

Assessment and Decision-Making in Complex Limb Fracture Management: Limb Salvage Versus Primary Amputation

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Rezumat

Evaluare și decizie terapeutică în managementul fracturilor complexe ale membrelor: salvarea membrului versus amputația primară

Introducere: Leziunile complexe ale membrelor reprezintă o provocare majoră în practica de traumatologie și ortopedie, prin severitatea distrucțiilor tisulare și prin complexitatea deciziilor terapeutice. Stabilirea abordului care oferă rezultatul optim – salvarea membrului sau amputația primară – rămâne un subiect controversat.

Metode: A fost realizată o sinteză narativă structurată a literaturii, prin interogarea bazei de date PubMed, Embase și Scopus, incluzând studii publicate între 2008 și februarie 2026; căutarea bibliografică a fost efectuată în perioada octombrie 2025 – februarie 2026. Cuvintele cheie utilizate au inclus „limb salvage”, „primary amputation”, „mangled extremity” și „MESS”. Au fost incluse studii care evaluau sisteme de scor pentru severitatea leziunilor și rezultate clinice.

Rezultate: Sistemele de scor pentru severitatea leziunilor au demonstrat o acuratețe predictivă limitată, sensibilitatea scorului MESS stabilindu-se între 46% și 72%, iar specificitatea între 70% și 84%. Studiul Lower Extremity Assessment Project (LEAP) a raportat rezultate funcționale comparabile între salvarea membrului și amputație la o urmărire de doi ani. Ambele abordări s-au asociat cu rate ridicate de complicații, salvarea membrului necesitând frecvent intervenții multiple și o recuperare prelungită.

Concluzii: Sistemele de scor pentru severitatea leziunilor nu trebuie utilizate izolat. Decizia terapeutică trebuie să acorde prioritate rezultatelor funcționale, evaluării multidisciplinare și factorilor centrați pe pacient, în contextul progreselor actuale din chirurgia reconstructivă și din recuperare medicală.

Cuvinte cheie: salvarea membrului, traumatism, amputație, studiu LEAP, MESS

Abstract

Background: Complex limb injuries present a major challenge in trauma and orthopaedic practice due to the severity of tissue damage and the complexity of treatment decisions. Determining whether limb salvage or primary amputation provides the optimal outcome remains controversial.

Methods: A structured narrative review was conducted using PubMed, Embase, and

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Scopus, including studies published between 2008 and 2026, with the literature search performed between October 2025 and February 2026. Keywords included “limb salvage,” “primary amputation,” “mangled extremity,” and “MESS.” Studies evaluating injury severity scoring systems and clinical outcomes were included.

Results: Injury severity scoring systems demonstrated limited predictive accuracy, with MESS sensitivity ranging from 46–72% and specificity between 70–84%. The Lower Extremity Assessment Project (LEAP) study reported comparable functional outcomes between limb salvage and amputation at two-year follow-up. Both approaches were associated with high complication rates, with limb salvage often requiring multiple procedures and prolonged recovery.

Conclusion: Injury severity scoring systems should not be used in isolation. Decision-making should prioritise functional outcomes, multidisciplinary assessment, and patient-centred factors within the context of modern reconstructive and rehabilitation advances.

Keywords: limb salvage, trauma, amputation, LEAP study, MESS

Introduction

Complex limb injuries (CLI) represent a significant challenge in trauma and orthopaedic practice due to the severity of injuries and the complexity of clinical decision-making (1). These injuries often involve extensive damage to multiple anatomical structures including bone, soft tissue, nerves, and vascular components (2). When several of these systems are simultaneously disrupted, the injury is often described as a mangled extremity, commonly resulting from high-energy mechanisms (2). These include road traffic collisions, falls from height and penetrating trauma. In the UK, there are approximately 20,000 cases of major trauma annually, 86% of these cases being lower limb injuries involving mostly open tibial/fibula fractures (3).

The management of complex limb injuries presents a fundamental clinical dilemma: whether to attempt limb salvage or proceed with primary amputation. Advances in microsurgical techniques, orthoplastic collaboration and trauma systems have significantly improved limb salvage rates (1,4). However, these developments have also complicated decision-making, as salvage procedures may involve multiple operations, prolonged recovery, and higher complication rates. Consequently, the decision must balance anatomical feasibility with functional outcomes and quality of life.

