Original Article

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# Validity of Mangled Extremity Score System to Predict Limb Salvage on Cases of Traumatic Popliteal Artery Injuries: A Case Series and Review of the Literature

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**Background:** Popliteal artery injuries carry a risk of amputation rate ranging from 9.7% to 28%. The mangled extremity score system (MESS) was originally authenticated in only 26 patients and it was concluded that an MESS ≥ 7 equated to a 100% rate of amputation. In this study we add the effects of combined arterial venous injuries and combined arterial venous and nerve injuries to the risk of amputation and correlate them with the MESS.

**Methods:** This is a retrospective single arm cohort study conducted using 25 patients included between 1 January 2020 and 1 January 2023 at two hospitals, Ain Shams University Hospital and Shebin Elkoom Teaching Hospital. The study defined two groups: the amputation and non-amputation groups. It assessed the validity of the MESS to predict limb salvage in cases of traumatic popliteal artery injuries.

**Results:** The overall rate of amputation was 64%. Patients presenting with MESS ≥ 8 had an amputation rate of 25%, while patients with MESS ≥ 9 had an amputation rate of 75%. Patients presenting with combined popliteal artery and vein or combined artery, vein and nerve injury had a 100% rate of amputation (MESS ≥ 8). There was no 30-day mortality.

**Conclusions:** MESS ≥ 9 carries a high risk of amputation (75%). Combined arterial and venous injuries or arterial, venous and nerve injuries, which already have a high MESS, also carry a high risk of amputation. All of them could be predictors of limb salvage in popliteal artery injury.

**Keywords:** *Popliteal Artery Injury; MESS; Mangled Score*

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## INTRODUCTION

Lower extremity arterial injury may result in limb loss after blunt or penetrating trauma. Popliteal vessel injuries, in particular, remain uncommon accounting for 0.2% of all traumas and lead to amputation rates ranging from 9.7% to 28% [1]. Blunt mechanism and concomitant injuries, such as fractures and knee dislocations, as well as severe soft tissue damage, lead to a significantly higher rate of amputation compared to penetrating trauma [2]. Fractures around the knee result in vascular injuries in about 3% of all cases. However, the incidence of vascular events is about 16% when posterior knee dislocation is present [3]. Traffic accidents (injuries related to motor vehicle and motorcycle accidents) and sports activities (skiing, football) are the

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main reasons for knee injuries associated with posterior knee joint dislocation [4]. Falls from height are the second most common cause of knee dislocations [5]. Up to one-third of patients with popliteal artery trauma undergo amputation, resulting in a negative impact on their quality of life. Phantom limb pain is reported in up to 76% of patients, chronic back pain in 42.1%, residual limb pain in 62.9%, prosthesis-related skin problems in 58% and depression in 24% [6]. Some patients may undergo serial attempts at revascularization after injury but may opt (or be forced) to have an amputation later if appropriate healing does not occur. Therefore, patient selection for revascularization attempts is of paramount importance to ensure the optimum outcome in this patient population. Predictive factors of limb outcome are vital in determining which patients are suitable candidates for revascularization [6]. Predictive scoring systems, primarily created in the 1980s and early 1990s, have proved invalid. The mangled extremity score system (MESS) is calculated by undertaking a subjective review of soft tissue damage, limb ischemia, shock and age revascularization [7]. This system was originally authenticated in a small study with only 26 patients that concluded that an MESS greater than 7 equated to a 100% rate of amputation revascularization [7]. In this study we added the effects of combined arterial venous injuries and combined arterial venous and nerve injuries to the risk of amputation and correlated them with the MESS.

## METHODS

### *Study Population*

This is a retrospective single arm cohort study conducted using 25 patients included between 1 January 2020 and 1 January 2023 at two hospitals, Ain Shams University Hospital and Shebin Elkoom Teaching Hospital. Patients had popliteal artery injuries with different modality of trauma. The study defined two groups, the amputation and non-amputation groups, and assessed the validity of the MESS to predict limb salvage in cases of traumatic popliteal artery injuries. We also added the effects of combined arterial venous injuries and combined arterial venous and nerve injuries to the risk of amputation and correlated them with the MESS.

### *Injury Mechanisms*

Injury mechanisms included those that were: low energy (stab, gunshot, simple fracture); medium energy (dislocation, open/multiple fractures); high energy (high speed motor car accident or rifle shot); and very high energy (high speed trauma with gross contamination). All cases were operated on (see technical repair below) by two consultants, the authors. The primary endpoint was limb salvage; the secondary endpoint was 30-day mortality.

