



RESEARCH ARTICLE

A STUDY OF USE OF COMPUTED TOMOGRAPHY ANGIOGRAPHY AND MANGLED EXTREMITY SEVERITY SCORE AS PREDICTORS OF LIMB SALVAGE IN EXTREMITY VASCULAR TRAUMA

Arockia sundari J J, Naren Shetty, Nikhila Pinjala, Devender singh, Gnaneshwar atturu , Pinjala Ramakrishna.

Manuscript Info

Manuscript History

Received: 25 August 2020

Final Accepted: 28 September 2020

Published: October 2020

Key words:-

Vascular Injury, Extremity Trauma,
Computed Tomography Angiography,
Mangled Extremity Severity Score

Abstract

Back Ground: Major loss of limb and life remains as an increasing importance as the occurrences of arterial injuries are increasing . The prevention of such events and accurate identification of the limbs at risk, remains our serious concern.

Introduction: There has been a longtime search for definitive score or test for evaluation of patients with vascular injuries. Mangled Extremity Severity Score (MESS) has been proved as predictor of viable limbs and Computed tomography Angiography (CTA) as an essential tool in diagnosing arterial injury. We did this study in India , combining MESS and CTA for predicting outcomes of arterial injury of extremity trauma victims in our hospital .

Methods: A prospective, observational study of limb injuries between 2016 and 2018 in trauma unit was performed. We examined the clinical signs, operative findings using Mangled Extremity Severity Score and Computed tomography Angiography at presentation and compared with resultant limb salvage outcome.

Results: Out of 100 people , 70 people fulfilled the inclusion criteria . Our study resulted an accuracy of 94.3% indicating perfect predictive ability of limb salvage by using the MESS score. CT angiography as the predictable variable and limb salvage as outcome variable showed an accuracy of prediction was 92.9% and excellent predictable accuracy of 97.1% when combining MESS with CTA.

Conclusions: Combining clinical assessment using MESS and CTA improves the diagnostic accuracy of vascular injury and the need for immediate intervention for limb salvage procedures, and prevents amputation by delay.

Copy Right, IJAR, 2020,. All rights reserved.

Introduction:-

Background

The vascular injuries constitute about 3 % of civilian injuries and around 7 % of the combat associated trauma [7,23,38]. Unlike the military experience, the civilian vascular trauma, in developing countries, are occupational local violence and mostly due to motor vehicle accidents.

No study has combined CT angiography and MESS score for better prediction ability of limb viability or amputation for arterial injury.

So, we performed this study in civilian population with limb trauma, at Nizam's Institute of Medical Sciences, Hyderabad. CT angiography and MESS score were used to predict limb viability and amputation.

Corresponding Author:- Arockia J

Peripheral vascular injuries can result from penetrating or blunt trauma to the extremities^{26,27}. Which are documented during armed conflict as far back as the Greek and Roman civilizations and even before those eras. Antipersonnel mines also were responsible for the majority of civilian extremity vascular injuries.

The frequency of traffic collisions in India is among the highest in the world, a National Crime Records Bureau (NCRB) reported that every year, more than 1,35,000 traffic collision-related deaths occur in India. Indian roads were at their deadliest in 2014 claiming more than 16 lives every hour on average.

Clinical presentations of vascular injuries are not always straight forward¹⁰. If they are not recognized and treated early, result in disastrous consequences of loss of limb or life^{8,13}. Multiple factors are involved in determining accurate diagnosis and the prognosis of the affected limb. Traumatic vascular injuries of the extremities pose major challenges to the vascular surgeons. The most common factor involved is delay in achieving the reperfusion of the acutely ischemic limb. According to the literature, prompt repair of arterial injuries of the extremities improves outcome in terms of limb function and mortality related to blood loss. ^{1,,22}

Scoring systems have been developed as a means to predict amputation and functional outcome. MESS has been helpful as a predictor of the viability of traumatized limbs. Since 1999, CT angiography has excellent diagnostic performance for imaging traumatic arterial injuries in the extremities ^{6,,11,16} and more sensitive and specific in diagnosing vascular injuries than ultrasound.⁴

Aims And Objectives:-

Aim:

To assess the accuracy of diagnosis of extremity vascular injury in trauma patients by using Computed Tomography angiography and Mangled Extremity Severity Score in predicting limb salvage.

