intestinal perforation included all patients with clinical history of typhoid fever and findings of antimesenteric perforation of the ileum at operation. Cholecystitis included patients undergoing operation for gallstone disease.

The SAS score (Table 1) was calculated by summing three intraoperative variables that compromise the score: lowest heart rate, lowest mean arterial pressure (MAP) and estimated blood loss (EBL) [3]. Heart rate and MAP were obtained through anesthesia case logs at the conclusion of the operation. When MAP was not directly recorded, it was calculated from intraoperative recordings of systolic blood pressure (SBP) and diastolic blood pressure (DBP) using the equation: $MAP = (SBP + 2 * DBP)/3$. EBL was determined based on surgeon estimates. Surgeons were queried at the end of each operation to estimate EBL. The SAS score was stratified into four categories: high risk (SAS 0–4), moderate risk (SAS 5–6), mild risk (SAS 7–8) and low risk (SAS 9–10).

The primary outcomes were in-hospital mortality and major complications. Only in-hospital outcomes were assessed due to resource limitations making 30-day outcomes difficult to assess. Major complications were classified based on American College of Surgeons-National Surgical Quality Improvement Program (ACS NSQIP) modified to the local environment based on treating physician assessment [24]. Complications included: return to operating room, fascial wound dehiscence, evisceration, deep and superficial wound infections, septic shock, deep venous thrombosis, pneumonia, pulmonary embolism, sepsis, acute renal failure, unplanned intubation, coma greater than 24 h, bleeding requiring greater than 4 units of red cell transfusion within 72 h after operation, ventilation greater than 48 h after operation, stroke and cardiac arrest requiring cardiopulmonary resuscitation.

Standard descriptive analysis was employed to examine patient characteristics. Logistic regression calculated the odds of mortality or major complications by SAS category. To test the score's discriminatory ability, area under the

Table 2 Patient characteristics

	N	%
Gender		
Male	143	65.6
Female	75	34.4
Past medical history		
Chronic conditions ^a	22	10.1
Infectious ^b	6	2.8
Obstetrics and gynecology	2	0.9
None	188	86.2
Past surgical history		
General surgery	17	7.8
Obstetrics and gynecology	6	2.8
Orthopedic	2	7.8
None	193	88.5
Type of surgery		
Emergency	170	78
Elective	48	22
Diagnosis		
Intestinal obstruction	97	44.5
Appendicitis	30	13.8
Peptic ulcer disease	25	11.5
Other ^c	21	9.6
Trauma	20	9.2
Typhoid intestinal perforation	14	6.4
Cholecystitis	11	5.1
Outcomes		
Mortality (N = 218)	39	17.9
Major complications (N = 218)	61	28.0
Deep wound infection	23	37.7
Unplanned reoperation	21	34.4
Ventilator use greater than 48 h	6	9.8
Pneumonia	4	6.6
Sepsis	4	6.6
Cardiac arrest	2	3.3
Deep venous thromboembolism	1	1.6

^a Diabetes, hypertension, peptic ulcer disease, arthritis, asthma

^b Human immunodeficiency virus, tuberculosis

^c Gastrointestinal bleed, cyst, pelvic inflammatory disease, fistula

receiver operating characteristic (ROC) curves was generated and c-statistics calculated. Multivariate logistic regression determined independent variables associated

Table 3 Characteristics of survivors and non-survivors

	Total	Survivors		Non-survivors		<i>p</i> value
		<i>N</i>	%	<i>N</i>	%	
Age						
<20 years	25	19	11	6	15	0.062
21–40 years	98	88	49	10	26	
41–60 years	61	47	26	14	36	
>60 years	34	25	14	9	23	
Gender						
Male	143	122	68	21	54	0.088
Female	75	57	32	18	46	
Diagnosis						
Intestinal obstruction	97	86	48	11	28	<0.001
Appendicitis	30	28	16	2	5	
Peptic ulcer disease	25	17	10	8	21	
Other	21	11	6	10	26	
Trauma	20	20	11	0	0	
Typhoid intestinal perforation	14	8	4	6	15	
Cholecystitis	11	9	5	2	5	
Emergency status						
Emergency	170	134	75	36	92	0.017
Elective	48	45	25	3	8	
SAS^a risk category						
Low risk	27	27	15	0	0	<0.001
Mild risk	66	64	36	2	5	
Moderate risk	75	63	35	12	31	
High risk	50	25	14	25	64	

^a Surgical Apgar score

with mortality and major complications. Variables included in the multivariate model included age, gender, diagnosis, emergency status and SAS risk category. Data were analyzed using Stata 13.0 (College Station, TX).