### *Technical Repair*

All patients went through preliminary trauma evaluation. There was no decision to undertake primary amputation. Under general anesthesia, the vascular team made a temporary arterial shunt, followed by orthopedic fixation in cases of orthopedic fractures. Vascular exploration of injured vessels took place with repair of the popliteal vessels. Methods of repair included 20 interposition reverse saphenous vein grafts and five femoro-popliteal bypass operations in which two cases were done using vein conduits and three cases were done using polytetrafluoroethylene grafts (Figures 1 and 2).

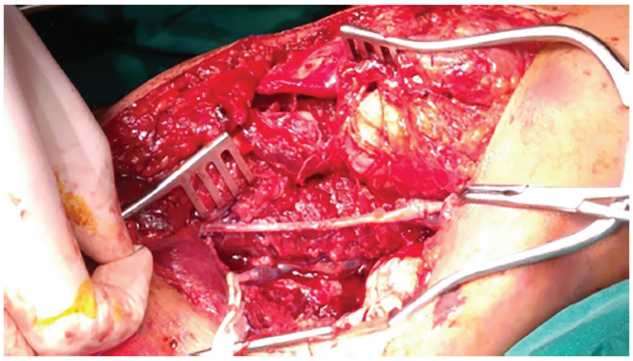

***Figure 1*** Repair of the popliteal artery using interposition reverse saphenous vein graft.

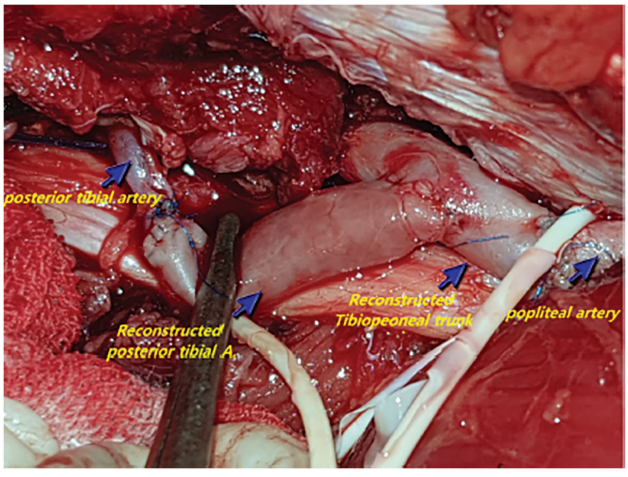


***Figure 2*** Reconstructed posterior tibial artery and tibioperoneal trunk.

### *Statistical Analysis*

Descriptive data were statistically analyzed using SSPS version 26, IBM. Qualitative data were expressed as number and percentage, while quantitative data were expressed as mean and standard deviation (SD). Student's *t*-test was used for comparison of quantitative variables of normally distributed data. The chi-square test ($\chi^2$) was used to study the association between the descriptive variables of the two groups, amputation and non-amputation. Whenever any of the expected cells were less than five, Fisher's exact test was used. A *P* value of less than 0.05 was considered statistically significant.

### *Ethical Approval and Informed Consent*

Ethical approval to report these cases was given by the Ethical Committee of Ain Shams University Hospitals and Shebin Elkoom Teaching Hospital. Written informed consent was obtained from the patients.

## RESULTS

The study included 25 patients presenting with traumatic popliteal artery injury over 3 years between 1 January 2020 and 1 January 2023. There were 17 men (68%) and eight women (32%). The age range of patients was 15–50 years, with a mean age of 35 years. All patients (100%) had no history of comorbidities including diabetes mellitus, hypertension and ischemic heart diseases. Five patients were active smokers (Table 1). There were 23 cases that had blunt trauma (92%), two cases that had penetrating trauma (8%) and one case that was iatrogenic, which therefore was excluded (Figure 3). The mechanisms of injury were low-energy trauma in two patients (8%), medium-energy trauma in five patients (20%), high-energy trauma in 11 patients (44%) and very-high-energy trauma in seven patients (28%). With regard to the shock state at time of admission, there were nine patients (36%) with systolic blood pressure greater than 90 mmHg, 16 patients (64%) with transient hypotension and no case presented with persistent hypotension (Table 1). With regard to the extent of injury, 12 patients (48%) had sustained isolated popliteal artery injury, six patients (24%) had injury of both the popliteal artery and vein (PAV) and seven patients (28%) had combined popliteal artery, vein and nerve (PAVN) injuries.