Objective of the study:-

Primary (a): To diagnose the patients with arterial injury to lower limb and upper limb presenting before 6 hours of injury, 6- 12 hrs and after 12 hrs, needing immediate and urgent interventions of limb salvage.

(b) : To identify patients who are at higher risk of developing acute limb threatening ischemia by using CT angiography and MESS score as tools.

Secondary (c) : To evaluate the accuracy of combination of MESS score with CT angiography in predicting limb salvage outcome in extremity trauma with arterial injury.

Material And Methods:-

Study Site:

This study was carried out in the department of Peripheral Vascular Surgery, Nizam's Institute of Medical Sciences, Hyderabad. This study was approved by the Institutional Ethics Committee of Nizam's Institute of Medical Sciences.(EC/NIMS/1912/2017)

Study Population:

Patients attending the vascular surgery OPD and emergency department with extremity trauma who fulfill the inclusion criteria were included in the study.

Study Design:

Prospective, observational study SAMPLE SIZE: 100 patients The sample size is calculated depending on the previous study by Inaba KJ (2006) Trauma.;march 60(3):502-6) .Based on estimates of proportion was calculated with the 95% confidence interval with precision of 5%, and obtained a sample size of 63. Hence we have included the sample size of 100 in our study (source: <http://sampsize.sourceforge.net/cgi-bin/si.cgi>)

Time Frame:

September 2016 to March 2018. Study period of 18 months.

Inclusion criteria:

All the patients who present with vascular injuries of extremities with or without associated orthopaedic and soft tissue injuries.

Presentation within 12 hrs with signs of viability.

Patients who present with salvageable limbs after >12 hours from the injury.

Exclusion criteria

Associated head injuries or major injuries to abdomen necessitating urgent attention first. Major isolated venous injuries Non-salvageable limb (with major tissue loss/mangled limbs).

Delayed presentation i.e. after 12 h after injury with no signs of viability. Patients with contraindication to CT scan.

Methodology:-**Selection Of Patients:**

All the patients presented to the department of vascular surgery emergency, NIMS with arterial injury fulfilling the inclusion and exclusion criteria were included in the study after taking an informed consent. Each patient included in the study had extremity trauma with absent (one or more) peripheral pulses with functional or partially functional limb.

Data Collection:

All cases of extremity trauma are included in the study are over an 18-months period between September 2016 to March 2018. All the patients presenting with traumatic injuries are clinically examined with relevant history, details of limb injury including mechanism and location of injury, clinical signs of viability were recorded with hand held doppler examination of limbs. MESS score was calculated. CT angiography was done in all patients with no contraindication.

Clinical Signs:

The hard and soft signs of vascular injury include loss of pulses in an extremity, expanding hematoma, thrill or bruit, active pulsatile bleeding, and neurologic deficit in the limb, which warrant evaluation for arterial injury. "Soft" signs of arterial injury include a cool limb, change in colour, nonexpanding hematoma, and non-pulsatile bleeding, in which prevalence of arterial injury is lower³⁷.

Salvageable limb is defined as the limb with signs of viability (warm, positive distal pulses, >90 % oxygen saturation and intact neurological signs), with repairable soft tissues and skeletal injuries.

The Mangled Extremity Severity Score (MESS) is an objective criterion for amputation prediction after lower- or upper-extremity injury. A MESS of 7 or higher has been used as a cutoff point for prediction of amputation. In 1990, Helfet et al.⁴² developed the score based on 4 parameters, which ranges from 1 to 14.

Mangled Extremity Severity Score

Velocity Ischemia Shock

Age

VELOCITY

Low energy (stab: simple fracture: pistolgunshotwound)	1
Medium energy (open or multiple fracture, Dislocation)	2
High energy (high speed MVA of rifle GSW)	3
Very high energy (high speed trauma + gross contamination)	4

Ischemia

Poor pulse (low volume), normal capillary filling.	1
Pulselessness, paraesthesia, diminished capillary refill.	2
Totally avascular-Cool, paralyzed, insensate.	3

Score is doubled for ischemia which is > 6hrs.

Shock

Systolic BP > 90mmHg	0
Transient Hypotension	1
Persistent hypotension	2

Age

< 30years	0
30 - 50yrs	1
>50yrs	2

Maximum score = 11, or 14 if ischemia > 6hrs. (Ischemia score doubles)

Imaging:

In extremity trauma cases, we performed CT angiography with a PHILIPS Brilliance 16 slice Multi Detector Computed Tomography, acquiring four rows of 16X1.5mm sections at a pitch of 1.0 (0.938) (PHILIPS MEDICAL SYSTEMS, NETHERLANDS). An 18-gauge venous catheter was inserted into the forearm or leg vein.

