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Shock Index in Patients Undergoing Elective and Emergency General Surgical Procedures: A Predictor of Morbidity Risk and Outcomes

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ABSTRACT

Introduction: Shock index (SI) has gained popularity as a quick and inexpensive screening tool for patients of trauma or obstetric hemorrhage to predict risk of mortality and morbidity especially transfusion requirement. It has further been studied for sepsis in recent times. Though not specific the shock index has been shown to be a sensitive tool in alerting physicians of patients that may require greater medical attention. It has not been studied in patients undergoing general surgical procedures either elective or emergency.
Aims & Objectives: To assess the utility of shock index in patients undergoing both elective and emergency general surgical procedures and to assess outcomes of these patients.
Place and duration of study: It was a retrospective cohort study of in-patient records of the Department of General Surgery, Sir Ganga Ram Hospital, Lahore. The duration of study was from 1st September 2021 till 30th November 2021.
Material & Methods: From the medical records information was retrieved and the shock index was calculated by 'heart rate divided by systolic blood pressure' and was recorded for the following instances: (i)At admission (ii) Prior to induction of anesthesia (iii) In the immediate post-operative phase in the recovery unit (iv) post-operative Day 1 (v) at discharge. Patient's outcomes and investigations were also recorded. SPSS version 24 was used for data entry and analysis
Results: SI at admission and on post-operative Day 1 for emergency vs elective surgery was 0.82 and 0.72 vs 0.69 and 0.68. Shock index prior to induction was higher in the emergency surgery group and this was statistically significant. A shock index value of 0.81 was 71.7% and 72% specific for post-operative morbidities. The optimum value for shock index in ER and Elective surgery varies for each morbidity.
Conclusion: This is a simple tool and may increase appropriate resource allocation and increased observation for certain patients who are screened to be at higher risk of developing a specific morbidity post-operatively, especially in resource-limited countries like Pakistan.

Keywords: Shock Index, Elective, Emergency, General Surgery

INTRODUCTION

Shock index was first designed as a tool to predict mortality and need for transfusions in patients who had undergone trauma. It was a simple tool dividing the heart rate with the systolic blood pressure thus it could be used in the field prior to hospital arrival and in the hospital[1]. This tool developed in the late 1960s was found to have a normal value of less than 0.7 and in some studies, it was quoted to be 0.9. A value higher than this would be predictive of impending cardiovascular collapse and shock. However, traditionally this was limited to hypovolemic shock secondary to hemorrhage.[1]
From trauma the SI index was applied to obstetric hemorrhage, and it was found that an index of 0.7 was commonly found in vaginal deliveries with a blood loss less than 0.5 liters, however the index increased to 1.0 with greater blood loss and predictive of need for transfusion and morbidity.[2]
The SI index has recently gained interest by researchers in the emergency department setting beyond trauma and hemorrhagic shock.[1,3] They have postulated that it is a useful tool in categorizing in-patient morbidity and ICU stay for a variety of presentations including pulmonary embolism, heart attacks, sepsis amongst others.[3] In this regard they found that an SI greater than 1.2 had the greatest chances, nearly 12 times greater, of needing in-patient admission, intensive care and mortality for patients presenting to the emergency[1,3].
Studies found that an elevated SI of greater than 0.7 in patients who met the criteria for systemic inflammatory response system had a higher likelihood of having raised lactate levels and

predictive of septic shock and its associated morbidities as compared to those patients in which the index was normal.[4]

In patients undergoing surgery both elective and emergency, it is hypothesized that the catecholamine release as a stress response to surgery causes tachycardia in the post-operative period.[5] It has further been described that due to this sympathetic drive being accentuated due to surgical stress there is an associated increase in blood pressure as well in the post-operative period.[6] These changes may be transient or may persist, and if they persist, they may portend developing morbidities.[5]

There are no studies to our knowledge that have observed or calculated shock index for patients undergoing elective general surgical procedures and its association with morbidities and mortality in this cohort. This study was conducted to assess the utility of shock index in patients undergoing both elective and emergency surgery and to assess outcomes of these patients.