Although several scoring systems have been developed to guide decision-making, no single system reliably predicts functional outcomes following severe limb injury (5). This limitation highlights the importance of clinical judgement and multidisciplinary collaboration when managing complex limb trauma. This paper critically evaluates the assessment strategies and decision-making processes involved in

managing complex limb injuries, with emphasis on the evidence supporting limb salvage and amputation.

Methods

This article was conducted as a structured narrative review rather than a systematic review. A narrative synthesis was chosen because the aim was to critically appraise and integrate evidence across three related but heterogeneous domains - initial trauma assessment, injury severity scoring systems, and salvage/amputation management strategies - rather than to answer a single, narrowly defined clinical question amenable to a PICO framework and quantitative pooling. This approach allowed a broader contextual discussion of assessment tools and decision-making frameworks than a systematic review's stricter eligibility criteria would typically permit.

A literature search was performed across PubMed, Embase, and Scopus for articles published between 2008 and February 2026, with the search itself conducted between October 2025 and February 2026. Search terms included combinations of “limb salvage,” “primary amputation,” “mangled extremity,” “MESS,” and related scoring-system acronyms (MESI, PSI, LSI, GHOUSS, NISSA). Reference lists of retrieved articles were also hand-searched for additional relevant studies. Articles were considered for inclusion if they addressed the assessment, scoring, or management of complex limb injuries in the context of limb salvage versus amputation decision-making.

As this is a narrative rather than a systematic review, a formal PRISMA flow diagram was not constructed, and the exact numbers of articles identified, screened, and excluded at each stage were not recorded and are therefore not presented; study selection was undertaken iteratively by the authors

based on relevance to the topics covered rather than through a pre-specified, reproducible screening protocol. Likewise, no formal quality or risk-of-bias assessment of included studies was performed. These are recognised limitations of the narrative approach and are discussed further below; consequently, the observations in this review should be interpreted as a synthesis of the current evidence base rather than as a definitive, quality-weighted conclusion.

Assessment of Complex Limb Injuries

Initial Assessment

Effective management of complex limb trauma begins with a systematic and prioritised assessment based on trauma principles. Initial evaluation should follow the Advanced Trauma Life Support (ATLS) algorithm focusing on airway, breathing and circulation to identify life-threatening injuries before focusing on limb specific injuries (6). While severe limb injuries may appear dramatic, they should not distract clinicians from treating potentially fatal systemic injuries.

Haemorrhage control is a crucial aspect of early assessment. Extremity injuries can lead to significant blood loss and contribute to mortality if not managed promptly (4,6). Current guidelines recommend the use of direct pressure, compression dressings, splinting, and tourniquets to control bleeding. While tourniquet use has been associated with improved survival in military settings, its use in civilian settings has not been studied extensively. A study by Ibana et al found that tourniquet use is a lifesaving measure with low complication rates in the civilian setting (7). Clasper et al, however, reported a higher incidence of limb complications in patients with pre-hospital tourniquet use due to prolonged limb ischaemia, compared to non-tourniquet group (8). This highlights the need for balanced clinical judgement rather than strict protocol adherence.

Assessment of vascular integrity is central to determining limb viability. Clinical signs of vascular injury are often categorised into hard and soft signs. Hard signs include absent distal pulses, expanding haematoma and distal ischaemia indicating the need for urgent surgical exploration (9). However, reliance only on clinical examination may lead to missed injuries. Studies comparing diagnostic modalities have demonstrated that CT angiography (CTA) provides high sensitivity and specificity for detecting vascular injury (10). Therefore, all complex limb injuries must be assessed by a senior surgeon, photographed and imaged according to NICE and BOAST guidelines.

In addition to vascular assessment, clinicians must consider complications associated with severe limb

trauma. Conditions such as compartment syndrome and rhabdomyolysis can significantly worsen outcomes if not recognised early (11). The development of compartment syndrome requires urgent decompression through fasciotomy to prevent irreversible tissue damage, while rhabdomyolysis may result in systemic complications including acute kidney injury. The principles of Damage Control Orthopaedics (DCO) should be applied to prevent physiological deterioration and stabilise the fracture (12).