The CHUK Ethics Committee, University of Rwanda Institutional Review Board (IRB) and Johns Hopkins IRB approved this study.

Results

Two hundred and eighteen patients met inclusion criteria for the study. Median age was 34 years (IQR: 27–51 years), and 143 (65.6%) patients were male (Table 2). One hundred and eighty-eight (86%) patients reported no past medical history. One hundred and ninety-three (89%) patients reported no past surgical history. Past medical history was classified as chronic conditions, infectious conditions, obstetrics and gynecology or none. Chronic conditions included diabetes mellitus, hypertension, gastritis, peptic ulcer disease, constipation, arthritis or asthma. Infectious conditions included tuberculosis or

human immunodeficiency virus. Obstetrics and gynecology included current pregnancy or recent abortion. Past surgical history was classified as general surgery, obstetrics and gynecology orthopedic or none. Prior general surgery operations included exploratory laparotomy and hernia repairs. Prior obstetrics and gynecology operations included caesarean section and hysterectomy. Prior orthopedic operations included fracture fixation.

One hundred and seventy (78%) operations were emergent. Common diagnoses included intestinal obstruction ($N = 97$, 44%) and appendicitis ($N = 30$, 14%) (Table 2). Mean operative duration was 102 min (range 30–320 min). There were 39 (18%) deaths and 61 (29%) major complications. Common postoperative complications included deep wound infection ($N = 23$, 38%) and reoperation ($N = 21$, 34%) (Table 2). Characteristics of survivors are shown in Table 3. Characteristics of patients with major complications are shown in Table 4.

Median SAS was 6 (IQR: 5–7) (Table 2). Fifty (23%) patients had high-risk SAS, 75 (34%) had moderate-risk SAS, 66 (30%) had mild-risk SAS and 27 (10%) had low-risk SAS.

Table 4 Characteristics of patients with major complications

	Total	No complications		Complications		<i>p</i> value
		<i>N</i>	%	<i>N</i>	%	
Age						
<20 years	25	15	9	10	17	0.010
21–40 years	98	82	52	16	27	
41–60 years	61	39	25	22	37	
>60 years	34	22	14	12	20	
Gender						
Male	143	48	30	27	45	0.042
Female	75	110	70	33	55	
Diagnosis						
Intestinal obstruction	97	78	49	19	32	<0.001
Appendicitis	30	24	15	6	10	
Peptic ulcer disease	25	18	11	7	12	
Other	21	9	6	12	20	
Trauma	20	19	12	1	2	
Typhoid intestinal perforation	14	3	2	11	18	
Cholecystitis	11	7	4	4	7	
Emergency status						
Emergency	170	116	73	54	90	0.008
Elective	48	42	27	6	10	
SAS^a risk category						
Low risk	27	26	16	1	2	<0.001
Mild risk	66	59	37	7	12	
Moderate risk	75	54	34	21	35	
High risk	50	19	12	31	52	

^a Surgical Apgar score

In-hospital mortality increased as SAS decreased. In-hospital mortality occurred in 25 (50%) patients in the high-risk group, 12 (16%) in the moderate-risk group, 2 (3%) in the mild-risk group and there were no deaths in the low-risk group (Table 5). Patients with high-risk SAS had 32 times greater odds of death (95% CI 7.05, 145.24) and patients with moderate-risk SAS had 6.1 greater odds of mortality (95% CI 1.31, 28.34) compared with patients with mild-risk SAS. The discrimination in this model was high with a *c*-statistic of 0.79 (Fig. 1).

