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A New Tool to Assess The Risk of Limb Loss Following Peripheral Vascular Injuries in Trauma Patients at The Emergency Department

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ABSTRACT

Background: Recent studies have shown increased risk of limb loss and disability following peripheral vascular injuries, especially injuries associated with orthopedic and extensive soft tissue injury.

Objective: To provide an application of a simple tool that assesses the risk of limb loss following peripheral vascular injuries in trauma patients at the emergency department.

Patients and Methods: A retrospective cross-sectional study was conducted on 50 patients suffering peripheral vascular injury attending the Emergency Department at Menoufia University Hospitals and other hospitals over six months, starting from the 1st of July 2023. All patients were followed up for amputation risk as the outcome of the study. The median follow-up period was one month.

Results: A total of 31 patients with lower limb, 25 of them were high-risk (80.6%), and 15 of them underwent an amputation (48%). A total of 19 patients with upper limb, 10 of them were high risk (52.6%), and 3 of them underwent an amputation (15.8%). The amputation rate was significantly higher among patients with lower limb injuries compared to upper limb patients. The POPSAVEIT score was significantly important in stratifying the amputation risk of the patients, using a score of ≥3 for high-risk patients and <3 for low-risk patients. In our study, ROC (receiver operating characteristic) analysis shows that the POPSAVEIT score could be used as a predictive scoring system for the diagnosis of high and low-risk patients for amputation with an area under a curve of 0.829, 0.700 (p <.001) at 5% CI of (0.61–1.0, 0.498-0.902), using a cut-off of ≥3.5 and ≥3, with (75.1%, 80%) sensitivity and (65.3%, 70.1%) specificity for upper and lower limb vascular injury, respectively.

Conclusion: The POPSAVEIT score could be used as a predictive scoring system for the diagnosis of high and low-risk patients for amputation using a cut-off of ≥3.5 and ≥3, with (75.1%, 80%) sensitivity and (65.3%, 70.1%) specificity for upper and lower limb vascular injury, respectively.

Keywords: Traumatic peripheral vascular injury, Acute limb ischemia, Limb loss, Trauma patients.

INTRODUCTION

In civilian trauma centers, 40–75% of the vascular injuries treated are peripheral, which are classified as axillobrachial and branches in the upper extremity and femoropopliteal and branches in the lower extremities [(1)]. Handgun missiles with low muzzle velocity and low kinetic energy (less than 1,000 ft. lbs.) are responsible for almost half of these penetrating injuries [(2)].

Just 5-25% of patients receiving treatment have peripheral vascular injuries following physical trauma to the extremities, such as fractures, dislocations, crush injuries, and traction. The most frequent site is the extremities [(3)].

Of the arteries in the extremities, the brachial artery sustains 30% of injuries, whereas the femoral or popliteal arteries sustain 50-60%. Intimal injuries (Flaps, disruptions, or sub-intimal/intramural hematomas), full wall defects with pseudo-aneurysms or hemorrhage, complete transactions with hemorrhage or occlusion, arteriovenous fistulas, and spasm are the five recognized forms of vascular injuries [(4)].

Exsanguination death or the development of multiple organ failure following prehospital near exsanguination are the main risks for a patient with a major peripheral vascular damage [(5)]. Direct pressure or a compressive bandage, along with continuous resuscitation, should be used to treat bleeding from an injured extremity, which impacts "Circulation" during the Primary Survey of Advanced Trauma Life Support [(6)]. During the secondary survey of advanced trauma life support, the damaged extremities is evaluated if there is no bleeding. The presence or absence of normal pulses during physical examination or Doppler instrument usage determines the likelihood of an arterial damage [(7)]. Consequently, if the initial distal pulse palpation during the secondary survey records a difference between the injured and a contralateral uninjured extremity in the hemodynamically stable patient, a fracture or dislocation of a joint in the injured extremity should be realigned or relocated, respectively [(4)].

External bleeding, a fast-growing hematoma, any of the typical symptoms of arterial occlusion (Pulselessness, pallor, perishingly cold, paresthesia, pain, paralysis=6 "Ps"), and a palpable thrill/audible bruit are examples of "hard" or obvious indicators of an arterial damage in an extremity [(8)].

