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Original Research Article

A COMPARATIVE ANALYSIS OF LOWER EXTREMITY INJURY SEVERITY SCORING SYSTEM PREDICTING LIMB SALVAGE IN SEVERE OPEN INJURIES OF THE LEG

E. Ebanezer[1], J. Berin Jaba[2]

[1]Assistant Professor, Department of Orthopedics, Sree Mookambika institute of medical sciences, Kulasekaram, Tamilnadu, India
[2]Associate Professor, Department of Orthopedics, Sree Mookambika institute of medical sciences, Kulasekaram, Tamilnadu, India

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Corresponding Author:
Dr. J.Berin Jaba,
Email: drberinjaba@yahoo.com

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Abstract

Background: High-energy trauma to the lower extremity presents challenges in reconstruction and rehabilitation. This study aims to analyse the sensitivity and specificity of various lower-extremity Injury-severity scoring systems in the decision-making of limb salvage or amputation in high-energy leg injuries. **Materials and Methods:** This prospective study was conducted at the orthopaedics and spine surgery department, Ganga Hospital, Coimbatore, from June 2004 to June 2006. Thirty-five high-energy leg injuries in thirty-two patients were evaluated prospectively using seven lower-extremity injury-severity scoring systems to assist in the decision-making process of limb salvage or amputation. The trauma victims were resuscitated and assessed for life-threatening injuries simultaneously after hemodynamic stabilization and essential investigation like radiological assessment, USG abdomen, etc. **Result:** The MESS and NISSSA scores have higher specificity (71.4% and 81%) than the LSI, PSI and HFS-97 (61.9%, 47.6% and 47.6%, respectively), the sensitivity (85.7% and 64.3%) is lesser than the LSI, PSI and HFS-97 (100%). Even though the MESS and NISSSA have a higher positive predictive value (66.6% and 69.2%) than the LSI, PSI and HFS-97 (63.6%, 56% and 56%, respectively), the negative predictive value (88.2% and 77.2%) is lesser than the LSI, PSI and HFS-97 (100%). **Conclusion:** In conclusion, these scores have either high sensitivity or high specificity. This quality is not helpful in the decision-making process of amputation or salvage because an ideal limb salvage index should have 100% sensitivity and 100% specificity.

INTRODUCTION

High-energy trauma to the lower extremity presents challenges in reconstruction and rehabilitation. Management of these major injuries is associated with a high incidence of non-unions,[1,2] early and late infections,[3] prolonged treatment periods," high number of secondary procedures,[4] poor functional outcomes and the possibility of secondary amputations. With the advent of highly sophisticated internal and external fixation devices, microsurgical techniques in recent years and the enormous attention paid to severely injured patients, it is often thought that almost any extremity can be salvaged if the technique is good. Further medical advances such as free tissue transfers and the refined skills developed by micro-vascular surgeons tempt the orthopaedic surgeon even further to seek triumphs of technique over reason. These multidisciplinary approaches have been responsible for remarkable success in limb salvage and have improved the outlook for patients with a mangled leg.[5,6]

The decision to amputate or not to amputate has significant repercussions medically, economically, socially and medico-legally. Medically, the surgeon must do the best for the patient. It is the surgeon's natural inclination and the patient's and relatives' wish to preserve the limb whenever possible. However, the patients treated for limb salvage will undergo more complex surgeries, have a longer stay in the hospital and suffer more complications. In some of these patients, however, limb salvage may have subsequent harmful results, associated with high morbidity and often requires late amputation despite initial success.[7]

The prolonged hospitalization and recumbence harm the individual both physically and mentally. Also, by the time healing occurs, the final result is often marginal or worse than an early amputation would have been in terms of function and appearance.[8,9]

Medico-legally the surgeon may be questioned in several ways claiming that the treating surgeon should have followed a different course of treatment in both the limb salvage attempt and amputation. It must also be remembered that studies on the long-term outcome of mangled legs report higher impairment for amputees than the patients with successful reconstruction. So, the decision to amputate or salvage a severely injured leg must be taken on day one to avoid the above-mentioned adverse effects.[10] In patients acutely presenting with a severe leg injury, deciding between primary amputation and a salvage attempt is often difficult. Attempts to quantify the severity of the trauma and to establish numerical guidelines for the decision to amputate or salvage the limb have been proposed by several authors.[11-14]