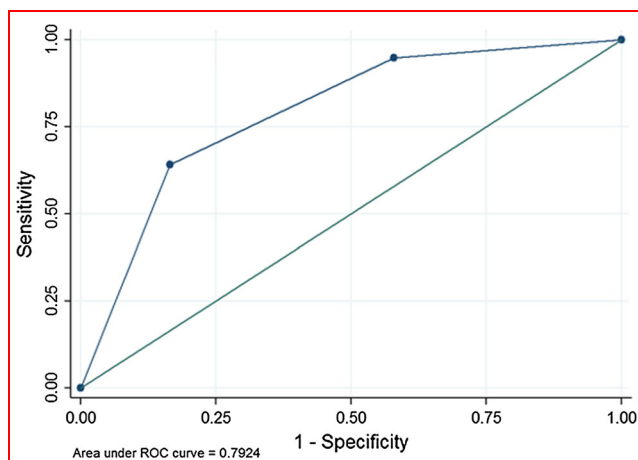
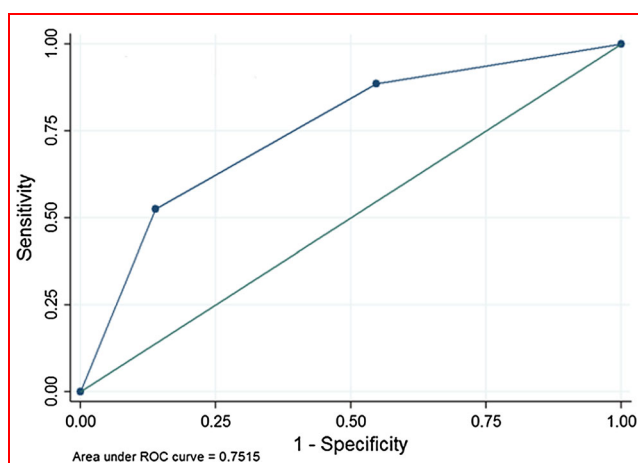
Major complications occurred in 32 (64%) patients in the high-risk category, 22 (29%) in the moderate-risk category, 7 (11%) in the mild-risk category and there were no complications in the low-risk category (Table 5). Patients with a high-risk SAS had 15 times greater odds of major complications (95% CI 5.66, 39.66) and patients with moderate-risk SAS had 3.5 greater odds of major complications (95% CI 1.38, 8.85) compared with patients with mild-risk SAS. The logistic regression model had high discrimination with a *c*-statistic of 0.75 (Fig. 2).

Combining in-hospital mortality and major complications resulted in similar findings (Table 5). In-hospital mortality or major complications occurred in 33(66%) patients in the high-risk group, 23(30.7%) patients in the moderate-risk group, 7(10.6%) patients in the mild-risk group and no patients in the low-risk group. The odds of in-hospital mortality or major complications were 16 times greater in patients with high-risk SAS (95% CI 6.15, 43.50) and 3.7 times greater in patients with moderate-risk SAS (95% CI 1.48, 9.40) compared to patients with mild-risk SAS.

A multivariate logistic regression model was created using age, gender, diagnosis, emergency status and SAS risk categories (Table 6). Controlling for other variables, in-hospital mortality was associated with SAS (odds ratio (OR) 5.09, 95% CI 2.59, 10.02), age (OR 1.60, 95% CI 1.00, 2.55) and diagnosis (OR 1.32, 95% CI 1.07, 1.63). Major complications were associated with emergency status (OR 4.2, 95% CI 1.16, 15.19), SAS (OR 3.19, 95% CI 1.97, 5.17), diagnosis (OR 1.3, 95% CI 1.09, 1.55) and

Table 5 Association of surgical Apgar score with mortality and major complications

	Surgical Apgar score			
	0–4 High risk	5–6 Moderate risk	7–8 Mild risk	9–10 Low risk
Total (%)	50 (23)	75 (34)	66 (30)	27 (10)
Mortality				
<i>N</i> (%)	25 (50)	12 (16)	2 (3)	0
Odds ratio (95% confidence interval)	32.0 (7.05, 145.24)	6.10 (1.31, 28.34)	Reference	–
Major complications				
<i>N</i> (%)	32 (64)	22 (29.3)	7 (10.6)	0
Odds ratio (95% confidence interval)	14.98 (5.66, 39.66)	3.50 (1.38, 8.85)	Reference	–
Mortality or major complications				
<i>N</i> (%)	33 (66)	23 (30.7)	7 (10.6)	0
Odds ratio (95% confidence interval)	16.36 (6.15, 43.50)	3.73 (1.48, 9.40)	Reference	–