MATERIAL AND METHODS

This was a retrospective cohort study where information was retrieved from patient's records. Patients records were examined for the months of September to November 2021. 42 (fourty-two) patients were included in the study. Post-hoc power analysis was 94%. Demographics such as age, gender and co-morbidities were recorded. Type of surgical procedure either emergent or elective was recorded. Intervention that the patient had undergone was recorded along with outcomes. Outcomes included mortality and morbidities during the hospitalisation such as length of hospital stay in days, transfusion requirements as units of whole blood, number of re-operations, ICU stay in days, need for post-operative ventilator support, CPR done for cardiac arrest, stroke or documented cerebrovascular accident, documented myocardial infarction, fever greater than 100.2F, occurrence of post-operative abdominal wall dehiscence, occurrence of wound infection according to CDC surgical wound classification, post-operative bleeding in milliliters as calculated from drains and soaked gauze dressing estimates, and hospital acquired infections of which wound, pneumonia etc were all included as long as micro-organism documented was commonly acquired. Patient's pre-operative complete blood count, liver function tests and renal function tests recorded along with repeat post-operative baselines. Patients who needed a nasogastric tube, foley catheter, drains in operative cavities placed and had a stoma created were recorded as events during in-patient stay. Intra-operative blood loss was recorded separately. Shock index as calculated by heart rate divided by systolic blood pressure was recorded for the following instances:(i) At admission (ii) Prior to induction of anesthesia (iii) In the immediate post-operative phase in the recovery unit (iv) post-operative day 1 (v) at discharge. SPSS Version 24.0 was used for data entry and analysis.

RESULTS

Demographics: 42 patients were included in the study. The mean age of patients was 35.6 ±SD 15.3 years. The youngest patient was 7 years old and the eldest was 80. There were 14.3% males and 85.7% females. Co-morbidities were present in our participants, and these are illustrated in Table-1.

Co-morbid	Frequency (N=42)	Percentage (%)
Diabetes	3	7.1
Hypertension	6	14.3
Ischemic Heart Disease	3	7.1
Chronic Kidney Disease	1	2.4
Thalassemia with pulmonary hypertension	1	2.4
Smoker	1	2.4
Previous Stroke	1	2.4
Asthma	1	2.4
Hepatitis C	2	4.8

Table-1: Frequency distribution of co-morbidities in our participants.

Patients underwent different surgical procedures. Fig-1 shows a pie-chart distribution of these procedures.

Similar surgical procedures were done in some cases with different diagnosis. These are elaborated to decrease ambiguity. Breast conservation surgery and MRM were done for invasive ductal carcinoma. Debridements were done for a pressure ulcer and a scrotal abscess which had undergone an incision and drainage as well.

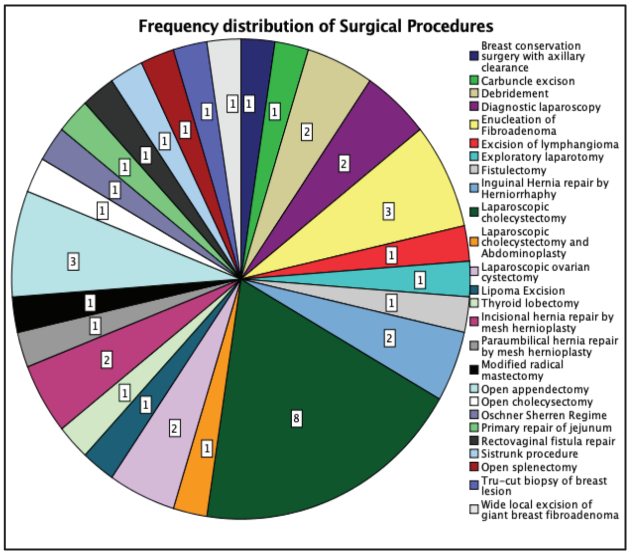

Fig-1: Pie chart frequency distribution of surgical procedures.

Legend**:** Each slice shows the frequency of the procedure, the colour of the slice correlates with the representative colour in the legend to the right of the pie-chart which shows the procedure done.