Published lower-extremity injury-severity scoring systems include MESS, PSI, LSI, NISSSA, HFS-97 and GHOISS. The developers of these scoring systems attempted to validate them by demonstrating a high sensitivity and specificity rate in predicting limb salvage. Ideally, a trauma limb-salvage index should be 100% sensitive (all amputated limbs with a score at or above the threshold) and 100% specific (all salvaged limbs with a score below the threshold). In the decision to amputate, high specificity is important to ensure that no salvageable limb is incorrectly assigned for amputation. Sensitivity is also important to guard against inappropriate delay in amputation when the limb is ultimately not salvageable, which may lead to high rates of complications. The clinical utility of these various scoring systems in the decision-making process of limb salvage or amputation depends on their level of sensitivity and specificity.

Aim

This study aims to analyse the Sensitivity and Specificity of various lower-extremity Injury-severity scoring systems in the decision-making of limb salvage or amputation in high-energy leg injuries.

MATERIALS AND METHODS

This prospective study was conducted at the Orthopaedics and spine surgery department, Ganga Hospital, Coimbatore, from June 2004 to June 2006. Thirty-five high-energy leg injuries in thirty-two patients were evaluated prospectively using seven lower-extremity injury-severity scoring systems to assist in the decision-making process of limb salvage or amputation. Informed consent and approval were obtained before the study started.

Inclusion Criteria

High energy injuries resulting in a functionally severed leg, Injuries associated with risk of amputation, Gutilo-Anderson type IIIB fractures with severe muscle damage, nerve injury, and major bone injury, Gustilo-Anderson type IIIC fractures, and Severe injuries to the distal aspect of the tibia were included.

Exclusion Criteria

Primary treatment was received before admission, patients were non-ambulatory before the injury, and patients with life-threatening head injuries (Intra-cranial haemorrhage), associated with burns to the injured limb and spinal cord injury were excluded.

The mean age of the patient was 30 years (range 11-60 years). Twenty-seven patients had injuries from road traffic accidents, four from falling marble stones on their legs, and 1 had injuries from falling from a height. Twenty-eight patients were male, and four patients were female. Nine patients had an injury in the left leg, 20 in the right leg, and 3 in both legs. Nine legs were associated with vascular injury requiring salvage repair. 13 patients had major injuries in the same limb. Fourteen patients were associated with major injuries in the other limbs. 4 patients were related to other systemic (chest/abdomen) injuries.

The practices for the care of high-energy leg injuries included the following as a combined procedure or a staged procedure: Simultaneous resuscitation and assessment/Reassessment, Management of life-threatening injuries by specialist surgeons, emergency debridement of the wounds, stabilization of the fractures with external fixator, vascular repair if need/Faciotomy if a vascular repair was done, definitive soft tissue cover in the form of a free flap, definitive bone procedures - conversion to LRS if bone transport requires/ILN or Plate fixation with or without bone grafting.

The trauma victims were resuscitated and assessed for life-threatening injuries simultaneously after hemodynamic stabilization and essential investigation like radiological assessment, USG abdomen, etc. They were taken up for surgery as close to the admission as possible. The index surgical procedure consisted of wound debridement, skeletal stabilization with an external fixator or plate, vascular repair if needed and fasciotomy if a vascular repair was done, and managing life-threatening injuries by an appropriate specialist surgeon. Definitive soft tissue cover to the leg was performed within 5-10 days. The external fixator is converted to LRS during the flap or staged procedure if a bone loss occurs. Definitive bone procedures consisted of conversion to LRS and bone transport, LRS itself, ILN fixation and plate fixation with or without bone grafting.

Antibiotic coverages were given intravenously throughout the surgical period and orally in the follow-up period. All patients were followed-up till the bone union that allowed partial or full weight-bearing.

All limbs were graded at the time of the index surgical procedure, as soon as the patient was stabilized hemodynamically and taken up for surgery by a team of orthopaedic surgeons and plastic surgeons with more than five years of experience in treating open injury of the limbs. The

attending surgeons characterized the injury component and the severity of the injury in each component for the scoring indices (LSI, PSI, MESS, NISSSA, HFS-97, Gustilo-Anderson Grading and Ganga Hospital Score). The decision to amputate or undertake salvage was taken independently by a consensus of the senior members of the plastic and orthopaedic teams without any bias or consideration of any score. Amputations were defined as immediate if they were performed as an index procedure without an attempt of salvage. Amputations were defined as secondary if they were amputated after a salvage attempt.
The scoring indices LSI, PSI, MESS, NISSSA, HFS-97, Gustilo-Anderson grading and Ganga Hospital score were evaluated for sensitivity, specificity, and positive and negative predictive values.