**Fig. 1** Receiver operating characteristic (ROC) curves for surgical Apgar score and inpatient mortality**Fig. 2** Receiver operating characteristic (ROC) curves for surgical Apgar score and inpatient major complications

gender (OR 0.45, 95% CI 0.21, 0.97). Mortality and major complications combined were associated with emergency status (OR 4.32, 95% CI 1.2, 15.61), SAS (OR 3.32, 95% CI 2.04, 5.38) and diagnosis (OR 1.3, 95% CI 1.09, 1.55).

Discussion

This study shows that the SAS can be used in a low-income country with a high burden of emergent surgical conditions to identify patients undergoing exploratory laparotomy who are at high risk of in-hospital mortality and morbidity. A prior study had been conducted in a global patient population, including sites in low- and middle-income countries [5]. However, the previous study was primarily elective operations with few trauma operations and did not separately analyze outcomes from LMICs, making it difficult to compare the findings in a low-income country where emergency operations constitute a large burden of disease [5].

The median SAS score in our cohort was 6, which is lower than the scores reported in previous validation studies [4–6, 10]. Correlating with the lower SAS scores, there is also higher rate of morbidity and mortality in this population, consistent with prior studies [23]. The mortality rate of patients undergoing laparotomy was 18%. This is similar to other low-resource settings where mortality rates range from 15 to 19.5% [25–27]. Prior SAS validation studies reported major complications rates of 9.2–14.1% and mortality rates of 1.4–2.3% [3, 4]. The lower SAS and higher morbidity and mortality rates seen in this patient population are likely attributable to multiple variables. One factor may be the higher proportion of emergency patients in this study. There is a large volume of emergency cases seen at this hospital, whereas previous studies validating

Table 6 Multivariate logistic regression model of factors associated with mortality and major complications

	Unadjusted odds ratio (95% confidence interval)	<i>p</i> value	Adjusted odds ratio (95% confidence interval)	<i>p</i> value
Mortality				
Age	1.28 (0.90, 1.86)	0.170	1.60 (1.00, 2.55)	0.046
Gender	0.56 (0.27, 1.10)	0.091	0.48 (0.19, 1.21)	0.119
Diagnosis	1.35 (1.15, 1.59)	<0.001	1.32 (1.07, 1.63)	0.008
Emergency	4.03 (1.18, 13.7)	0.026	8.79 (0.98, 78.89)	0.052
SAS ^a risk category	5.68 (3.13, 10.3)	<0.001	5.09 (2.59, 10.02)	<0.001
Major complications				
Age	1.19 (0.87, 1.63)	0.275	1.42 (0.96, 2.10)	0.080
Gender	0.53 (0.29, 0.98)	0.044	0.45 (0.21, 0.97)	0.043
Diagnosis	1.34 (1.15, 1.54)	<0.001	1.30 (1.09, 1.55)	0.003
Emergency	3.26 (1.31, 8.13)	0.011	4.20 (1.16, 15.19)	0.029
SAS ^a risk category	3.69 (2.39, 5.68)	<0.001	3.19 (1.97, 5.17)	<0.001
Mortality or major complications				
Age	1.21 (0.89, 1.65)	0.231	1.46 (0.99, 2.17)	0.057
Gender	0.58 (0.31, 1.06)	0.075	0.50 (0.23, 1.07)	0.075
Diagnosis	1.33 (1.16, 1.54)	<0.001	1.30 (1.09, 1.55)	0.003
Emergency	3.44 (1.38, 8.57)	0.008	4.32 (1.20, 15.61)	0.025
SAS ^a risk category	3.83 (2.48, 5.91)	<0.001	3.32 (2.04, 5.38)	<0.001