Scoring Systems

Several scoring systems have been developed to support the assessment of complex limb injuries, including the Mangled Extremity Severity Score (MESS), Mangled Extremity Syndrome Index (MESI), Predictive Salvage Index (PSI), Limb Salvage Index (LSI), Nerve Injury, Ischaemia, Soft-tissue injury, Skeletal injury, Shock and Age of patient score (NISS-SA), and Ganga Hospital Open Injury Severity Score (GHOISS) (5,14). These scoring systems attempt to quantify injury severity by incorporating variables such as patient age, shock, ischaemia time, and soft-tissue damage (5). While these tools provide a structured approach to evaluation of injury, their clinical usefulness remains debated.

One of the most widely recognised and used scoring systems is the Mangled Extremity Severity Score (MESS) (13). MESS incorporates four main parameters: skeletal and soft tissue injury, limb ischaemia, shock, and patient age. Each parameter is assigned a score, with higher values indicating greater injury severity. A score of 7 or above has traditionally been considered predictive of amputation (13). The simplicity and rapid calculation of MESS have contributed to its widespread adoption in clinical practice, particularly in emergency and trauma settings where rapid decision-making is critical.

Despite its popularity, the predictive accuracy of MESS has been questioned. Several studies have shown that improvements in vascular reconstruction, microsurgical techniques, and orthoplastic collaboration have enabled successful limb salvage in cases where MESS would previously have suggested amputation (17). As a result, MESS may overestimate the likelihood of limb loss in modern trauma systems. Furthermore, the scoring system does not adequately account for factors such as patient comorbidities, rehabilitation potential, or advances in reconstructive surgery, which can significantly influence outcomes (17).

A modified version of MESS, the Nerve Injury, Ischaemia, Soft-tissue injury, Skeletal injury, Shock, and Age of patient score (NISSSA), adds an explicit

Table 1. Scoring systems in complex limb injuries

Scoring System	Full Name	Key Components Assessed	Score Range	Amputation Threshold (Commonly Used)	Main Purpose	Advantages / Limitations
MESS (13)	Mangled extremity severity score	Skeletal/soft-tissue injury, limb ischemia, shock, age	1–14	≥7 suggests amputation	Rapid decision aid for severe limb trauma	Advantage: rapid, bedside calculation from basic examination alone. Limitation: reported sensitivity 46–72% and specificity 70–84%; does not account for comorbidities, rehabilitation potential, or modern reconstructive advances (17).
MESI (14)	Mangled extremity syndrome index	Skeletal injury, limb ischemia time, shock, age, nerve injury, soft-tissue injury	Up to ~20+	≥20 suggests amputation	Evaluates severity of mangled extremity syndrome	Advantage: incorporates a broader variable set than MESS, including nerve injury. Limitation: more time-consuming to calculate, which limits practicality in the acute setting (14).
PSI (14)	Predictive salvage index	Bone injury, muscle injury, vascular injury, warm ischemia time	0–12	≥8 suggests amputation	Predict likelihood of limb salvage after vascular injury	Advantage: focuses specifically on vascular injury, useful after major vascular trauma. Limitation: derived from a small cohort and less validated across general mangled-extremity populations (14).
LSI (15)	Limb salvage index	Arterial injury, nerve injury, bone damage, muscle injury, skin injury, venous injury, ischemia time	Variable (often up to ~20)	≥6 suggests amputation	Comprehensive evaluation of limb injury severity	Advantage: broad multi-domain coverage (arterial, nerve, bone, muscle, skin, venous injury). Limitation: complexity limits routine clinical use, and external validation is more limited than for MESS (14).
GHOISS (16)	Ganga hospital open injury severity score	Skin/soft tissue injury, bone injury, functional tissues (muscle, tendon, nerve), comorbid factors	3–20+	≥17 suggests amputation	Designed for severe open limb injuries, especially Gustilo IIIB	Advantage: a “grey zone” (14–17) acknowledges outcome uncertainty rather than forcing a binary decision, and some studies report improved accuracy over earlier scores. Limitation: complex and training-intensive, largely confining routine use to specialised orthoplastic centres (14,16).
NISSSA (14)	Nerve injury, ischaemia, soft-tissue injury, skeletal injury, shock, age of patient score	Nerve injury, limb ischaemia (time-weighted), soft-tissue injury, skeletal injury, shock, age	0–22	≥11 suggests amputation	Modified MESS incorporating nerve injury to refine salvage/amputation prediction	Advantage: captures nerve injury, a key determinant of functional prognosis. Limitation: nerve assessment relies largely on plantar sensation, no longer an absolute contraindication to salvage with modern nerve repair; sensitivity and specificity remain controversial (14).