Diagnostic laparoscopy was performed for two patients, one was found to have an ectopic tubal pregnancy and the other an infected ventriculo-peritoneal shunt with intra-abdominal abscess around the shunt. Lymphangioma excision was done for a lymphangioma of the neck. Exploratory laparotomy was done for a patient found to have had a uterine rupture and small bowel perforation secondary to instrumentation during a dilatation and curettage. Thyroid lobectomy was done for a benign goiter. Primary jejunum repair was done due to blunt trauma to the abdomen that had caused a mesenteric hematoma with jejunum perforation. Splenectomy was done for a thalassemia patient with splenomegaly.

Placement of Nasogastric Tubes, Foleys, Drains and Stoma formation: 7.1% (n=3) of all patients had a nasogastric tube placed during hospital stay. 23.8% (n=10) had a per-urethral Foley catheter placed. 2.4% (n=1) had an ileostomy sited. 42.9% (n=18) had a drain placed in a surgically created dead-space or body cavity.

Intra-operative blood loss: Mean intra-operative blood loss was 129 ±SD 16.03 ml in emergency surgery. Mean intra-operative blood loss was 88.75 ±SD 10.91 ml in elective surgery. Outcomes were noted in terms of morbidity and mortality. (Table 4)

Shock Index Mean Scores: Shock index for all included patients is shown in Table-2.

SI Time Measured	Shock Index Values for All Participants: Mean Value ± Standard Deviation	Max. Range	Min. Range
At Admission	0.73 ± 0.17	1.43	0.48
Prior to Anesthesia	0.78 ± 0.14	1.20	0.50
Post Op Recovery Unit	0.73 ± 0.15	1.05	0.48
Post Op Day 1	0.69 ± 0.10	0.95	0.52
At Discharge	0.70 ± 0.13	1.07	0.50

SI Time Measured	Shock Index Values Stratified by Surgery Type: Mean Value± Standard Deviation		Max. Range		Min. Range	
	ER	Elective	ER	Elective	ER	Elective
At Admission	0.82 ± 0.26	0.69 ± 0.11	1.43	0.95	0.48	0.50
Prior to Anesthesia	0.91 ± 0.15	0.73 ± 0.11	1.20	1.08	0.73	0.50
Post Op Recovery Unit	0.79 ± 0.15	0.71 ± 0.14	0.98	1.05	0.55	0.48
Post Op Day 1	0.72 ± 0.13	0.68 ± 0.98	0.95	0.90	0.60	0.52
At Discharge	0.66 ± 0.11	0.71 ± 0.13	0.89	1.07	0.55	0.50

Table-2: Mean shock index values for all patients included in the study at different time intervals and stratified for elective and emergency surgery

Baseline investigations at admission and at discharge.

Investigations	Mean Value & Standard Deviation: At Admission, Mean Value ± Standard Deviation		At Discharge, Mean Value ± Standard Deviation	
	ER	Elective	ER	Elective
Creatinine mg/dL	1.95 ±2.25	0.64±0.2	1.09±0.77	0.61±0.12
Hemoglobin g/dl	11.2±2.98	11.4±1.7	10.31±1.7	11.2±1.20
Platelet count x109/L	248.9±109.4	261±96.5	266.4±75.05	240±59.4
WBC x109/L	11.74±7.01	8.60±2.4	9.38±2.11	8.40±1.60
ALT IU/L	33.4±25.6	32.9±25.2	24.8±15.6	30.2±25.8
AST IU/L	23.7±9.63	33.9±14.1	27.5±11.4	32.1±13.9

Table-3: Baseline investigations mean values at admission and at discharge.

Elective Surgery: The mean length of hospital stay was 5.00±SD3.58. The mean transfusion requirements were 0.13 ±SD 0.55 units of whole blood. The mean ICU stay in days was 0.06 ±SD 0.35. All patients in this group were discharged and there were no mortalities. No patients needed re-exploration or subsequent operative procedures. No patients experienced a cerebro-vascular accident or cardiovascular collapse requiring CPR. No patients experienced a myocardial infarction nor abdominal wall dehiscence. No patients had post-operative pneumonia or urinary tract infections whereas 3.1% (n=1) needed intubation and ventilator support post-operatively.9.4% (n=3) had a post-operative fever. 3.1% (n=1) experienced a surgical site infection. 65.6% (n=21) had no post-operative bleeding as collected in drains or dressings. 34.4% experienced post-operative bleeding. Only 6.3% (n=2) had bleeding more than 200ml.