We administer 100 to 110 mL of iohexol (Omnipaque) 300 mg of iodine per milliliter; Amersham, Ireland) intravenously with a power injector, at a rate of 4 mL/sec. we use bolus tracking of contrast media (18-25sec).

Scanning is delayed for 25 seconds after the beginning of the injection for upper-extremity scanning or 50 seconds for lower-extremity scanning. An arterial injury is more obvious when the reformatted images are reviewed than when the axial images are interpreted alone.

CT angiographic signs of arterial injury studied include non opacification, abrupt narrowing or cutoff with presence or absence of distal reformation or runoff, single or multiple (more than one) vessel injury, presence or absence of muscle swelling or distortion (by comparing with normal side), level of vessel injury and the vessel injured, active extravasation of contrast material, pseudo-aneurysm formation, and arteriovenous fistula formation and associated fractures or injuries.

The diagnostic accuracy was calculated from CT angiography findings with intra operative diagnosis of arterial injury like contusion, thrombosis, transection.

Statistical Analysis:

Data was entered using Microsoft Excel and analysed using EPI INFO version 7. Data was summarized in percentages and proportions. Univariate analysis using Chi-square test and Fisher's exact test was used for categorical variables with significance level at 5% to determine the association of various associations. ($p < 0.05$ was considered statistically significant). For each predictor variable, sensitivity and specificity were calculated using Fisher's exact test. ROC was plotted using 1-specificity on X-axis (False positive fraction, FPF) and sensitivity (True positive fraction, TPF) on Y-axis for all the predictor variables.

The data analysis for limb salvage was done with respect to study objectives as mentioned for patient parameters, injury, involved injured limb, MESS value and CTA findings.

The patient's limb outcome was studied with respect to viable functional limb with palpable pulses at the time of discharge after a week.

Results:-

The present study comprised of 100 traumatic injury patients presented to NIMS, emergency department during September 2016 to March 2018. Based on the inclusion criteria and institutional protocol, 30 patients who did not

require surgery who were on conservative medical management were excluded from the study. Hence the data of 70 patients who underwent surgery and followed up were included in the study.

ROC curve: Prediction of outcome (limb salvage) using MESS Score and CT Angiography:

The predicted probability of limb salvage was assessed by using area under the curve of receiver operating (ROC) curve.

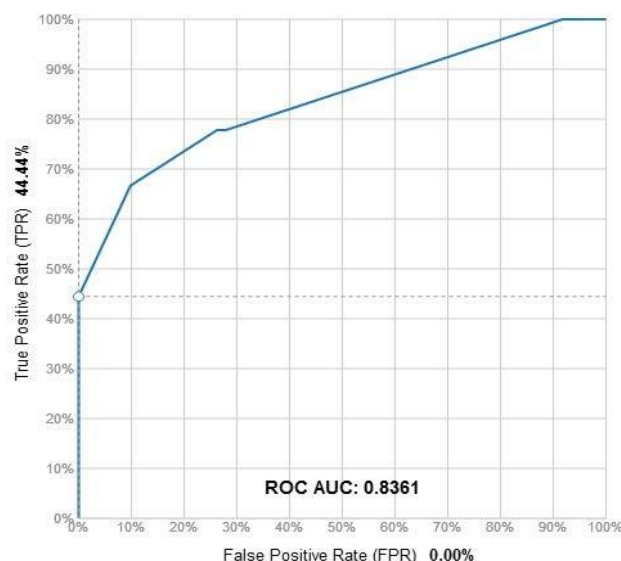
We have used first with MESS score as predicated variable and limb salvage was used as outcome variable. For each predictor variable, sensitivity and specificity were calculated using Fisher's exact test. ROC was plotted using 1-specificity (FPF, false positive fraction) on X-axis and sensitivity (TPF, true positive fraction) on Y-axis for all the predictor variables.



Figure 1:- ROC curve plotted to determine the prediction of limb salvage using MESS score in patients arterial injury. TPF, True Positive Fraction; FPF, False Positive Fraction. AUC: 0.952.