MESS = Mangled Extremity Severity Score; MESI = Mangled Extremity Syndrome Index; PSI = Predictive Salvage Index; LSI = Limb Salvage Index; GHOISS = Ganga Hospital Open Injury Severity Score; NISSSA = Nerve Injury, Ischaemia, Soft-tissue injury, Skeletal injury, Shock, Age of patient score

nerve-injury component to the four original MESS domains, with a score of 11 or above suggested as predictive of amputation (14). While nerve injury is a clinically important addition, NISSSA's assessment of it relies largely on plantar sensation as a proxy for nerve integrity — a finding no longer considered an absolute contraindication to salvage given modern nerve repair techniques — and reported sensitivity and specificity for NISSSA remain, like those of MESS, controversial (14).

More recently, the Ganga Hospital Open Injury Severity Score (GHOISS) has been proposed as a more detailed classification system for open fractures of the lower limb (16). This system evaluates the severity of injury across multiple domains including skin, skeletal structures, and functional tissues (14). Some studies

suggest that GHOISS demonstrates improved accuracy when predicting the feasibility of limb salvage compared with earlier scoring systems (16). However, the complexity of this scoring system and the training required for consistent application have limited its widespread adoption outside specialised orthoplastic centres.

Evidence from the Lower Extremity Assessment Project (LEAP) demonstrated that although these scores can assist in risk stratification, they are poor predictors of long-term functional outcomes (18). Notably, the LEAP investigators distinguished between two related but separate questions: whether a score can identify which limbs require amputation, and whether it can predict the patient's eventual functional outcome. On the first question, none of the indices reliably identified, at the time of injury, the

patients who would ultimately undergo amputation (4,18). On the second, evidence was similarly discouraging: none of the scores were predictive of ultimate functional recovery, which instead correlated more strongly with pre-injury patient characteristics — such as comorbidity, socioeconomic status, and self-efficacy — than with either the severity score itself or the choice of salvage versus amputation (4,18). Furthermore, many scoring systems were developed prior to modern trauma systems and advances in reconstructive surgery, limiting their relevance in contemporary practice (17). Therefore, while scoring systems can support clinical assessment, they should not replace comprehensive evaluation or multidisciplinary discussion.

Management of Complex Limb Injuries

Limb Salvage

Management of complex limb trauma requires careful evaluation of whether limb salvage or primary amputation will provide the best outcome for the patient. Limb salvage involves removal of damaged bone or soft tissue, followed by reconstruction to restore structural integrity and preserve a functional limb (19). It is generally considered when restoration of blood flow, adequate soft-tissue coverage, and stable skeletal fixation are achievable (19). Advances in vascular reconstruction, microsurgery, and orthopaedic fixation have expanded the possibilities for limb salvage that previously would have required amputation.

Orthopaedic stabilisation is a key component of limb salvage and may involve external fixation, intramedullary nailing, or plating (20). Techniques such as the Ilizarov method allow gradual bone reconstruction and deformity correction through a process called distraction osteogenesis, while preserving surrounding soft tissues (20). However, these procedures can be technically demanding and require prolonged treatment periods. Soft-tissue reconstruction is equally important, with modern plastic surgical techniques involving local flaps, free tissue transfer, and negative pressure wound therapy to improve the success of limb salvage in cases with extensive soft-tissue loss (21). These techniques can be used to temporarily stabilise and dress the wound, essentially buying critical time to have fully informed discussions and evaluate the likelihood of a successful salvage attempt.