According to the primary author, **Leigh Ann O'Banion**, "traumatic popliteal artery injuries present a serious clinical challenge because they are associated with the greatest risk of limb loss of all peripheral vascular injuries, with major amputation rates of 14-25%". Previous grading methods, such as the Mangled Extremity Severity Score (MESS), attempted to define a point beyond which healing is ineffective. **O'Banion and colleagues** studied the outcomes of individuals who had undergone surgical repair for traumatic

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popliteal artery injuries and discovered characteristics that were independently related with limb loss. They compared clinical data from individuals who required significant (above ankle) amputations to those who did not, and then validated the new grading method in a random 20% of this cohort [9].

Those who lost main patience had a major amputation rate of 46%, whereas the total amputation rate was 16% at a mean follow-up of 69 days. The importance of careful follow-up is highlighted by these findings. The following were significant preoperative risk factors for amputation: lack of distal Doppler signals, orthopedic damage, and SBP <90 mm Hg [10]. These data were used to generate a Popliteal Scoring Assessment for Vascular Extremity Injuries in Trauma (POPSAVEIT) score, which awards two points for the orthopedic damage and no Doppler signals, and one point for blood pressure. The grading method that revealed amputation rates was verified to be 25.5% for a score of 3–5 points, compared to 5.9% for a score of 0–2 points [11].

The POPSAVEIT score separates the results of a thorough evaluation of the patient into three crucial parts, according to **O'Banion**: ischemia, musculoskeletal deformity, and measurements of global physiological damage. Using the damage rating scales developed by the American Association for the Surgery of Trauma, which are commonly used and approved in trauma centers, this preoperative assessment tool might be utilized to effectively communicate with and risk-stratify patients across centers [9].

Furthermore, risk stratification could be helpful when establishing expectations and talking about the prognosis with patients, their families, and other healthcare professionals. When evaluating this risk as soon as the patient arrives at the emergency department, the POPSAVEIT tool might be helpful [9].

In this study we aimed to evaluate the efficacy and accuracy of popliteal scoring system as a simple tool for assessing risk of limb loss following upper and lower limbs peripheral vascular injuries in trauma patients at the emergency department, and also analysis of risk factors for major amputation and comparing incidence of amputation between upper and lower limb traumatic vascular injury.

PATIENTS AND METHODS

A retrospective cross-sectional study was conducted on 50 patients suffering peripheral vascular injury attending the Emergency Department at Menoufia University Hospitals and other hospitals over 6 months, starting from the 1st of July 2023. Patients were followed up for amputation as the outcome of the study, the median follow up period was one month.

Patients' selection criteria

In this study, we included all patients above 18 years old, both sexes, patients suffering peripheral vascular injury in the upper and lower extremities. However, we excluded paediatric patients, iatrogenic vascular injury, and patients with chronic peripheral vascular diseases.

All participants were subjected to:

Personal data were taken, including age and gender. Physical examination: ABCDE evaluation. Full history taking including: medical history as hypertension, diabetes, dyslipidaemia, drug history, previous surgical history and smoking. Full clinical examination: focused on: General examination: assessment of GCS and measurement of vital signs including blood pressure, temperature, respiratory rate, heart rate and O_2 saturation. Local examination: Chest, abdominal, cardiac, vascular and neurological examination.

Doppler ultrasound for peripheral pulsation

Distal Doppler signals and the existence or lack of palpable distal pulses were among the data points for the vascular examination findings. With a value of 0 for the presence of preoperative distal Doppler signals, 2 for the lack of distal Doppler signals, and 1 for the absence of pulse in patients without Doppler signal data available, a composite variable for the vascular examination was developed in order to address missing Doppler examination data and develop a scoring system that could also be used in austere environments without Doppler equipment.

X-ray and further imaging if needed.
Popliteal score evaluation for vascular extremities injuries.

Table (1): Popliteal scoring assessment.

Risk factors	Points
Systolic pressure < 90 mmHg	1
Associated orthopaedic injury	2
Lack of preoperative distal Doppler signal	2
Lack of palpable preoperative distal pulses	1

Associated orthopaedic injuries were defined as fractures or dislocations. Patients were followed up for detection of amputated cases as the outcome of the study, the median follow up was one month.

Ethical consideration

Patients were asked to provide written informed permission after describing the purpose of the study. The study protocol was approved by the Ethical Scientific Committee of Menoufia Faculty of Medicine (IRB: 7/2023OBSG). All patients were clinically assessed on their arrival in accordance with the ATLS protocol of management of polytrauma patients. The study adhered to the Helsinki Declaration throughout its execution.