Patients with sharp popliteal artery injury had a 5% risk of amputation, while those with blunt trauma had a 69.5% risk of amputation. There was a correlation between high-energy injuries and risk of amputation, whereas we observed nine cases of amputation (81.1%) with high-energy injuries and seven cases (100%) with very-high-energy injuries (Table 2).

With regard to associated injuries, 23 cases were associated with orthopedic injuries and fractures (92%) and 16 cases with muscles crush injury (64%). Fasciotomy was carried out for 12 cases (48%), six cases received prophylactic fasciotomy and another six received delayed fasciotomy. There were 15 patients (60%) who presented with delayed ischemia, or had more than 6 hours of ischemia. The amputation rate among them was 66.6% (10 patients). There were 20 patients (80%) who presented with severe ischemia (coldness, paralysis and loss of sensation). The rate of amputation among this group was 80%. There were five cases presenting with mild ischemia (pulseless, paresthesia, slow capillary refill) and there was no rate of amputation among them (Table 3).

The overall amputation rate in this study was 64%. The relative high risk of amputation was mainly

***Table 1*** Socio-demographic and clinical data of the patients.

| | *Number* | *%* |
|---|---|---|
| Age | | |
| <30 years | 7 | 28 |
| 30–50 years | 18 | 72 |
| Gender: male | 17 | 68 |
| Comorbidity: No | 25 | 100 |
| Active smoker | 5 | 20 |
| Type of injury | | |
| Sharp | 2 | 8 |
| Blunt | 23 | 92 |
| Injury mechanism | | |
| Low energy | 2 | 8 |
| Medium energy | 5 | 20 |
| High energy | 11 | 44 |
| Very high energy | 7 | 28 |
| Shock | | |
| SBP >90 mmHg | 9 | 36 |
| Transient hypotension | 16 | 64 |
| Persistent hypotension | 0 | 0 |

*SBP: systolic blood pressure.*

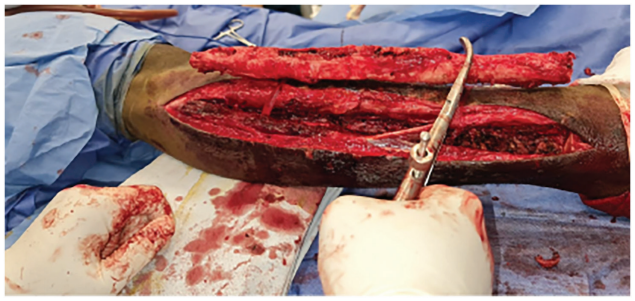

***Figure 3*** Iatrogenic popliteal artery injury after fibulectomy due to chronic osteomyelitis.

***Table 2*** Correlation between type of injury, mechanism of injury and shock state with risk of amputation.

| | *Amputation* | | *No Amputation* | | | |
|---|---|---|---|---|---|---|
| | *Number* | *%* | *Number* | *%* | *FE* | *P Value* |
| Type of injury | | | | | | |
| Sharp | 0 | 0.0 | 2 | 100 | 3.865 | 0.120 |
| Blunt | 16 | 69.5 | 7 | 30.5 | | |
| Injury mechanism | | | | | | |
| Low energy | 0 | 0.0 | 2 | 100 | $\chi^2$ | |
| Medium energy | 0 | 0.0 | 5 | 100 | 17.898 | <0.001** |
| High energy | 9 | 81.1 | 2 | 18.1 | | |
| Very high energy | 7 | 100 | 0 | 0.0 | | |
| Shock | | | | | | |
| SBP >90 mmHg | 4 | 25.0 | 5 | 55.6 | 2.334 | 0.200 |
| Transient hypotension | 12 | 75.0 | 4 | 44.4 | | |

*FE: Fisher's exact test; $\chi^2$: chi-square test; **P<0.001: highly significant. SBP: systolic blood pressure.*