A profile with area under the curve, (C) = 0.5 showing no predictable ability whereas (C) = 1 has perfect predictable ability.

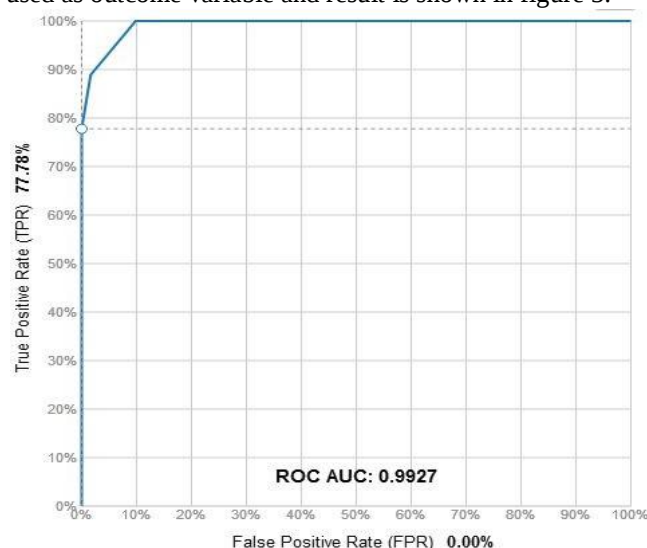
As shown in Fig, 1, the area under the ROC curve, C = 0.952 with an accuracy of 94.3% indicating perfect predictive ability of limb salvage by using the MESS score.



92.9% Accuracy		0.6154 F-measure	
100.0% Precision	44.4% Recall	0.6409 Phi coefficient	
0.0% FPR	5.7% % positive instances	777.8% Lift	
56.8% K-S statistic	0.406 Kendall's Tau	0.4375 Spearman's Rho	

Figure 2:- ROC curve plotted to determine the prediction of limb salvage with CT angiography in patients arterial injury. TPF, True Positive Fraction; FPF, False Positive Fraction. AUC: 0.831.

As shown in the figure 2, ROC curve was plotted with CT angiography as the predictable variable and limb salvage as outcome variable and result showed the predictable accuracy with AUC of 0.831 with an accuracy of prediction was 92.9% Further, we have used both MESS score and CT angiogram as predicated variables and limb salvage was used as outcome variable and result is shown in figure 3.



97.1% Accuracy		0.875 F-measure	
100.0% Precision	77.8% Recall	0.8678 Phi coefficient	
0.0% FPR	10.0% % positive instances	777.8% Lift	
90.2% K-S statistic	0.5245 Kendall's Tau	0.592 Spearman's Rho	

Figure 3:- ROC curve plotted to determine the prediction of limb salvage by combined analysis of MESS score and CT angiogram in patients arterial injury. TPF, True Positive Fraction; FPF, False Positive Fraction. AUC: 0.992.

Data shows that by combining both MESS score and CT angiogram indicates excellent prediction with AUC of 0.99. with an accuracy of prediction of 97.1%.

Discussion:-

Despite the modern surgical interventions, vascular injuries can still cause extremity loss and mortality. The extremity salvage rate in our study was 87.14% in the arterial injury with apparently viable limbs at presentation in our Institute which is comparable with the study done by Sharma D et al, in which the extremity salvage rate was 91.3%³².

Traumatic vascular injuries of the limbs remain a significant challenge especially in third world countries²⁰. In Road traffic injuries among penetrating traumas were very common in an Indian study analysis done in 2007, had

70% exclusively in male patients. This is like what was reported from Sweden and Thailand but totally different from that from the USA, where gunshot injury was the primary cause. Penetrating injuries were 59.06%, Road traffic injuries 70%, Blunt injury 25.5%, Fall 40%, Industrial accidents 8%.²⁷

In contrast our study analysis of the majority of the trauma is due to blunt injuries, reported as 82.85% of total arterial injury, and 93.10% of blunt limb trauma is due to road traffic accidents followed by penetrating injuries most of which are occupational.

The distribution of vascular trauma published in literature from European studies and trauma registries showed a higher number of lower limb injuries as compared to upper limb⁹ which is consistent with our study.

Tan et al.³⁵ evaluation of mechanism of injury revealed that blunt injury was more common in patients with lower extremity vascular trauma and penetrating injury was present in upper extremity trauma and complication was more common in blunt trauma than penetrating trauma. Our study showed 61.42% of lower limb (43 patients) injuries were due to blunt injury and 21.42% of upper limb (15 patients) injuries were due to blunt injury, and complications were more in blunt injury.