Statistical analysis

The statistical analysis was performed using SPSS version 26.0. Quantitative variables were

provided as mean ± SD and examined using the unpaired student t-test. Qualitative variables were provided as frequency and percentage (%) and compared using the X^2-test.

Univariate logistic regression was used to determine the association between a dependent variable and various independent variables. A two-tailed P value < 0.05 indicated statistical significance.

RESULTS

A flowchart of the study population: 56 patients suffering peripheral vascular injury attending the Emergency Department at Menoufia University Hospitals over one year, starting from the 1st of July 2023. 6 patients were excluded from the study and 50 subjects participated in the study. **(Figure 1).**

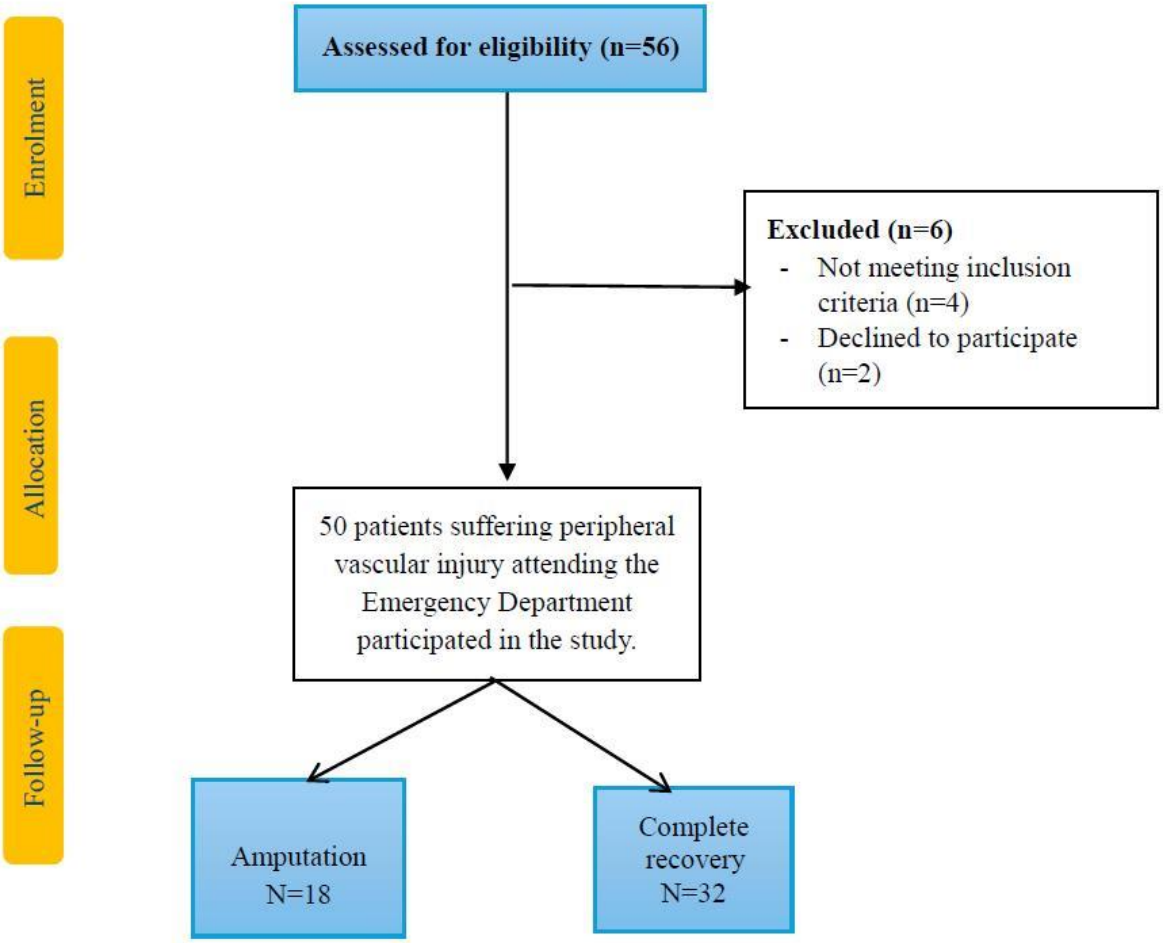

Figure (1): Flowchart of patients suffering peripheral vascular injury attending the Emergency Department.