Emergency Surgery: The mean length of in hospital stay was 9.60 ±SD 11.73 days. The mean transfusion requirements were 1.10 ±SD 1.72 units of whole blood. The mean ICU stay in days was 0.50 ±SD 1.08 days. All patients were discharged and there were no mortalities. None of the patients required intubation and ventilatory support or cardio-pulmonary resuscitation. None of the patients experienced a cerebrovascular accident, a myocardial infarction or had post-operative pneumonia. 20% (n=2) required re-operation or subsequent surgeries. 50% (n=5) experienced post-operative fever. 20% (n=2) had an abdominal wall dehiscence and 40% (n=4) had a surgical site wound infection. 10% (n=1) had a urinary tract infection post-operatively. 70% (n=7) patients experienced no post-operative bleeding. 10% (n=1) experienced less than 200ml post-operative bleeding, 10% (n=1) experienced more than 200ml but less than 500ml bleeding, and 10% (n=1) experienced greater than 500ml post-operative blood loss.

Association analysis: Shapiro-Wilk test was run to see if data regarding Shock Index at different time intervals was normally distributed. Shock Index at admission and Shock Index prior to induction of anesthesia were not normally distributed with Shapiro Wilk Values less than 0.05. Shock Index in the immediate post-operative phase, on post-operative day 1 and at discharge were normally distributed. Mann-Whitney U test was done to see if there was a statistically significant difference between shock index at admission and prior to induction of anesthesia phase between elective and emergency surgery. P-value of 0.11 was obtained for SI at admission and P-value of 0.002 was obtained for SI prior to induction to anesthesia. We found that prior to induction of anesthesia there was a significant difference between shock indices between the two groups. Independent samples T-test was done to see if there was a difference in the mean shock indices between the two groups in the recovery room post-operatively, on post-operative Day 1, and at discharge. P- Values of 0.17, 0.47 and 0.27 were obtained respectively showing there was no significant difference. ROC curve was run for SI prior to induction of anesthesia and at admission. The area under the curve and optimal value along with its sensitivity and specificity were noted for different outcomes. These are shown in Table-4.

Out come	Shock Index	*Optim Value	*Sens itivity	*Spec ificity	AUC	P-Value	
						ER	Elective
*TSF	At Admission	0.80	66.7 %	82.8%	0.713	0.29 7	0.99
	Prior to Induction of Anesthesia	0.75	83.3 %	57.1%	0.726	0.28	0.002
Re-op	At Admission	0.98	50%	97.4%	0.603	0.35	-
	Prior to Induction of Anesthesia	1.04	50%	97.4%	0.718	0.25	-
*Int & Vent	At Admission	0.80	100%	72.5%	0.763	-	1.00
	Prior to Induction of Anesthesia	0.76	100%	52.5%	0.525	-	0.07
Fever	At Admission	0.78	50%	69.7%	0.606	0.35	0.84
	Prior to Induction of Anesthesia	0.79	50%	63.6%	0.608	0.84	0.970
*AW D	At Admission	0.98	100%	100%	1.00	0.35	-
	Prior to Induction of Anesthesia	0.98	100%	94.9%	0.981	0.89	-
*W I	At Admission	0.62	60%	28%	0.483	0.35	0.10
	Prior to Induction of Anesthesia	0.74	80%	41.7%	0.664	0.80	0.07
UTI	At Admission	0.98	100%	97.5%	1.00	0.35	-
	Prior to Induction of Anesthesia	1.04	100%	97.5%	1.00	0.25	-
Post-op Bleed	At Admission	0.71	35.7 %	48.1%	0.455	0.31	0.11
	Prior to Induction of Anesthesia	0.79	35.7 %	56%	0.421	0.30	0.41
Length of Stay > 5 Days	At Admission	0.67	76.9 %	50%	0.709	0.26	0.63
	Prior to Induction of Anesthesia	0.71	76.9 %	28.6%	0.492	0.32	0.008
ICU Admiss ion	At Admission	0.80	100%	76.3%	0.899	0.33	1.00
	Prior to Induction of Anesthesia	0.76	66.7 %	52.6%	0.614	0.94	0.07
Intra-op Blood Loss >100ml	At Admission	0.78	50%	69.7%	0.538	0.35	0.99
	Prior to Induction of Anesthesia	0.80	50%	63.6%	0.595	0.57	0.05
*AVG	At Admission	0.81	71.7 %	72%	-	-	-
	Prior to Induction of Anesthesia	0.83	72%	64.1%	-	-	-

