VALIDITY OF SURGICAL APGAR SCORE IN PREDICTING OUTCOMES IN PATIENTS UNDERGOING ELECTIVE NEUROSURGICAL PROCEDURES – A RETROSPECTIVE STUDY

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ABSTRACT

Introduction: The Surgical Apgar Score (SAS) was developed as a tool to predict morbidity and mortality after surgery, incorporating three intraoperative variables [heart rate, mean arterial blood pressure (MAP), and estimated blood loss (EBL)] to identify patients at the highest risk of postoperative complications and death. We conducted this study to determine the usefulness of SAS in predicting postoperative complications in patients undergoing elective cranial neurosurgical procedures.

Materials & Methods: In this retrospective study, data of 150 adult patients (aged above 18) undergoing elective neurosurgical procedures was retrieved. The primary endpoint of our study was the occurrence of major complications or mortality within 30 days of the index surgery.

Results: The patients’ mean age was 42 years (± 14.8) and 44.7% of those patients were females. The overall mortality rate for the cohort was 3.33% (five out of 150) and 105 patients (70%) had developed one or more complications. Of the five patients who died, four had an SAS of 3–4 and one had an SAS of 5. The SAS of approximately three-fourths of the patient population was in the range of 5–8. Seventy-seven patients of the 105 with complications had an SAS of 0–6. The SAS of the remaining 28 patients (26.7%) was in the range of 7–10. SAS, the duration of the surgery and that of the hospital stay were independently associated with the occurrence of the complications after adjusting for the confounding factors.

Conclusion: SAS is a simple scoring system that can be used in the case of neurosurgical patients undergoing craniotomy to predict postoperative complications.

Keywords: Surgical Apgar Score, major complications, perioperative outcome, mortality, elective neurosurgical procedure


INTRODUCTION

Perioperative clinicians and surgeons require a tool to predict the outcomes in patients after surgery. Several scoring systems have been used for prognostication and risk stratification, such as the American Society of Anesthesiologists (ASA)’s physical status classification, the physiological and operative severity score for the enumeration of mortality and morbidity (POSSUM), the acute physiology and chronic health evaluation (APACHE), and the simplified acute physiology score (SAPS).
However, each of these scoring systems has limitations, especially with regard to the ease of use in clinical practice. The Surgical Apgar Score (SAS) was developed as a predictor of morbidity and mortality after surgery, incorporating three intraoperative variables (heart rate, mean arterial blood pressure (MAP), and estimated blood loss (EBL)) to identify patients at the highest risk of postoperative complications and death. The major advantage of using this score lies in the simplicity of its calculation and the parameters used to calculate the score, reflecting a combination of surgical complexity and a patient’s response to surgical stress. SAS has been validated in a large cohort of general and vascular surgical patients, as well as in patients undergoing selected procedures in specialty areas such as orthopedics, urology, and gynaecology. However, there have been limited studies to assess the utility of SAS in predicting outcomes for neurosurgical patients. Here, we studied the usefulness of SAS in predicting postoperative complications in patients undergoing elective cranial neurosurgical procedures.

### MATERIALS & METHODS

This was a retrospective study of adult patients (aged above 18) undergoing elective craniotomy for various indications, such as intracranial tumors, arteriovenous malformations (AVMs) and cerebral aneurysms, at a tertiary care neuroscience center. This study was reviewed and approved by the Institutional Ethical Committee and the requirement for a consent form was waived off.

Data was retrieved from the case files and anesthesia records available in the medical records section of NIMHANS, Bengaluru, India. Patients for whom all data points could not be collected were excluded from the study. The following information was collected for each patient: gender, age, presence or absence of preoperative systemic hypertension, diabetes mellitus, coronary artery disease (CAD), bronchial asthma, and seizures. SAS was calculated for each patient in the manner shown in Table 1.

#### Table 1. Calculation of SAS

<table>
<thead>
<tr>
<th></th>
<th>0 points</th>
<th>1 point</th>
<th>2 points</th>
<th>3 points</th>
<th>4 points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated blood loss (EBL) in ml</td>
<td>&gt;1,000</td>
<td>601–1,000</td>
<td>101–600</td>
<td>&lt;100</td>
<td></td>
</tr>
<tr>
<td>Lowest mean blood pressure (MAP) in mm Hg</td>
<td>&lt;40</td>
<td>40–54</td>
<td>55–69</td>
<td>&gt;70</td>
<td></td>
</tr>
<tr>
<td>Lowest heart rate (beats per minute)</td>
<td>&gt;85*</td>
<td>76–84</td>
<td>66–75</td>
<td>55–65</td>
<td>&lt;55*</td>
</tr>
</tbody>
</table>

*SAS is calculated at the end of the surgery from the estimated blood loss, lowest mean arterial pressure, and lowest heart rate as entered in the anesthesia record during the surgery. The score is the sum of the points from each category.