There were statistically significant differences between lower and upper limb injury patients regarding comorbidities (was higher among lower limb injury cases than upper), mechanism of injury (blunt trauma was more predominant in lower limb vascular injuries while penetrating trauma was more predominant in upper limb vascular injuries), and SBP on arrival (tends was higher in upper limb vascular injuries than lower limb). There were no statistically significant differences regarding age, sex, Glasgow Coma Scale, ischemia time, pulse, and oxygen saturation (Table 2).

Table (2): Demographic, comorbidities, and clinical data for the patients studied.

		Studied patients		
		Lower limb (N=31)	**Upper limb (N=19)**	***P value***
Age/year		31.03±13.85	34.01±9.84	0.365
		N (%)	**N (%)**	
Gender	Males	28 (89.4%)	14 (73.7%)	0.119
	Females	3 (9.6%)	5 (26.3%)	
Comorbidities	Free	26 (83.9%)	16 (84.2%)	**0.047***
	HTN	3 (9.7%)	0 (0.0%)	
	DM	0 (0.0%)	3 (15.8%)	
	HTN+DM	2 (6.5%)	0 (0.0%)	
Mechanism of injury	Penetrating	8 (25.8%)	12 (63.1%)	**0.009***
	Blunt	23 (74.2%)	7 (36.9%)	
SBP on arrival		93.9±19.23	101.89±10.59	**0.006***
Glasgow Coma Scale (GCS)		14.58±0.5	15.0±0.00	0.199
Ischemia time (hr)		3.93±1.26	5.63±8.19	0.382
Pulse		119.06±13.85	105.6±14.15	**0.002***
Oxygen saturation		94.96±2.15	94.42±5.23	0.675

*: Significant

There were statistically significant differences between lower and upper limb injury patients regarding risk factors for major amputation. SBP on arrival was significantly higher among upper than lower limb injury patients. Absence of preoperative distal pulses and initial Doppler signal, associated orthopaedic injury, and associated vascular injury were significantly more frequent among lower than upper limb injury patients. The POPSAVEIT score was significantly higher among lower than upper limb injury patients (Table 3).

Table (3): Analysis of risk factors for major amputation among the studied patients.

Variables		**Studied patients**		***P value***
		Lower limb (N=31)	**Upper limb (N=19)**	
SBP on Arrival		93.9±19.23	101.89±10.59	0.104
Absence of preoperative distal pulses	Yes	29 (93.5%)	16 (84.2%)	0.285
	No	2 (6.5%)	3 (15.8%)	
Absence of initial Doppler signal	Yes	20 (64.5%)	14 (73.7%)	0.50
	No	11 (35.5%)	5 (26.3%)	
Associated orthopedic injury	Free	8	11	**0.001***
	Fracture dislocation femur	3	0	
	Tibial fracture	9	0	
	Femur fracture	4	0	
	Tibial +fibular fracture	7	0	
	Ulnar fracture	0	3	
	Ulnar + radius fracture	0	3	
	Elbow dislocation	0	2	
Associated vascular injury	Popliteal artery	15	0	**0.001***
	Anterior tibial	5	0	
	Popliteal +ant post tibial art	3	0	
	Posterior tibial	2	0	
	Superficial femoral	2	0	
	Common femoral	4	0	
	Brachial artery	0	10	
	Ulnar and radial artery	0	3	
	Axillary vein	0	3	
	Ulnar artery	0	3	
POPSAVEIT score		3.38±1.84	2.78±1.65	^{U}***P*=0.021***

U: Mann-Whitney U test, *: Significant

On multivariate regression analysis, the significant preoperative risk factors were independently associated with amputation in the final model included SBP<90 mm Hg (OR, 2.34), associated orthopaedic injury (OR, 3.42), and lack of preoperative pedal Doppler signals (OR, 3.42) and initial palpable pulse (OR, 1.67) (Table 4).

Table (4): Multivariate analysis of risk factors for major amputation among the studied patients.