Table-4: Shows the optimal value of shock index for different outcomes at admission and prior to induction of anesthesia, along with sensitivity and specificity of that value and the area under curve of the receiver operating curve along with P-values for ANOVA done to test association of means between the two variables.

* Optim value= Optimal value, TSF=Transfusion, Int &Vent=Intubation & Ventilation, AWD= Abdominal Wall Dehiscence, WI= Wound Infection, AVG = Average Values for All Outcomes

T-test was done to see if there was any association between age and length of stay, p-values of 0.62 for emergency surgery group and 0.84 for elective surgery group was computed. P-values were higher than 0.05 thus showing no significant effect of age on length of stay. Chi-square test was done to see if there is any correlation between S.I index at admission for all cases and presence of diabetes, hypertension, or ischemic heart disease. P-value of 0.22, 0.62 and 0.76 respectively was obtained showing no correlation.

DISCUSSION

In various studies the Shock index has been found to be a sensitive tool to alert the physician of whether morbidities may occur, primarily the need for transfusion or resuscitation due to hypovolemic shock in the setting of trauma. Different studies have quoted different cut-off values for the shock index above which it is considered a sensitive tool. Some studies have quoted 0.7 others have found 1.0 to be a better indicator. Primarily in the shock state or the stress state the body's physiological response would be to increase its heart rate with a concurrent decrease in systolic blood pressure thus showing an increasing trend of shock index.[1, 2]

Studies done initially were in populations that were not South Asian. Recent studies done in Pakistan have found that the shock index at a value of above 0.7 is a good predictor of the presence of raised lactate levels in patients suspected of being in severe sepsis.[7]The Pakistan Emergency Department Surveillance program captured the vitals of 274, 436 patients in the field presenting with various complaints. They found that many patients visiting the emergency department did not have their vital signs taken due to high burden of patients in these departments and only sick patients who were likely to be admitted or observed had their vitals recorded. For the patients with vital signs the authors calculated the shock index and found that in patient's fever, abdominal pain, chest pain, vomiting and diarrhea as the presenting symptoms the shock index was elevated in 12.8%, 8.4%, 13.3%, 10.2% and 12.9% respectively. This shows us that the shock index can be widely used in the emergency department regardless of the presenting symptom and beyond obstetric hemorrhage or trauma.[8]

A study done that correlated the incidence of post-intubation hypotension and cardiac arrest to the shock index prior to intubation found that that the chances for both increased as the value of SI increased from 0.8 and 0.9 respectively. This is an example of the shock index being a predictor for morbidity based on the patient's pre-intervention cardiovascular physiological status.[9]

There is a lack of literature exploring the SI in elective surgery. Elective surgery, like emergency surgical procedures, carries the risk of morbidities and mortality especially in high-risk patients or complicated high-risk surgeries. The SI may be a simple tool to alert the surgeon of pre-operative elective patients who might be at a higher risk for ensuing morbidity and mortality and thus may increase preparedness. The index may be used as an adjunct for risk stratification along with already available scoring systems that help stratify risk for pre-operative patients.