*The occurrence of pathologic bradyarrhythmia, including sinus arrest, atrio-ventricular block or dissociation, junctional or ventricular escape rhythms and asystole, receive no points for the lowest heart rate.

The primary endpoint of our study was the occurrence of major complications or mortality within 30 days of the index surgery. The major complications are stated as follows:

- Acute renal failure
- Bleeding that required transfusion of one or more units of red blood cells or whole blood within 72 hours of surgery
- Cardiac arrest requiring cardiopulmonary resuscitation
- Coma duration of 24 hours or longer
VALIDITY OF SAS IN PATIENTS UNDERGOING ELECTIVE NEUROSURGICAL PROCEDURES

- Deep venous thrombosis (DVT)
- Myocardial infarction (MI)
- Unplanned re-intubation
- Ventilator use for 48 hours or more
- Pulmonary embolism
- Stroke
- Wound disruption
- Surgical site infection
- Sepsis/septic shock
- Psuedomeningocele
- Seizure

The complications were assessed by reviewing progress notes, discharge summaries, laboratory values and radiology records from the picture archiving and communication system (PACS). The length of the hospital stay was noted for each patient.

Statistical Analysis
Statistical analysis was performed using the SPSS 19.0 software. Descriptive statistics were calculated for all quantitative variables. The categorical variables were described as frequencies or percentages.

As there were only five deaths in our study population (out of 150 patients), no statistical tests could be applied to compare the association of mortality with SAS or other variables. Raw data was analyzed using mean and standard deviation between the patients who died and those who survived.

The non-parametric Mann Whitney U test was used to test the association of SAS, duration of the surgery and that of the hospital stay with each type of major complication. Subsequently, a logistic regression analysis was performed to evaluate the predictive accuracy of SAS alone in predicting postoperative complications. A p-value of less than 0.05 was considered statistically significant.

RESULTS
We could obtain complete data for 150 patients (aged above 18) undergoing elective craniotomy at NIMHANS, Bengaluru, India.

Patient characteristics
The study included 150 patients undergoing elective craniotomy (Table 2). The mean age of the patients was 42 years (± 14.8). The study involved 67 (44.7%) women and 83 (55.3%) men. The most common surgery (craniotomy) was performed for supratentorial pathology in 88 patients (58.6%), infratentorial pathology in 39 patients (26%) and clipping of intracranial aneurysms in 23 patients (15.3%).

Thirty-six patients (24%) in the cohort had hypertension, 18 (12%) had diabetes mellitus, 24 (16%) had seizure disorder, two had bronchial asthma, and one had CAD before the operation.

The SAS of approximately three-fourths of the patient population was in the range of 5–8. Fifty-six patients (37.3%) had an SAS of 5–6, 55 (36.6%) had an SAS of 7–8, 31 (20.6%) had an SAS of 3–4, six (4%) had an SAS of 9–10, and only two (1.3%) had an SAS of 0–2.

The mortality rate for the cohort was 3.33% (five of 150). Of the five patients who died, four had an SAS of 3–4, while one had an SAS of 5–6.

Frequency of complications
Of the 150 patients, 105 (70%) had one or more of the complications mentioned above. The association of the complications with gender, SAS, type of surgery and co-morbidities is described in Table 2.

Seventy-seven patients of the 105 with complications (73.3%) had an SAS of 0–6. The remaining 28 patients with no complications (26.7%) had an SAS of 7–10. The graphical representation of the association between SAS and the number of patients with and without complications is given below (Figure 1).
Table 2. Association of complications with gender, SAS, type of surgery, and co-morbidities