Risk factors	**P value**	**OR**	**Relative OR**
SBP on arrival less than 90 mmHg	**0.001***	2.34	1
Associated fracture	**0.009***	3.42	1.8
Absent initial Doppler signal	**0.027***	3.42	1.5
Absent initial palpable pulse	**0.029***	1.67	1
Vascular assessment composite variable		**POPSAVEIT score**	
Variables	**P value**	**OR**	**POPSAVEIT score**
SBP on arrival less than 90 mmHg	**0.043***	2.3	1
Associated fracture	**0.014***	1.7	2
Absent initial Doppler OR Absent initial palpable pulse	**0.002***	2.06	2 or 1 if the later

*: Significant

A total of 31 patients with lower limb, 25 of them were high-risk (80.6%), and 15 of them underwent an amputation (48%). A total of 19 patients with upper limb, 10 of them were high risk (52.6%), and 3 of them underwent an amputation (15.8%). The amputation rate was significantly higher among patients with lower limb injuries compared to upper limb patients. POPSAVEIT score was significantly important in stratifying the amputation risk of the patients, using a score of ≥3 for high-risk patients and <3 for low-risk patients (Table 5).

Table (5): Analysis of cases by limb and risk classification.

Category	**Lower Limbs N=31, (62%)**	**Upper Limbs N=19, (38%)**	
Amputation Count			
Yes	15 (48%)	3 (15.8%)	
No	16 (52%)	16 (84.2%)	
POPSAVEIT score			
High-risk	25 (80.6%)	10 (52.6%)	
Low-risk	6 (19.4%)	9 (47.4%)	
Risk Factor	P-Value	Odds Ratio (OR)	Impact on Amputation Risk
SBP on arrival <90 mmHg	**0.001***	2.34	Increases risk by 2.34 times
Associated bone fractures	**0.009***	3.42	Increases risk by 3.42 times
Absence of initial Doppler signal	**0.027***	3.42	Increases risk by 3.42 times
Absence of initial palpable pulse	**0.029***	1.67	Increases risk by 1.67 times

*: Significant

In our study, ROC (receiver operating characteristic) analysis shows that the POPSAVEIT score could be used as a predictive scoring system for the diagnosis of high and low-risk patients for amputation with an area under a curve of 0.829, 0.700 (p <.001) at 5%CI of (0.61–1.0, 0.498-0.902), using a cut-off of ≥3.5 and ≥3, with (75.1%, 80%) sensitivity and (65.3%, 70.1%) specificity for upper and lower limb vascular injury, respectively (Figure 3, 4).

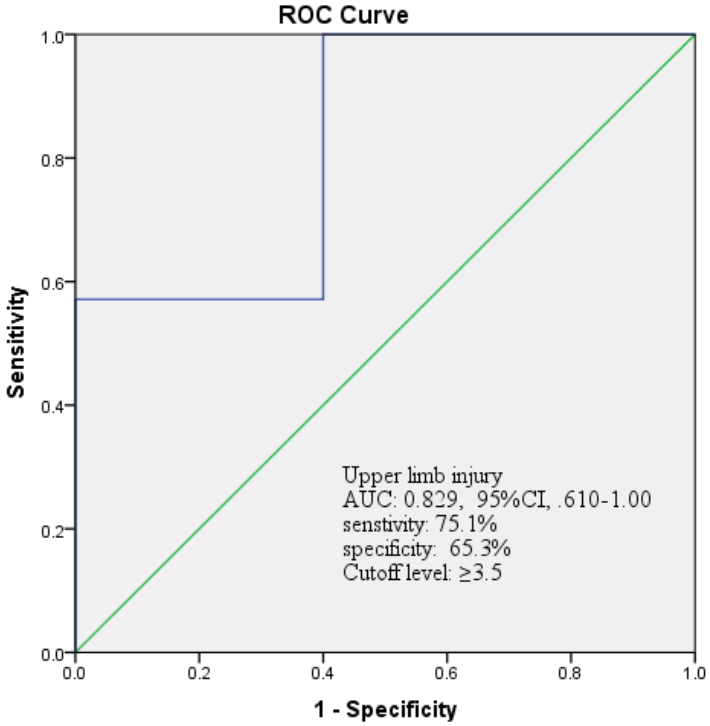

Figure (2): ROC analysis of POPSAVEIT score for the diagnosis of upper limb risk for amputation.