We measured the shock index at 5 intervals for all patients. These intervals were at admission, which we had hypothesized would be different for patients presenting to the emergency department versus for those being operated electively. Prior to anesthesia induction at this point the patient had been nil per oral and was being prepared for surgery. We then evaluated the SI in the post-operative recovery unit, this is when the patient has the stress response fro surgery, and we were expecting that this SI would likely be the same for both groups. We expected there to be a difference on post-operative Day 1 since patients who had emergency surgery may have had more tissue trauma and were more likely to have morbidities as compared to patients who were undergoing elective surgery, however we expected the SI to be similar at discharge for both groups. SI is frequently measured in patients at admission and prior to any intervention later on in the course of admission, however we expanded our measurements.[10]

We found that that the SI for emergency surgery was higher than elective surgery at admission and prior to surgery with mean values of 0.82 ±SD 0.26 vs 0.69 ±SD 0.11 at admission and 0.91 ±SD 0.15 vs 0.73 ±SD 0.11. The values were closer for the other time intervals. The Mann-Whitney U test showed us that prior to induction of anesthesia the SI was significantly different between the two groups. From this we were able to infer that prior to induction of anesthesia may be the optimum time to measure SI index for both elective and emergency surgeries.

Between the groups, emergency surgery patients had a higher mean WBC count and mean creatinine. This is likely due to multi organ involvement with sepsis or systemic inflammation. We found a modest difference in the amount of intra-operative blood loss which had a mean of 129ml in emergency surgery and 88.75ml in elective surgery. The groups had a mean difference in length of stay of 9.60 days for emergency surgery and 5 days for elective surgery, this was found to be significantly different using T-test with a p-value of 0.05. This is expected as patients after emergency surgery need prolonged antibiotics and bedside care.[11]

We calculated the optimal value for SI for different morbidities both at admission and prior to surgery and this was regardless of which type of surgery they had. Patients who required transfusions could be screened using an SI of 0.80 or greater at admission. Patients with an SI of 1.0 or above may be at higher risk of needing re-operations. Patients with an SI of greater than 0.80 may be at higher risk for intubation and ventilation requirements post-operatively. Patients with an SI of 0.98 may be at a higher risk for abdominal wall dehiscence after surgery. Patients with an SI of 0.74 may be at higher risk of experiencing wound infections and those with an SI of 1.0 may be at a higher risk of experiencing urinary tract infections. An SI of 0.80 may be used to identify patients at a higher risk at the time of anesthesia induction who may experience greater than 100ml intra-operative blood loss or post-operative blood loss. An average value for all morbidities inclusive was determined to be 0.81 at admission and 0.83 prior to induction of anesthesia. These values can be used in both elective and emergency general surgery scenarios.

Keeping in view previous literature, an SI of greater than 0.9 mainly in trauma patients has been found as an optimal cut off for patients that have greater bleeding and transfusion requirements. Our findings for intra-operative and post-operative bleeding has a similar finding of an SI of 0.98 and above. Thus we can confidently suggest the use of this value for both elective and emergency general surgical procedures.[12] Another study done found that instead of a value of 0.9 a value of 0.8 or higher was more sensitive in detecting patients who had occult bleeding following trauma.[13] This was an interesting study as we found that an SI of 0.8 and above was sensitive in picking up more than just bleeding in surgical patients, but other in-hospital morbidities as well. Again, supporting our hypothesis that the shock index may be a useful tool for detecting a range of post-operative morbidities and may alert the clinician either at the time of admission or prior to induction of anesthesia that a patient may need more intensive care or support and observation during hospital stay.[13]

Moreover, the shock index has primarily been reported to be in the normal range if it is between 0.5 and 0.7.[14]As a predictor shock index values of greater than 0.80 or 0.90 have been used with a higher risk of morbidity with increasing values. Though our study findings agree with this, and for all morbidities we found that an optimal value of shock index was higher than 0.70, we believe that morbidity specific data may aid the surgeon in making better decisions.

Our study was a small study which is its limitation however it is the first study to explore the shock index and its utility in screening for morbidities following elective and emergency surgery.

CONCLUSION

We believe the shock index may be an inexpensive and rapid screening tool for morbidities encountered in general surgical patients. More studies and with pooled data may eventually be able to identify an optimal value for shock index both at admission and prior to surgery at which a surgeon may be able to screen patients undergoing both elective and emergency surgery using the shock index in a morbidity specific fashion. This is a simple tool and may increase appropriate resource allocation and increased observation for certain patients who are screened to be at higher risk of developing a specific morbidity post-operatively, especially in resource-limited countries like Pakistan.

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