<table>
<thead>
<tr>
<th>Patient characteristics</th>
<th>No.</th>
<th>Complications</th>
<th>No complications</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total group</td>
<td>150 (100%)</td>
<td>105</td>
<td>45</td>
<td>5</td>
</tr>
<tr>
<td><strong>SAS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–2</td>
<td>2</td>
<td>2 (100%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3–4</td>
<td>31</td>
<td>30 (96.7%)</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>5–6</td>
<td>56</td>
<td>45 (80.3%)</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>7–8</td>
<td>55</td>
<td>26 (47.2%)</td>
<td>29</td>
<td>0</td>
</tr>
<tr>
<td>9–10</td>
<td>6</td>
<td>2 (33.33%)</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td><strong>Case type</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supratentorial</td>
<td>88</td>
<td>65</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>Infratentorial</td>
<td>39</td>
<td>26</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Aneurysms</td>
<td>23</td>
<td>17</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>83</td>
<td>57</td>
<td>26</td>
<td>2</td>
</tr>
<tr>
<td>Female</td>
<td>67</td>
<td>47</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td><strong>Systemic HTN</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>36</td>
<td>25</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>No</td>
<td>114</td>
<td>114</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td><strong>CAD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1</td>
<td>0</td>
<td>1 (100%)</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>144</td>
<td>105 (70%)</td>
<td>39</td>
<td>5</td>
</tr>
<tr>
<td><strong>Asthma</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2</td>
<td>1 (50%)</td>
<td>1 (50%)</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>148</td>
<td>104 (70.2%)</td>
<td>44 (29.8%)</td>
<td>5</td>
</tr>
<tr>
<td><strong>Seizures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>24</td>
<td>13 (54.1%)</td>
<td>11 (55.9%)</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>126</td>
<td>92 (73%)</td>
<td>34 (27%)</td>
<td>5</td>
</tr>
</tbody>
</table>

Figure 1. Association of number of patients with complications and SAS (the figure shows that as SAS decreases, the number of patients with complications increases)

Figure 2. Association of SAS, duration of surgery, and that of hospital stay with the complication rate
Variables associated with mortality
We observed that the mean SAS was significantly less in patients who died (3.8 ± 1.30) compared to those who survived (5.97 ± 1.69). The mean duration of the hospital stay (12.27 ± 8.15 vs. 6.2 ± 3.03 days) was longer and the mean age was higher (53.8 ± 17.16 vs. 42.4 ± 14.6 years) in non-survivors compared to survivors.

Variables associated with complications
After adjusting for confounding factors such as age, gender, associated co-morbidities, duration of surgery, type of surgery, and duration of hospital stay, we found that SAS, the duration of the surgery and that of the hospital stay were independently associated with the occurrence of complications (Table 3).

Table 3. Association of occurrence of complications with SAS, the duration of the surgery and that of the hospital stay

<table>
<thead>
<tr>
<th>Complications</th>
<th>APGAR score *</th>
<th>Duration* (hours)</th>
<th>Duration of hospital stay* (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>7.2 ± 1.2</td>
<td>4.3 ± 1.3</td>
<td>7.3 ± 2.8</td>
</tr>
<tr>
<td>Yes</td>
<td>5.3 ± 1.6</td>
<td>5.0 ± 1.7</td>
<td>14.1 ± 8.7</td>
</tr>
<tr>
<td>p value</td>
<td>0.001</td>
<td>0.013</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Among the patients who developed complications, the mean SAS (5.3 ± 1.6) was significantly lower (p = 0.001) compared to patients with no complications (7.2 ± 1.2). The mean duration of the surgery in patients without complications was 4.3 ± 1.3 hours and it was significantly less (p = 0.013) compared to patients who had developed complications (5.0 ± 1.7 hours). Similarly, the mean duration of the hospital stay for patients with complications was 14.1 ± 8.7 days, which was significantly more (p = 0.001) than that for patients without complications (Figure 2). SAS was able to predict the occurrence of complications in 91% of the patients, while its ability to predict that a patient would not develop complications was recorded at 51.1%. Thus, SAS has high sensitivity and low specificity in predicting complications.

The statistics for SAS in predicting complications showed that R^2 = 0.257 with a beta power of 0.410 (confidence interval: 0.296–0.568). The R^2 value indicated that SAS alone can predict the occurrence of complications in patients undergoing elective craniotomy 25% of the time.

DISCUSSION
In this retrospective study of 150 adult patients undergoing elective craniotomy for supratentorial/infratentorial space-occupying lesions and intracranial aneurysms, we observed that a lower SAS indicated higher 30-day complications. In addition, SAS could possibly predict specific types of complications such as the requirement for blood transfusion, postoperative fever, surgical site infection, and postoperative seizures that may not be predicted by preoperative characteristics alone.

The raw data demonstrated that five patients (3.3%) in our cohort died and four of those had an SAS of 3–4, while one had an SAS of 4–6. The small number of deaths in our study precluded the application of any statistical method to analyze the association of risk factors specific to mortality.

The mortality rate in our study population can be compared to all-cause mortality in a study by Ziewacz JE et al., where the mortality rate was 2.6%. Patients with an SAS of 0–2, 3–4, 5–6, 7–8 and 9–10 had 30-day mortality rates of 12.5%, 7.5%, 6.0%, 1.2%, and 1.7%, respectively.