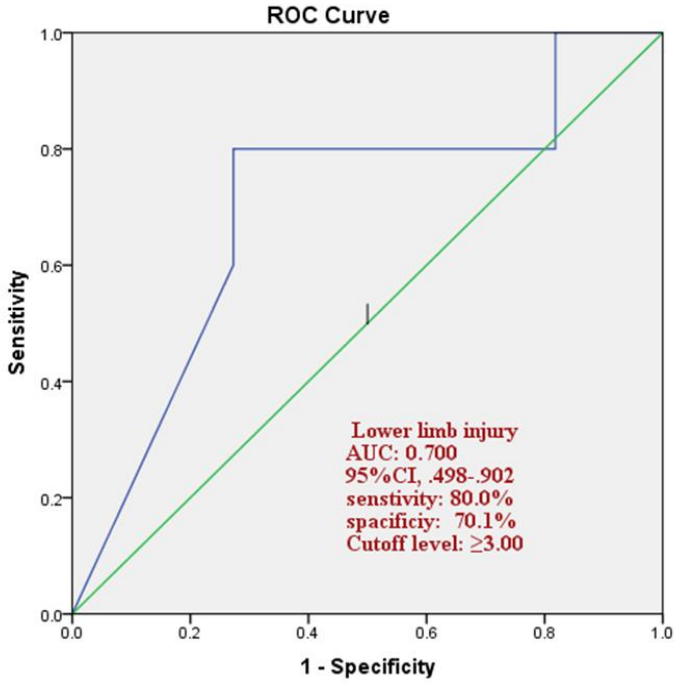

Figure (3): ROC analysis of POPSAVEIT score for the diagnosis of lower limb risk for amputation.

DISCUSSION

Peripheral arterial injury (PAI) is relatively rare in patients following trauma, accounting for 1.0%–3.7% of the total trauma load. Of these, the most injured arteries are the femoral and popliteal arteries. These injuries carry a high morbidity rate and an amputation rate of 28%–76 %. Blunt trauma accounts for 28%–54 % of PAIs, and peripheral vascular injuries, which could be easily overlooked as concomitant distracting injuries or polytrauma, are present in more than 50% of patients with blunt trauma [12].

A number of recent studies have emphasized the necessity of a scoring system that is applicable to all patient populations and is both predictive and pertinent [13-15]. In present study we aimed to provide POPSAVEIT (Popliteal scoring assessment for vascular extremities injuries in trauma) as a simple, easy to use tool for assessing risk of limb loss following upper and lower limbs peripheral vascular injuries in trauma patients at the emergency department and to evaluate its efficacy and accuracy. We also aimed to compare risk factors and incidence of amputation between upper and lower limb traumatic vascular injury. To achieve that aim, a prospective cross-sectional study was conducted on 50 patients suffering from peripheral vascular injury attending the Emergency Department at Menoufia University Hospital and other hospitals over one year, starting from the 1st of July 2023.

Our study showed that there was statistically significant difference between lower and upper limb injury patients regarding comorbidities, mechanism of injury, and SBP on arrival; there were no statistically significant differences regarding age, sex, Glasgow Coma Scale, ischemia time, pulse, and oxygen saturation. Our study showed that there were statistically significant differences between lower and upper limb injury patients regarding risk factors for major amputation, SBP on arrival was significantly higher among upper than lower limb injury patients. Absence of preoperative distal pulses and initial Doppler signal, associated orthopaedic injury, and associated vascular injury and amputation rate were significantly more frequent among lower than upper limb injury patients. POPSAVEIT score was significantly higher among lower than upper limb injury patients. Significant preoperative risk variables, such as SBP <90 mm Hg, were independently related with amputation in the final model (OR2.34; P=0.001; decrease in blood pressure <90 nm/Hg increased the risk of amputation 2.34-folds). Associated orthopaedic injury (OR, 3.42; P = 0.009 increased risk of amputation 3.42 folds), and lack of preoperative distal Doppler signals (OR, 3.42; P=0.027; increased risk of amputation 3.42folds) and lack of initial palpable distal pulse (OR, 1.67; P=0.029; increased risk of amputation 1.67 folds). A total of 31 patients with lower limb, 25 of them were high-risk (80.6%), and 15 of them underwent an amputation (48%). A total of 19 patients with upper limb, 10 of them were high risk (52.6%), and 3 of them underwent an amputation (15.8%). The amputation rate was significantly higher among patients with lower limb injuries compared to upper limb patients.