Khan FH et al.^{20,24} study series on vascular injury showed that the most common was popliteal artery injury (43%). In our study, popliteal artery injury was noted in 37 patients (52.85%), with 30 salvageable limbs (81.1%), which was not statistically significant.

Sah B et al, review consists of most of cases presented to the casualty after six hours of the vascular injury (52%) and only 48% of the cases presented within six hours after trauma. Time of presentation is a very critical prognostic factor of limb and overall survival². Since the duration of presentation had a significant effect in delaying primary revascularization and limb loss¹².

This is in contrast to our study which shows no significance of time of presentation and salvageable limb unless it is also associated with severity of ischemia as per the analysis shows (p 0.015) significant association of MESS ischemia (doubled) score (>6 hours) .

The importance of early presentation after vascular injury is well recognized and six hours of the golden period of restoring perfusion is recommended in many studies.^{25,3} skeletal muscles are possibly the most principal tissue to respect in the context of vascular trauma and ischemia. Anticoagulation at the time of vascular repair was a crucial to limit the no-reflow phenomenon²¹.

Helfet et al. described that a MESS score greater than or equal to 7 had a 100% predictable value for amputation. In a series of 164 severely injured lower limbs all cases with a score of seven or more required amputation³¹.

Prichayudh et al.^{29,36} examined the result of upper-extremity vascular injury management and Eleven Multivariate analysis revealed that the only factor significantly associated with amputation prediction was the MESS score. No amputations were performed in patients who had a MESS score < 7. MESS score of 7 or more in upper limb injury did not indicate that amputation is needed.

In our study we had 14 patients with MESS score ≥ 7 , out of which 9 limbs (64.28%) were salvaged. This also had no correlation with original paper by Johnson in 1990¹⁹ showed 100% limb loss if MESS score was ≥ 7 .

We found MESS score to be the best outcome predictor of limb salvage by ROC analysis (AUC of 0.952) with an 94.3% accuracy of prediction of limb salvage, whereas with CT angiography the ROC AUC was 0.83 with an accuracy of 92.9%.

In 1999, Soto et al.³³ described a study followed by a prospective study reported in 2001.³⁴ and showed a sensitivity of 95.1% and a specificity of 98.7% for detecting proximal arterial injuries in the upper and lower extremities. In 2004, Busquets et al.⁵ also Inaba et al.^{17,18} did a retrospective review with the results of a prospective study for extremity trauma, and the sensitivity and specificity rate of CTA for detecting clinically significant arterial injuries was 100%.

In our study also CT angiography had 100% sensitivity and 100% positive predictive value for diagnosing arterial injury.



Picture 1:- CT angiography shows right popliteal artery injury- non opacification with distal vessels runoff.

In another study, arterial transection carried a high risk of limb loss due to propagating thrombosis^{15,25}. In our study also, Out of 67 patients with presence of distal reformation in CT angiography, we have 61 limbs (91%) salvaged, 6 limbs (8.9%) not salvaged. This association between presence of distal reformation in CT angiography and viability of the limb was statistically significant with p value 0.0016 (less than 0.05). As seen in other studies³⁰, the most important predictive factor for limb salvage was the presence of distal runoff in angiography, which is consistent with our study.

Also in our study, findings of absence of muscle swelling and muscle distortion as homogeneous appearance in CT angiography, we have 91% limbs salvaged, with good prognosis, which has statistical significance.

In our study, Out of total salvageable cases, majority 42 patients (68.8%) had single vessel injury, with better prognosis. Out of 44 patients with Single vessel injury, we have 42 limbs (95.4%) salvaged. This association between vessel involvement seen in CT angiography and viability of the limb was statistically significant.

Out of 56 patients with CT angiography findings of proximal vessel (above knee, above elbow) injury, we have 51 limbs (91%) salvaged, which did not show statistical significance.

The recent literature search classified vascular injury into five types: an intimal damage which consists of intimal flaps, interruption, or sub-intimal/inner hematomas, absolute wall defects with pseudo aneurysms or injury, absolute transections with bleeding, AVF and vessels spasm. The most common injury in our study are intimal injury or occlusion were in blunt trauma, while complete wall defect and transection occurred with less common penetrating trauma, which were seen as non opacification of the injured segment of the vessel, abrupt cut off with no distal flow, extravasation of contrast in CTA.