In our study, we did not find any association between mortality and the type of surgery. With regard to preoperative medical co-morbidities such as hypertension, diabetes, CAD, asthma and seizures, there was no association of any of these factors with mortality and this finding was similar to the study conducted by Ziewacz JE et al., where prior diagnosis of hypertension and diabetes did not affect mortality rates. Our results with regard to the association of mortality with SAS is also consistent with the study findings of Reynolds et al., who showed the significant
association between SAS and all-cause mortality in a cohort of 7,589 neurosurgical patients\textsuperscript{12}. Moreover, in this study, we found that the predictive power of SAS decreases as the time after surgery increases.

We observed that although the mean duration of the hospital stay in our patients with complications was significantly more (14.1 ± 8.7 days) compared to the patients without complications (7.3 ± 2.8 days), the mean duration of the hospital stay in patients who died was only 6.2 ± 3.0 days compared to those who survived (12.27 ± 8.5 days). Thus, neurosurgical patients with a low SAS should be identified early and monitored aggressively, as they are at the risk of developing complications or dying.

To date, SAS has been studied and validated as a useful tool to predict the postoperative outcomes in colorectal surgery, vascular surgery, neurosurgery and some gynecological and urologic procedures\textsuperscript{7–11}. The data from our study demonstrated that an SAS range of 0–2 was associated with a 100% rate of complications, whereas the score range of 9–10 was associated with 33%. Scores of 3–4, 5–6 and 7–8 were associated with complication rates of 96.7%, 80.3% and 47.2%, respectively. This demonstrated that SAS and the possibility of developing complications are inversely related. Compared to the study by Ziewacz JE \textit{et al.}, the incidence of complications at various levels of SAS is considerably higher in our study, probably because the authors (of that study) only considered blood transfusions of more than four units as a complication\textsuperscript{11}.

After accounting for the confounding factors such as age, gender, type of surgery and associated co-morbidities, we observed that the rate of complications in our cohort was associated with SAS, duration of surgery and duration of hospital stay. In addition, our data demonstrated that there was a statistically significant inverse relationship between SAS, the risk of infectious and neurological complications and the requirement for blood transfusion. However, SAS was not able to predict the occurrence of unplanned reintubation.

In the logistic regression analysis, SAS had a significant R\textsuperscript{2} value of 0.257. This suggested that even after excluding other influencing factors, SAS alone had the power to predict complications in our patient population 25% of the time, which is clinically significant for a single scoring system.

One of the main concerns with the use of SAS is whether it is just a surrogate marker for preoperative risk factors such as age, type of surgery and associated co-morbidities. To answer this, many studies compared the utility of SAS in predicting the risk of complications before and after detailed preoperative risk adjustment\textsuperscript{8,11}. Our results also indicated that SAS is able to predict the occurrence of complications, even after accounting for preoperative co-morbidities and duration of surgery. Thus, SAS may serve as a simple tool to assess a patient’s immediate postoperative status and provide early warnings with regard to the risk of likely complications such as need for blood transfusion, postoperative development of infectious complications, coma and requirement for ventilation.

\textbf{LIMITATIONS OF STUDY}

This was a retrospective study, and the findings may have been confounded by unmeasured disease states or other factors associated with both SAS and the postoperative outcomes, for which we were unable to adjust. Moreover, there may be under-reporting and inaccuracies in the retrospective assessment of complications. Furthermore, we did not evaluate the patients’ condition after they were discharged from the hospital. The neurological complications were broadly defined as ‘stroke’, ‘coma’ or ‘seizures’ and specific neurologic deficits were not evaluated. These measures are consistent with the complications reported by the American College of Surgeons National Surgical Quality Improvement Program\textsuperscript{13}. However, compared to other types of surgery, neurosurgical patients are at a high risk of
developing neurological complications such as stroke and seizures. Our sample was limited to the elective craniotomy procedures performed at a tertiary care neurocenter; hence, the applicability of the results to emergency craniotomy for traumatic brain injury or other semi-elective procedures or procedures performed in a peripheral center is questionable. Moreover, the parameters used to estimate SAS could be prone to observer bias. However, the broad categories used to calculate the score were well within the observers’ range of precision.14

To conclude, SAS is a simple scoring system that can be used in the case of neurosurgical patients undergoing craniotomy to predict postoperative complications. This could be the early warning required in clinical practice that can help identify patients at the risk of developing complications and assist in the aggressive management of patients, leading to improved outcomes.

REFERENCES