In our study, ROC (receiver operating characteristic) analysis shows that the POPSAVEIT score could be used as a predictive scoring system for the diagnosis of high and low-risk patients for amputation with an area under a curve of 0.829, 0.700 ($p<0.001$) at 5% CI of (0.61–1.0, 0.498-0.902), using a cut-off of ≥3.5 and ≥3, with (75.1%, 80%) sensitivity and (65.3%,70.1%) specificity for upper and lower limb vascular injury. In this cohort, only 10% of patients had an SBP of less than 90 mm Hg, and 17% of those who needed amputation had one. The prevalence of severe hypotension in this group has been comparatively low and, we hope, will continue to reduce since the "Stop the Bleed" campaign and the use of tourniquets for extremities bleeding were implemented. This might account for its lower amputation prediction compared to the other two factors in the multivariate regression. Consequently, the POPSAVEIT score increased by 1 point for an initial SBP of less than 90 mm Hg. Additionally, we discovered that, in univariate analysis, the lack of an initial Doppler signal and related orthopedic damage were linked to amputation, and in multivariate analysis, they were regarded as the highest predictive risk factor. In the final multivariate model, while analyzing the patient comprehensively, the POPSAVEIT score divides the findings into three critical components: the lack of pedal Doppler signals can be thought of as a measure of ischemia, an SBP of <90 mm Hg as a measure of global physiological insult, and associated orthopedic injury as the presence of musculoskeletal deformity. Perhaps it is not surprising that these factors are separate dangers, and that the aggregation of these risk factors raises the chance of amputation exponentially [8]. Furthermore, **O'Banion *et al.*** [9] showed that the POPSAVEIT score appeared to properly classify patients into high-risk (3-5 points) and low-risk (0-2 points) groups for major amputations.

Several other studies have evaluated the efficacy of the POPSAVEIT score in predicting amputation risk following traumatic popliteal artery injurie [16-19]. The initial study introduced the POPSAVEIT score, assigning points based on SBP<90 mm Hg, associated orthopedic injury, and absence of preoperative pedal Doppler signals. A score ≥3 indicated high amputation risk, with a sensitivity of 85% and specificity of 49%. The area under the ROC curve was 0.750, demonstrating acceptable predictive capability. Multi-Institutional Validation: A subsequent study across 14 U.S. institutions included 146 patients and found that a POPSAVEIT score ≥3 was significantly associated with increased amputation rates. The ROC curve had an area under the curve of 0.750, meeting validation criteria. Additionally, at Zagazig University

Study, in Egypt, a study of 76 patients conducted by **Zidan *et al.*** [20] reported that a POPSAVEIT score ≥3 had a sensitivity of 78.6% and specificity of 59% for predicting high amputation risk .

Another study emphasized that in settings with delayed presentations (mean total delay to surgery of approximately 14 hours), both POPSAVEIT and MESS scores were poor predictors of amputation. The authors suggested that these scoring systems should not be relied upon in patients with delayed presentations [21]. Additionally, we hypothesize that the high- and low-risk classifications within a particular center will probably be maintained, even if the actual amputation rates may vary significantly between centers. In peripheral extremity vascular trauma, the POPSAVEIT score may aid in improving reporting guidelines and pave the way for future, more thorough research. Compared to the MESS and other scoring systems that can need specialized analysis to get the proper score, this score's simplicity represents a significant potential benefit [22]. However, even with the greatest score of 5, the estimated amputation rate is 50%. As a result, it is obvious that the POPSAVEIT score should not be used alone to determine which individuals require primary amputation. Although the principle of life over limb remains essential, the salvage potential of limbs is frequently unknown until later in the therapy process [23].

CONCLUSION

A straightforward and useful technique for preoperatively classifying patients into low- and high-risk groups for major amputation is the POPSAVEIT score. This ability to risk stratify may also be helpful when discussing the prognosis and establishing expectations with patients, their families, and other healthcare professionals. One benefit of the POPSAVEIT score is that it may be used in a wide range of situations since the Advanced Trauma Life Support-based trauma survey usually includes the first blood pressure, musculoskeletal deformity examination, and an extremity vascular assessment. The POPSAVEIT score has been validated in multiple studies as a practical tool for stratifying amputation risk in traumatic popliteal artery injuries as mentioned in discussion. However, clinical judgment and consideration of individual patient factors remain essential.

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