Primary Amputation

Despite these advances, limb salvage is not always the optimal strategy. In such circumstances, primary amputation may provide better functional outcomes and reduce the risk of repeated surgeries and compli-

cations. Primary amputation is indicated when there is irreversible limb ischaemia with vascular compromise exceeding six hours (22). This results in irreversible muscle necrosis, release of toxic metabolites leading to systemic complications such as tissue reperfusion injury (12,22). Furthermore, severe contamination, extensive bone and soft tissue loss means attempts at limb salvage are likely to be unsuccessful and primary amputation is the only feasible solution.

The decision whether to perform the amputation proximal to the injury, or within the zone of injury depends on multiple factors. Amputations proximal to the injury site allow for a durable stump that forms within healthy tissue (22,23). These patients also achieve faster rehabilitation due to excellent wound healing and reduced risk of revision surgery (23). However, amputation at the zone of injury maximises residual limb length while preserving joint functionality and improving prosthetic potential. Ultimately the most important determinant appears to be soft tissue coverage. The surgical team must carefully consider whether there is enough muscle tissue to cover the bone that allows for optimum use of prosthesis in these patients. This approach often involves complex reconstruction techniques that increase the likelihood of infection and failure (24).

Research comparing limb salvage and amputation has produced mixed findings. The LEAP study demonstrated that long-term functional outcomes between the two approaches were largely comparable at two and seven years follow up (25). However, patients undergoing limb salvage were more likely to require multiple surgeries and experience complications (21,25). Conversely, early amputation may allow faster rehabilitation and earlier return to function with prosthetic support (21). These findings suggest that the choice of treatment should prioritise overall functional recovery rather than anatomical preservation alone.

The timing of amputation also influences outcomes. Evidence suggests that delayed amputation following failed salvage attempts is associated with higher complication rates, longer hospital stays, and poorer patient outcomes compared with early amputation when limb salvage is unlikely to succeed (26). Therefore, clinicians must carefully evaluate the potential benefits and risks of salvage attempts to avoid unnecessary morbidity.

Importantly, decision-making should also incorporate patient-centred factors such as occupation, psychological wellbeing, social support, and expectations regarding recovery. Patients must be provided with realistic information about the likelihood of them

regaining full function, whether they can run, possibility of a limp and chronic pain (27). Busse et al reported that patients who experienced failed salvage surgery would choose early amputation if presented with the same choice again (27). Studies have shown that while limb salvage may offer psychological benefits for some patients, these advantages must be weighed against the physical and social burdens of prolonged treatment.

Modern Prosthetic Rehabilitation

Beyond the immediate salvage-versus-amputation decision, advances in prosthetic rehabilitation are increasingly relevant to counselling patients about long-term function after amputation. Targeted muscle reinnervation (TMR) involves surgically coapting transected peripheral nerves to redundant motor nerve branches, either at the time of amputation or as a delayed procedure, giving each nerve somewhere to go and something to do. When performed acutely, TMR reduces the formation of symptomatic neuromas and residual or phantom limb pain, and can substantially improve control of myoelectric prostheses by providing additional, intuitive electromyographic signal sites (28). Osseointegration offers a complementary advance for patients who struggle with conventional socket prostheses: a titanium implant is anchored directly into the residual long bone and connects to an external prosthetic limb through a transcutaneous abutment, avoiding socket-related discomfort and improving comfort, mobility, and quality of life. Its principal limitation is the transcutaneous interface itself, which carries an ongoing risk of soft-tissue and, less commonly, deep periprosthetic infection, alongside mechanical risks such as implant loosening or fracture (29). Both techniques remain most established at specialist centres, but their growing evidence base makes them increasingly relevant when discussing the long-term functional potential of amputation with patients.

Limitations

This study is limited by its structured narrative design and does not represent a formal systematic review. Selection bias may be present, and no formal quality assessment of included studies was performed. Additionally, heterogeneity between studies limits direct comparison.