Picture 2:- Intraoperative photo of partial tear of brachial artery in upper limb trauma patient.

In our study, the surgical intervention done among the 70 patients were Bypass with GSV graft in 50 patients(50%), primary repair with direct anastomosis in 11 patients (11%), primary amputation in 3 patients, and secondary amputation in 6 patients (6%), consistent with standard management also described in study by Wahlgren et al.³⁹



Picture 2:- Intraoperative picture of popliteal artery injury repair with interposition GSV graft.

CT angiography had 100% sensitivity and 100% positive predictive value for diagnosing arterial injury. Furthermore, we have used the MESS score and CT angiogram as predated variables and limb salvage was used as outcome variable and found excellent prediction with AUC of 0.99 with accuracy of prediction was 97.1%. The predictive accuracy with CT and MESS individually was 92.9% and 94.3% respectively in predicting limb salvage. Together CTA and MESS, the accuracy was 97.1%. This data clearly indicates that both MESS score and CT angiogram when combined provides excellent prediction of limb salvage.

Conclusion:-

With the rising trend of RTA and violence, vascular injuries are becoming a major contributor of limb loss, with increased morbidity and mortality. The most common factor is the assessment of severity of injury and diagnosis of arterial injury. By using CT angiography for diagnosis of vascular injury and predicting the prognosis outcome of limb salvage along with MESS score was undertaken in this study.

1. CT angiography was done in 100 patients with arterial injury, but only 70 of these patients had surgical exploration. In them the CT findings are confirmed with the intra-operative findings of arterial injury, suggesting 100% accuracy. With usage of MESS score in assessing the limb salvage, the patients are divided into two groups based on the MESS score <7 and >7 . The limb salvage is better in those <7 in both the upper and lower limbs.
2. ROC analysis shows the overall accuracy with CT and MESS was 92.9% and 94.3% respectively in predicting limb salvage. Together, the accuracy was 97.1%. Hence the assessment of trauma patients for arterial injury using MESS score and CT angiography can be done as predictor of the limb salvage.
3. And this study proves that MESS score has adjunct value in prognosis of arterial injury in extremity trauma and CT angiography has diagnostic and predictive role when arterial injury is suspected.

Recommendations:-

1. Prioritizing and triaging the arterial injury patients amongst extremity trauma cases.
2. Appropriate clinical evaluation with MESS score, with time saving measures.
3. CT angiography to be considered in stable and indicated patients for diagnosis and to assess the prognosis of limb salvage.
4. Emergency ambulatory services, road traffic safety practices, safety measures at work places are the key factors for reducing vascular injury and limb loss.

Limitation of the study:

We have not included the cases with active arterial bleeding from upper limb injury with threatened limb as CT angiogram could not be done, as they were shifted immediately for intervention.