RESULTS

Of the 14 amputations, ten legs underwent primary amputation, and four underwent secondary amputation. In the primary amputations, 8 were Grade IIIC, and 2 were Grade IIIB. In the secondary amputations, all were Grade IIIB.
Of the 21 salvages, only one leg was Grade IIIC, and the remaining 20 were Grade IIIB [Table 1].

Table 1: Distribution of scores in the study.

		Amputation	Salvage
Gustilo Anderson classification	**IIIB**	6	20
	IIIC	8	1
Predictive salvage index	Score 8 and >8	**14**	**11**
	Score <8	**0**	**10**
Limb salvage index	Score 6 and >6	**14**	**8**
	Score <6	**0**	**13**
Mangled extremity severity score	Score 7 and >7	**12**	**6**
	Score <7	**2**	**15**
NISSSA score	Score 11 and >11	**9**	**4**
	Score <11	**5**	**17**
Hannover fracture scale - 97	Score 9 and >9	**14**	**11**
	Score <9	**0**	**10**
Ganga hospital score	Score 14 and >14	**6**	**1**
	Score <14	**0**	**19**

Table 2: Sensitivity and specificity of the scores in the study.

Scores	Sensitivity	Specificity	PPV	NPV
PSI	100%	47.6%	56%	100%
LSI	100%	61.9%	63.6%	100%
MESS	85.7%	71.4%	66.6%	88.2%
NISSSA	64.3%	80.9%	69.2%	77.2%
HFS-97	100%	47.6%	56%	100%
GHOISS	100%	95%	86%	100%

The PSI has a sensitivity of 100%, specificity of 47.6%, positive predictive value of 56% and negative predictive value of 100%.
The LSI has a sensitivity of 100%, specificity of 61.9%, positive predictive value of 63.6% and negative predictive value of 100%.
The MESS has a sensitivity of 85.7%, specificity of 71.4%, positive predictive value of 66.6% and negative predictive value of 88.2%.
The NISSSA Score has a sensitivity of 85.7%, specificity of 71.4%, positive predictive value of 66.6% and negative predictive value of 77.2%.
The HFS-97 has a sensitivity of 100% and a specificity of 47.6%, a positive predictive value of 56% and a negative value of 100%.
The GHOISS had a sensitivity of 100%, specificity of 95%, positive predictive value of 86% and negative predictive value of 100% [Table 2].

DISCUSSION

Open leg fractures with severe soft tissue trauma remain a major challenge in management with a high potential for limb loss, at times loss of life from sepsis and poor functional outcome even after adequate treatment.[15,16]
Recent advances in plastic and orthopaedic surgery have improved the outlook for patients with a mangled leg, but not without complications. Salvage or amputation must be the first decision in managing a severely injured leg, as failed reconstructions can lead to secondary amputations. The outcome of severe open injury of the leg depends on the severity of the injury.[17]
Many Injury-severity scores for the lower limb have been developed to assist the surgical team in the salvage or amputation decision-making process. These are the Mangled Extremity Severity score (MESS), Limb Salvage Index (LSI), Predictive Salvage Index (PSI), Nerve injury, Ischemia, Soft-tissue injury, Skeletal injury, Shock and Age Of the patient score (NISSSA), Hannover Fracture Scale-97 (HFS-97) and Ganga Hospital Open Injury Severity Score (GHOISS).
The most widely used landmark classification system for open fractures is that of Gustilo-

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Anderson. This classification system divides the open fractures into Types I, II, and III based on the size of the wound.[18] Type III is further subdivided into IIIA, IIIB and IIIC based on the severity of soft tissue damage and associated vascular injury.[19]

Gustilo's classification is based on the size of the wound rather than the extent of injury to all limb components. Severe involvement of one component has a different treatment protocol and functional outcome than an injury with more than one component. Gustilo's grading can change with debridement and again if the wound requires re-debridement.[20] This undermines the value of the classification as an initial guide to the treatment.[10]