Conclusion

Complex limb trauma presents significant challenges for clinicians due to the severity of injuries and the

complexity of treatment decisions. Effective management requires a systematic assessment based on trauma principles, combined with detailed evaluation of vascular, neurological, and musculoskeletal injuries. As this narrative review did not include a formal quality or risk-of-bias appraisal of the underlying studies, these observations should be regarded as a synthesis of the current evidence base rather than a definitive, quality-weighted verdict on any single assessment strategy.

Although scoring systems such as MESS and GHQISS provide useful frameworks for evaluating injury severity, current evidence demonstrates that they are insufficient for predicting functional outcomes. Consequently, clinical judgement and multidisciplinary collaboration remain essential in determining the most appropriate treatment strategy.

Advances in orthopaedic fixation, vascular repair, and reconstructive surgery have expanded the possibilities for limb salvage. However, these procedures may involve prolonged recovery and higher complication rates, meaning that primary amputation remains a valid treatment option in selected cases.

Ultimately, decision-making in complex limb trauma should adopt a patient-centred approach that prioritises functional outcomes, quality of life, and long-term rehabilitation. Future research should focus on improving predictive models and integrating patient-reported outcomes to support more informed and individualised treatment decisions.

Authors' Contributions

Adele Zacken: conceptualization, methodology. Kayaththery Varathan: data curation, writing - original draft preparation. Yasmin Sheik: writing - reviewing and editing, supervision. Uzair Khan: writing - reviewing and editing, supervision. Diana Sabbagh: writing - reviewing and editing, supervision. Ayman El-Zanaty: writing - reviewing and editing, supervision.

Conflicts of Interest

The authors declared no potential conflicts of interest.

References

1. Black CK, Ormiston LD, Fan KL, Kotha VS, Attinger C, Evans KK. Amputations versus salvage: reconciling the differences. *J Reconstr Microsurg.* 2021;37(1):32-41.
2. Arnez ZM, Tyler MP, Khan U. Describing severe limb trauma. *Br J Plast Surg.* 1999; 52(4):280-5.
3. McCullough AL, Haycock JC, Forward DP, Moran CG. II. Major trauma networks in England. *Br J Anaesth.* 2014;113(2):202-6.
4. Ly TV, Travison TG, Castillo RC, Bosse MJ, MacKenzie EJ, LEAP Study Group. Ability of lower-extremity injury severity scores to predict functional outcome after limb