^a SAS surgical Apgar score

SAS have had a lower proportion of emergent cases [3, 4, 6, 10, 15, 23, 28]. The lower SAS in this patient population may be an indication of the overall health of the patients at presentation. The lower SAS suggests that the patients in Rwanda are more critically ill. Finally, an additional reason for lower SAS may be due to differences in intraoperative management of the patients in this setting. The availability and range of anesthetic, analgesia, and vasopressor agents as well as the availability of blood products is limited in low-resource settings, which could lead to differences in intraoperative management. Further studies correlating outcomes with preoperative risk stratification could better elucidate the variations in SAS score. However, this is often difficult in resource-limited settings where a broad range of laboratory studies is not routinely performed or available.

There have been various scoring tools developed to predict postoperative outcomes [29–32]. Many of the variables used in these tools are not routinely collected in low-resource settings. The SAS developed by Gawande and colleagues in 2007 is simple to use at the bedside and effective in predicting postoperative outcomes [3–5]. This study shows that the SAS can be used in a limited-resource setting to predict in-hospital mortality and major morbidity in patients undergoing laparotomy. These findings parallel former validation studies across the different surgical disciplines conducted in HICs [3–13].

The prompt recognition and management of postoperative complications is critical in improving outcomes in surgical patients [33]. A tool such as the SAS can be used to risk stratify patients at risk for postoperative complications. While the SAS has been shown to predict outcomes, few studies have implemented the tool to change clinical management [6]. One study validating SAS at a UK district general hospital found limited opportunities to improve outcomes in patients identified at high risk by SAS [6]. However, the patient population and risk factors in the UK district hospital is likely different than a Rwandan referral hospital. Haddow et al. [34] developed a randomized controlled trial using SAS to guide postoperative care. The incidence of complications was lower in the intervention arm, though this was not statistically significant. Currently, there are no interventions based on SAS in Rwanda, but future studies are being developed that would evaluate interventions based on SAS scores. These include admitting patients with high-risk SAS to a higher level of care such as the ICU or high-dependency unit. As the most common complications found in this study were related to the operative wound (wound infection and wound dehiscence), additional studies will evaluate strategies to improve wound care, preventing infection and wound breakdown in high-risk SAS patients.

While the numbers used to calculate SAS are relatively easy to collect, the data may not always be consistently

recorded. EBL is often underestimated by the operating surgeon. However, the SAS EBL categories are sufficiently wide where this is unlikely to have impacted measures. One of the strengths of this study is that accurate data collection was obtained due to constant oversight and supervision from the lead author. It is unclear how accurately these data are collected on a routine basis. The SAS requires frequent monitoring of vital signs intraoperatively. If this is not available, the discriminative ability of the SAS may be altered. Consistent utilization of these data points, however, would encourage more consistent recordings of these values. Local staff may benefit from basic training in collecting data on SAS components to maintain accurate recordings.

Our study has a number of limitations. In under-resourced settings, there is scarce access to routine healthcare and individuals are commonly under-diagnosed or undiagnosed for a variety of medical and surgical illnesses [35–37]. While other studies are able to adjust for these covariates in their analysis, this was not possible due to the limited data available. The study did not collect data on all potential factors associated with adverse outcomes. Prior studies in this hospital have assessed risk factors for morbidity and mortality in various patient populations [23, 38]. In these prior studies, morbidity and mortality were not associated with symptom duration, operating surgeon or anesthesiologist [23]. We were unable to capture data on the cause of death as this is poorly recorded in this setting. The initial Gawande study evaluated 30-day outcomes [3]. However, due to resource limitations, challenges in data collection and outpatient follow-up, all outcomes in this study were in-hospital and clinically diagnosed. Out-of-hospital complications were not captured, and there were limited resources to detect other complications. As such, the complication rate is likely underestimated.

Conclusions

This study demonstrates the ability of SAS to identify patients with postoperative risk after laparotomy in Rwanda. SAS is a tool, using routinely collected data that can be used in limited-resource settings. The findings from this study can be applied to other low-resource settings performing laparotomy with a high burden of emergency operations. Future studies should be developed implementing SAS into clinical practice to guide patient management and resource allocation.

Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest and no financial disclosures to report.

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