***Table 3*** Clinical assessment of the patients (*n* = 25).

| | | | *Amputation* | | *No Amputation* | | | |
|---|---|---|---|---|---|---|---|---|
| | *Number* | *%* | *Number* | *%* | *Number* | *%* | *FE* | *P Value* |
| Limb ischemia | | | | | | | | |
| Pulseless, paresthesia, slow capillary refill | 5 | 20 | 0 | 0 | 5 | 100 | 11.111 | 0.002* |
| Cool, paralysis, numb/insensate | 20 | 80 | 16 | 66.6 | 4 | 44.4 | | |
| Limb ischemia for >6 hours | | | | | | | | |
| Yes | 15 | 66.66 | 10 | 62.5 | 5 | 55.6 | 0.116 | 1.000 |
| No | 10 | 33.33 | 6 | 37.5 | 4 | 44.4 | | |
| Mangled score | | | | | | | | |
| Mean ± SD | 8.00 ± 1.89 | | 9.19 ± 0.83 | | 5.89 ± 1.27 | | 7 .861[a] | <0.001** |
| Range | 5.0 – 14.0 | | 8.0 – 10.0 | | 5.0 – 8.0 | | | |
| Popliteal vein injury | | | | | | | | |
| Yes | 6 | 24 | 5 | 83.3 | 1 | 16.7 | 15.234 | <0.001** |
| No | 19 | 76 | 3 | 18.7 | 9 | 100 | | |
| Combined nerve and popliteal vein injury | | | | | | | | |
| Yes | 7 | 28.0 | 7 | 100 | 0 | 0 | 5.469 | 0.027* |
| No | 18 | 72.0 | 9 | 50 | 9 | 50 | | |

*FE: Fisher's exact test; a Student's t-test; **P<0.001: highly significant; *P<0.05: significant. SD: standard deviation.*

correlated with a high MESS, where 48% of the patients presented with an MESS of 9 or above. Patients who presented with isolated popliteal artery trauma had an MESS of less than 8 and they did not lose their limbs. Patients presenting with combined PAV or PAVN had an MESS of 8 or more with a 100% rate of amputation. There was a statistically significant correlation between risk of amputation and PAV or PAVN injuries, severity of limb ischemia, as well as the MESS (Table 4). The MESS may be a predictor of limb salvage in the case of traumatic popliteal artery injuries. Patients presenting with an MESS of 8 or lower had a 25% amputation rate, while patients presenting with an MESS of 9 or more had an amputation rate of 75%, $P < 0.001$, sensitivity 75% and specificity 100% (Table 4 and Figure 4).

A limitation of our study is the potentially low number of cases and high rate of amputation, which could be correlated to high MESS, severity of mechanism of injury and severity of limb ischemia presentation.

***Table 4*** Classification of mangled extremity score system (MESS) according to cut-off point and its relation to amputation.

| | *Amputation* | | *No Amputation* | | *Total* | | | |
|---|---|---|---|---|---|---|---|---|
| | *Number* | *%* | *Number* | *%* | *Number* | *%* | *FE* | *P Value* |
| Mangled score | | | | | | | | |
| <8.5 | 4 | 25.0 | 9 | 100.0 | 13 | 52.0 | 12.981 | <0.001** |
| ≥8.5 | 12 | 75.0 | 0 | 0.0 | 12 | 48.0 | | |

*FE: Fisher's exact test; **P<0.001: highly significant.*

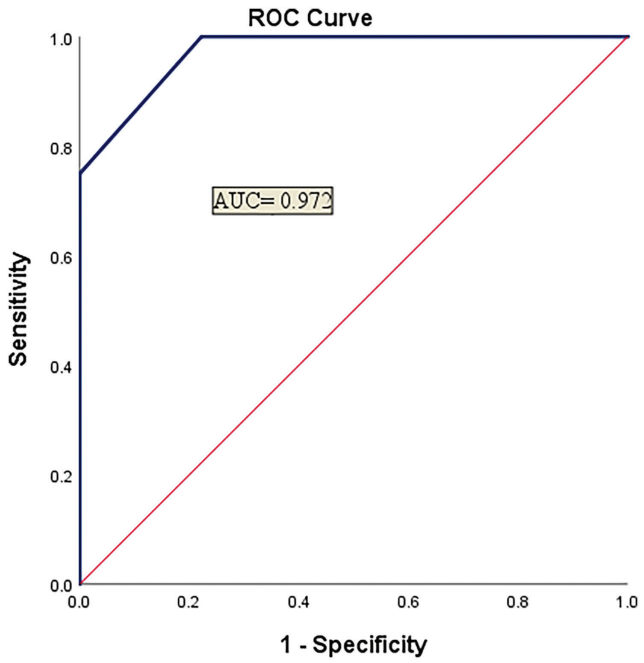


***Figure 4*** Receiver operating characteristic curve (ROC) for the MESS as a predictor for amputation showed that the minimum cut-off point was 8.5 with an area under the curve (AUC) of 0.972, sensitivity of 75%, specificity of 100% and 95% confidence interval of 0.918–1.000.