- salvage. *J Bone Joint Surg Am.* 2008;90(8):1738-43.
5. Stefano L, Giovanni R, Pietro DF, Matteo O, Lara L, Nicola F. Which is the best score and classification system for complex injuries of the limbs? Some recommendations based on a systematic literature review. *European Journal of Plastic Surgery.* 2022; 45(4):551-60.
6. Dogjani A, Selmani E, Zaimi E, Haxhirexha K, Biberaj P, Lenjani B, et al. Utilizing ATLS® Trauma Management Protocols: the gold standard for safe and effective care. *Family Medicine & Primary Care Review* 2025; 27(3): 329-333
7. Inaba K, Siboni S, Resnick S, Zhu J, Wong MD, Haltmeier T, et al. Tourniquet use for civilian extremity trauma. *J Trauma Acute Care Surg.* 2015;79(2):232-7;quiz 332-3.
8. Clasper J, Brown KV, Hill P. Limb complications following pre-hospital tourniquet use. *J R Army Med Corps.* 2009;155(3):200-2.
9. Wahlgren CM, Aylwin C, Davenport RA, Davidovic LB, DuBose JJ, Gaarder C, et al. Editor's Choice - European Society for Vascular Surgery (ESVS) 2025 Clinical Practice Guidelines on the Management of Vascular Trauma. *Eur J Vasc Endovasc Surg.* 2025;69(2):179-237.
10. Dreizin D, Smith EB, Champ K, Morrison JJ. Roles of trauma CT and CTA in salvaging the threatened or mangled extremity. *Radiographics.* 2022;42(2):E50-E67.
11. Saddawi-Konefka D, Kim HM, Chung KC. A systematic review of outcomes and complications of reconstruction and amputation for type IIIB and IIIC fractures of the tibia. *Plast Reconstr Surg.* 2008;122(6):1796-1805.
12. Serlis A, Sgardelis P, Vampertzis T, Rizavas K, Poullos P, Konstantopoulos G. Complex Limb Injuries: Limb Salvage Versus Amputation - A Mini Review and Meta-Analysis. *Adv Orthop.* 2025;2025:2884802.
13. Sharrock M. The mangled extremity: assessment, decision making and outcomes. *Acta Orthop Belg.* 2021;87(4):755-760.
14. Demir IA, Karsidag S. Scoring systems in major extremity traumas. In *Limb Amputation.* IntechOpen. 2019 Dec 9.
15. Lowenberg DW, Buntic RF, Buncke GM, Parrett BM. Long-term results and costs of muscle flap coverage with Ilizarov bone transport in lower limb salvage. *J Orthop Trauma.* 2013;27(10):576-81.
16. Okuku MD, Kabuye U, Khadolwa SA, Aweis AM, Xaviour OF, Abraha D, et al. Ganga hospital open injury severity score as a predictor of early failure of limb salvage among gustilo type III A and B tibia fractures in Uganda: a prospective cohort study. *BMC Surg.* 2025;25(1):77.
17. Omoto R, Umemura Y, Hanaoka K, Yonao Y, Kai H, Oi K, et al. Re-evaluation of cutting criteria for limb amputation using the Mangled Extremity Severity Score. *Trauma Surg Acute Care Open.* 2025;10(1):e001694.
18. Higgins TF, Klatt JB, Beals TC. Lower Extremity Assessment Project (LEAP) - the best available evidence on limb-threatening lower extremity trauma. *Orthop Clin North Am.* 2010;41(2):233-9.
19. Busse JW, Jacobs CL, Swiontkowski MF, Bosse MJ, Bhandari M, Evidence-Based Orthopaedic Trauma Working Group. Complex limb salvage or early amputation for severe lower-limb injury: a meta-analysis of observational studies. *J Orthop Trauma.* 2007;21(1):70-6.
20. Nayar SK, Alcock HM, Edwards DS. Primary amputation versus limb salvage in upper limb major trauma: a systematic review. *Eur J Orthop Surg Traumatol.* 2022;32(3):395-403.
21. Ndlovu S, Naqshband M, Masunda S, Ndlovu K, Chettiar K, Anugraha A. Clinical effectiveness of the Ganga Hospital Open Injury Severity Score for limb salvage versus amputation in patients with complex limb injuries: a systematic review and meta-analysis. *Bone Joint J.* 2023;105-B(1):21-28.
22. Ali A, Brundage SI. The Variables Affecting Decision-making Factors & Outcomes in Salvage versus Amputation for Complex Limb Injuries. *Ir Med J.* 2017; 110(10):661.
23. Noble T, Lineham B, Wiper J, Harwood P. Amputation in Trauma - How to achieve a good result from lower extremity amputation irrespective of the level. *Current Trauma Reports.* 2019;5(1):69-78.
24. Al Khaled N. Complex foot trauma: amputation versus reconstruction—Clinical evaluation and long-term quality of life (Doctoral dissertation).
25. Qureshi MK, Ghaffar A, Tak S, Khaled A. Limb salvage versus amputation: a review of the current evidence. *Cureus.* 2020;12(8):e10092.
26. Kim J, Choi W, Cho W, Moon J. Impact of delayed amputation on clinical outcomes compared to that of early amputation in patients with blunt polytrauma. *Sci Rep.* 2025; 15(1):8184.
27. Penn-Barwell JG, Bennett PM. Amputations and rehabilitation. *Surgery Oxford.* 2026; 44(2):146-149.
28. Chappell AG, Ramsey MD, Park S, Dumanian GA, Ko JH. Targeted muscle reinnervation - an up-to-date review: evidence, indications, and technique. *Arch Plast Surg.* 2025;52(3):153-168.
29. Barootchi E, Jirofti N, Daliri M, Moradi A. Lower limb osseointegrated prosthetics: are we standing on the edge of a new era? *J Orthop Surg Res.* 2026;21(1):255.