References:-

1. 12.1.Anderson RJ, Hobson RW 2nd, Padberg FT Jr, et al. Penetrating extremity trauma: identification of patients at high-risk requiring arteriography. *J VascSurg* 1990;11:544–548. 85. 2.Austin OM, Redmond HP, Burke PE, Grace PA, Bouchier-Hayes DB. Vascular trauma - a review. *J Am Coll Surg.* 1995;181(1):91–108.
2. 88.3. Blaisdell FW. The pathophysiology of skeletal muscle ischemia and the reperfusion syndrome: a review. *Cardiovascular surgery.* 2002;10(6):620-30.
3. 9. 4.Branco BC, Linnebur M, Boutrous ML, Leake SS, Inaba K, Charlton-Ouw KM, et al. The predictive value of multidetector CTA on outcomes in patients with below-the-knee vascular injury. *Injury.* 2015 Aug. 46 (8):1520-6.
4. 50.5.BusquetsAR, Acosta JA, Colone E, Alejandro KV, Rodriguez P. Helical computed tomographic angiography for the diagnosis of traumatic arterial injuries in the extremities. *J Trauma* 2004;56:625–628.
5. 22.6.CatalanoC, Frajoli F, Andrea L, et al. Infrarenal aortic and lower-extremity arterial disease: diagnostic performance of multi-detector row CT angiography. *Radiology* 2004;231:555–563. 42. Helfet DL, Howey T, Sanders R. Limb salvage versus amputation. Preliminary results of the Mangled Extremity Severity Score. *Clin OrthopRelat Res.* 1990;256:80–6.
6. 2.7.De Silva WDD, Ubayasiri RA, Weerasinghe CW, Wijeyaratne SM. Challenges in the management of extremity vascular injuries: A wartime experience from a tertiary centre in Sri Lanka. *World J Emerg Surg.* 2011;6:24.
7. 63.8.DuBose JJ, Savage SA, Fabian TC, Menaker J, Scalea T, Holcomb JB, et al. The American Association for the Surgery of Trauma PROspective Observational Vascular Injury Treatment (PROOVIT) registry: multicenter data on modern vascular injury diagnosis, management, and outcomes. *J Trauma Acute Care Surg.* 2015;78(2):215.
8. 82.9 Fingerhut A, Leppäniemi AK, Androulakis GA, Archodovassilis F, Bouillon B, Cavina E, et al. The European experience with vascular injuries. *Surg Clin North Am.* 2002;82(1):175–88.
9. 99.10 Dunn JC, Kusnezov N, Schoenfeld AJ, Orr JD, Cook PJ, Belmont PJ, Jr. Vascular Injuries in Combat-Specific Soldiers during Operation Iraqi Freedom and Operation Enduring Freedom. *Ann Vasc Surg.* 2016;35:30-7.
10. 95. 11.Fleiter TR, Mervis S. The role of 3D-CTA in the assessment of peripheral vascular lesions in trauma patients. *Eur J Radiol.* 2007;64(1):92-102.
11. 86. 12.Fox N, Rajani RR, Bokhari F, Chiu WC, Kerwin A, Seamon MJ, et al. Evaluation and management of penetrating lower extremity arterial trauma: An Eastern Association for the Surgery of Trauma practice management guideline. *J Trauma Acute Care Surg.* 2012;73(5 Suppl):S315–20.
12. 92. 13.Franz RW, Shah KJ, Halaharvi D, Franz ET, Hartman JF, Wright ML. A 5-year review of management of lower extremity arterial injuries at an urban level I trauma center. *J Vasc Surg.* 2011;53(6):1604–10.
13. 84. 14.Frykberg ER. Advances in the diagnosis and treatment of extremity vascular trauma. *Surgical Clinics of North America.* 1995;75(2):207-23.
14. 98.15 Hafez HM, Woolgar J, Robbs JV. Lower extremity arterial injury: results of 550 cases and review of risk factors associated with limb loss. *J Vasc Surg.* 2001;33(6):1212-9.
15. 77. repeat 15. Hafez HM, Woolgar J, Robbs JV. Lower extremity arterial injury: results of 550 cases and review of risk factors associated with limb loss. *J Vasc Surg.* 2001;33(6):1212-9. 14.16.Hodina M, Gudinchet F, Reinberg O, Schnyder P. Imaging of blunt arterial trauma of the upper extremity in children. *PediatrRadiol* 2001;31:564–568.