## DISCUSSION

MESS is calculated by subjective review of soft tissue damage, limb ischemia, shock and age revascularization. This system was originally authenticated in a small study with only 26 patients that concluded that an MESS greater than 7 equated to a 100% rate of amputation revascularization [7]. Multiple studies since the original MESS study have invalidated this scoring system, including a recent large, multicenter prospective study called the Lower Extremity Amputation Project (LEAP) [8]. The LEAP attempted to address concerns surrounding decision-making for limb salvage in the setting of severe lower extremity trauma, but ultimately failed to determine which factors were predictive of long-term outcome [8]. The multi-institutional, randomized LEAP trial was not able to validate predictive models for limb salvage scoring systems [8, 9]. Currently there are no scoring systems that adequately predict functional recovery of patients who present with the potential for limb salvage [9]. Loja et al. reported, between 2013 and 2015, 230 patients with lower extremity arterial injuries who were entered into the PROspective Vascular Injury Treatment registry. Patients being admitted with an MESS of 8 or greater was associated with a longer stay in the hospital and intensive care unit. After controlling for confounding variables including the mechanism of injury, degree of arterial injury, injury severity score, arterial location and concomitant injuries, the MESS between patients with salvaged and amputated limbs was no longer significantly different. Importantly, an MESS of 8 predicted in-hospital amputation in only 43.2% of patients [10]. It is important to have a method of arterial repair to have satisfactory outcomes. Inadequate debridement of contused popliteal artery always results in arterial thrombosis in the early postoperative period [11]. Vascular repair includes primary end-to-end anastomosis, vein graft interposition, or bypass grafting. The majority of popliteal artery injuries (always when the length of the damaged segment is more than 1.5–2 cm) secondary to knee dislocation require an interposition vein graft secondary to the extent of arterial injury. End-to-end repair may require extensive popliteal artery mobilization with sacrifice of collateral vessels to ensure a tension-free repair [12]. Most authors recommend avoiding the use of continuous sutures, because of a possible narrowing along the suture with growth [13, 14]. Ramdass et al. reported 32 cases that presented with popliteal artery injury. There were 20 cases of penetrating trauma (63%) and 12 cases of blunt trauma (37%). The amputation rate associated with popliteal artery injury was 28% with no significant difference in rates between penetrating and blunt trauma (25% vs. 33%). There was no statistical significance in rate of amputation and type of repair (reversed saphenous, synthetic graft or primary repair). Factors associated with poor outcomes include combined artery and vein injury, artery, vein and nerve injury (75% of the patients in each group), concomitant orthopedic injury with fracture in particular and

delayed transfer to vascular surgery [15]. Mullenix et al. reported a retrospective analysis of 1395 popliteal arteries collected from trauma data from the National Trauma Data Bank (NTDB). Amputation rates were 15% with combined artery and vein injuries, 21% for associated nerve injuries and 12% for major soft tissue disruptions. Independent predictors of amputation in logistic regression analysis of the entire cohort included bony fracture, complex soft tissue injury and nerve injury. The amputation rates for these patients stratified by mechanism of blunt versus penetrating trauma were higher for blunt trauma compared to those with penetrating injury (27% vs. 9%) [16]. Factors such as blunt (vs. penetrating) mechanism have been found to be an independent risk factor for amputation, with Grigorian et al. finding a 3.5-fold higher risk for amputation with blunt popliteal artery injury. They theorized that this was due to the higher force required to cause popliteal artery injury in the relatively protected region of the popliteal fossa as well as the increased risk of concomitant injuries such as popliteal vein injury [17]. Hafez et al. have reported the largest number of civilian lower limb arterial injuries and have established a protocol for combined injuries; they routinely repair arterial injuries prior to orthopedic or nerve injuries [18]. In this study we compared those patients who underwent orthopedic repair prior to vascular repair and found that there was no associated increased risk of amputation. In our patient population unstable fractures were felt to increase the risk of early graft failure or graft disruption secondary to manipulation of the lower extremity during orthopedic fixation [18]. We found that those patients requiring amputation had a higher incidence of blunt trauma (80% vs. 35%) and a higher MESS score (7.1 vs. 4.7). There was no difference in the incidence of amputation for those who underwent orthopedic fixation before vascular repair.

## CONCLUSIONS

Mangled extremity severity scores equal or over 9 carry a high risk of amputation of 75%. Combined arterial and venous injuries or arterial, venous and nerve injuries, which already have a high MESS, also carry a high risk of amputation. All of them could be used as predictors of limb salvage in popliteal artery injury.

### Ethics Statement

(1) All the authors mentioned in the manuscript have agreed to authorship, read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript.
(2) The authors declare that they have read and abided by the JEVTM statement of ethical standards including rules of informed consent and ethical committee approval as stated in the article.

### Conflicts of Interest

The authors declare that they have no conflicts of interest.

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### Author Contributions

All authors were responsible for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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