Nevertheless, each specific group still has significant variability in injury severity. Type IIIB includes a wide spectrum of injuries with high interobserver error rates.[20] This was shown by Brumback and Jones,[21] who found that agreement among the orthopaedic surgeons was only 60% regarding the classification of fractures ranging from Grade II to Grade IIIC with large inter-observer variations, leading to poor reliability and reproducibility. It was concluded that this system was not an adequate basis for treatment decisions.[22,23] While type IIIA and IIIC injuries do not pose many problems in evaluation, type IIIB injuries include a wide spectrum of injuries from easily manageable to hardly salvageable, making this classification inefficient in providing guidelines in decision-making and management.[24,25]

In this study, the Gustilo classification does not specifically address the severity of injuries of the musculotendinous and skeletal structures. Moreover, no clear-cut point has been described for decision-making regarding amputation or salvage. So, it isn't easy to calculate the sensitivity and specificity.

Howe et al,[5] described the PSI based on the degree of skeletal injury, degree of muscle injury, level of vascular injury and warm ischemia time. The concluded threshold value for amputation is a score of 8 and >8. In PSI, it is difficult to interpret the degree of severity of the injuries because the PSI does not clearly describe the mild, moderate and severe grades.

Russell et al,[26] described the Limb Salvage Index based on the degree of skeletal injury, soft tissue injury (skin, muscle), arterial and venous injury, nerve injury and duration of ischemia. The concluded threshold for amputation is a score of 6 and >6. A drawback in this classification is that the outcome of the initial reconstructive procedure must be known before the surgeon can score the variable "skin". For example, the variable describes primary closure, split-thickness skin grafting, and flap closures. Especially in injuries with severe tissue loss, management of skin lacerations can frequently change due to the necessary debridement of necrotic tissue.

Johansen described the MESS based on the age of the patient,[12] presence of shock and duration, degree of tissue injury and severity of limb ischemia. The concluded threshold for amputation is a score of 7 and >7. The vascular injury was not clearly defined in this score, allowing for evaluating patients with normal perfusion.

The NISSSA score described by McNamara is based on the level of nerve injury, duration of ischemia, degree of soft tissue injury, type of fracture, degree of fracture displacement and comminution, presence of shock and its duration, and age of the patient. The concluded threshold for amputation is a score of 11 and > 11. NISSSA score is based on sensory impairment and limb-salvage capacity, but ischemia, contusion, stretch or compression can cause transient neurological injury. The HFS-97 is a combination of logical variables, but a large number of parameters and the need to define soft tissue injury make its use difficult. The Ganga Hospital score, which is applicable in open fractures without vascular injury, gives equal importance to each component of the leg and to the associated co-morbid factors which influence the outcome of the limb.

After analyzing the results, it becomes clear that even though the LSI, PSI and HFS-97 have sensitivity (the ability of the scoring index to correctly predict the amputation in legs with a score at or above the threshold). The positive predictive value of 63.6%, 56%, and 56%, respectively (the probability that the legs with a score at or above the threshold will undergo amputation) means relatively more inappropriate amputations. The specificity of 61.9%, 47.6%, and 47.6% (LSI, PSI, HFS97, respectively) indicates the relatively lesser ability of the scoring index to predict the salvage in legs with a score below the threshold, even though they have 100% negative predictive value (the probability that the legs with a score below the threshold will undergo salvage pathway).

Although the MESS and NISSSA scores have higher specificity (71.4% and 81%) than the LSI, PSI and HFS-97 (61.9%, 47.6% and 47.6%, respectively), the sensitivity (85.7% and 64.3%) is lesser than the LSI, PSI and HFS-97 (100%). Even though the MESS and NISSSA have a higher positive predictive value (66.6% and 69.2%) than the LSI, PSI and HFS-97 (63.6%, 56% and 56%, respectively), the negative predictive value (88.2% and 77.2%) is lesser than the LSI, PSI and HFS-97 (100%).

CONCLUSION

In high-energy open leg injuries, the difficulty in the decision-making process (amputation or salvage) often arises in injuries without vascular injury that require repair for the salvage of the limb. Open leg injuries with a vascular injury require repair for the salvage of the limb. The decision to salvage the limb depends mostly on the reparability of the vessel, presentation time (<6hrs) and the patient's clinical condition at the time of presentation, which may not allow the repair of the injured vessel. In conclusion, these scores have either high sensitivity or high specificity. This quality is not helpful in the decision-making process of amputation or salvage because an ideal limb salvage index should have both 100% sensitivity and 100% specificity to be useful in the decision-making process of amputation or salvage in high-energy leg injuries.

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