16. 96. 17. Inaba K, Potzman J, Munera F, McKenney M, Munoz R, Rivas L, et al. Multi-slice CT angiography for arterial evaluation in the injured lower extremity. *J Trauma*. 2006;60(3):502-6;
17. 51. 18. Inaba K, Branco B, Reddy S, et al. Prospective evaluation of multidetector computed tomography for extremity vascular trauma. *J Trauma*. 2011; 70: 808–815.
18. 102. 19. Johansen K1, Daines M, Howey T, Helfet D, Hansen ST Jr. Objective criteria accurately predict amputation following lower extremity trauma. *J Trauma* 1990 May;30(5):568-72.
19. 65. 20. Khan FH, Yousuf KM, Bagwani AR. Vascular injuries of the extremities are a major challenge in a third world country. *J Trauma Manag Outcomes*. 2015 Jul 30;9:5.
20. 90. 21. Klocker J, Falkensammer J, Pellegrini L, Biebl M, Tauscher T, Fraedrich G. Repair of arterial injury after blunt trauma in the upper extremity - immediate and long-term outcome. *Eur J VascEndovasc Surg*. 2010;39(2):160.
21. 13. 22. McCorkell SJ, Harley JD, Morishima MS, Cummings DK. Indications for angiography in extremity trauma. *AJR Am J Roentgenol* 1985;145:1245–1247.
22. 1. 23. Menzoian JO, Doyle JE, Cantelmo NL, LoGerfo FW, Hirsch E. A comprehensive approach to extremity vascular trauma. *Arch Surg* 1985;120:801–805.
23. 91. 24. Mullenix PS, Steele SR, Andersen CA, Starnes BW, Salim A, Martin MJ. Limb salvage and outcomes among patients with traumatic popliteal vascular injury: an analysis of the National Trauma Data Bank. *J Vasc Surg*. 2006;44(1):94–100.
24. 87. 25. Nemati M, Nosratinia H, Goldust M, Raghifar R. Arterial injuries in extremities trauma, angiographic findings. *Pak J Biol Sci*. 2013;16(3):145-7.
25. 97. 26. Peck MA, Rasmussen TE. Management of blunt peripheral arterial injury. *Perspect Vasc Surg Endovasc Ther*. 2006;18(2):159-73.
5. 27. Perkins ZB, De'Ath HD, Aylwin C, Brohi K, Walsh M, Tai NR. Epidemiology and outcome of vascular trauma at a British Major Trauma Centre. *Eur J Vasc Endovasc Surg*. 2012;44(2):203–9.
26. 66. Perkins ZB, De'Ath HD, Aylwin C, Brohi K, Walsh M, Tai NR. Epidemiology and outcome of vascular trauma at a British Major Trauma Centre. *Eur J VascEndovasc Surg*. 2012;44(2):203–9.
27. 67. 28. Perkins ZB, Yet B, Glasgow S, Marsh W, Brohi K, Rasmussen TE, et al. Prognostic Factors for Amputation Following Surgical Repair of Lower Extremity Vascular Trauma: A Systematic Review and Meta-Analysis of Observational Studies. *JVS*. 2014;59(6):75S.
28. 47. 29. Prichayudh S1, Verananvattna A, Sriussadaporn S, Sriussadaporn S, Kritayakirana K, Pak-art R, Capin A, Pereira B, Tsunoyama T, Pena D. Management of upper extremity vascular injury: outcome related to the Mangled Extremity Severity Score. *World J Surg*. 2009 Apr;33(4):857-63.
29. 72. 30. Ravari H, Pezeshki Rad M, Bahadori A, Ajami O. Comparison of Conventional Angiographic Findings between Trauma Patients with or without Runoff. *Bull Emerg Trauma*. 2014;2(2):72-76.
30. 43. 31. Robertson PA. Prediction of amputation after severe lower limb trauma. *J Bone Joint Surg Br*. 1991;73(5):816–8.
31. 53. 32. Sharma D, Sisodia A, Devgarha S, Mathur RM. Management of vascular trauma: A single center 10 years experience *JCVS* 2014;2(3):33-38.
32. 48. 33. Soto JA, Munera F, Cardoso N, Guarin O, Medina S. Diagnostic performance of helical CT angiography in trauma to large arteries of the extremities. *J Comput Assist Tomogr* 1999;23:188–196.
33. 49. 34. Soto JA, Munera F, Morales C, et al. Focal arterial injuries of the proximal extremities: helical CT arteriography as the initial method of diagnosis. *Radiology* 2001;218:188–194.
34. 71. 35. Tan TW, Joglar FL, Hamburg NM, Eberhardt RT, Shaw PM, Rybin D, et al. Limb outcome and mortality in lower and upper extremity arterial injury: a comparison using the National Trauma Data Bank. *Vasc Endovascular Surg*. 2011;45(7):592-7.
35. 101. 36. Tolga Ege, Aytekin Unlu, Huseyin Tas, Dogan Bek, Selim Turkan, Aytac Cetinkaya. Reliability of the mangled extremity severity score in combat-related upper and lower extremity injuries. *IJO* 2015. 49(6):656-66.
36. 55. 37. Velinovic MM, Davidovic BL, Lotina IS, et al. Complications of operative treatment of injuries of peripheral arteries. *Cardiovasc Surg* 2000;8:256-264.
37. 3 38. Venermo M, Kantonen I, Suominen V, Salenius J, Roth WD, Lepäntalo M. [Emergency problems in vascular surgery]. *Duodecim*. 2009. 125(4):439-47.
38. 100. 39. Wahlgren C, Kragsterman B. Management and Outcome of Pediatric Vascular Injuries. *Journal of Vascular Surgery*. 2014;59(6):75S.