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ORIGINAL ARTICLE

Advancing Surgical Outcomes in Extremity Vascular Trauma: Insights from Clinical Experience

Ekstremite Vasküler Travmasında Cerrahi Sonuçların Geliştirilmesi: Klinik Deneyimlerden Elde Edilen Görüşler

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ABSTRACT

Background/Aim: Extremity trauma is a major contributor to global morbidity and mortality, comprising up to 70% of trauma admissions. Vascular injuries associated with extremity trauma pose significant challenges as the delays in diagnosis may lead to acute limb ischemia, compartment syndrome, and limb loss. Timely diagnosis and surgical intervention are essential for optimizing patient outcomes.
Methods: This retrospective cohort study analyzed 85 patients with vascular extremity traumas treated at a tertiary care hospital from 2018 to 2023. Patients with isolated soft tissue injuries or chronic injuries were excluded. Data on demographics, injury mechanisms, clinical presentations, diagnostic imaging, surgical interventions, and outcomes were collected. Primary outcomes included limb salvage and mortality rates, while secondary outcomes evaluated complications and functional recovery.
Results: The cohort had a mean age of 33.7 years, with a predominance of male patients (87.1%). Lower extremity injuries were the most common, with gunshot wounds as the leading cause (31.8%). Most (90.6%) presented within 6 hours of injury, and 55.3% exhibited hemodynamic instability. In 91.8% of cases, surgical intervention was required, predominantly involving interposition vein grafting and primary repairs. Limb salvage was achieved in 92.9% of patients, though 15.3% experienced complications, primarily ischemia and necrosis. The rate of iatrogenic trauma was significantly higher in hemodynamically stable patients (18.4% vs 4.3%, p=0.007).
Conclusion: Early surgical intervention in extremity trauma is crucial for high limb salvage rates and favorable outcomes. Despite a notable complication rate, timely management can mitigate adverse effects. Future studies should focus on improving long-term functional outcomes and developing comprehensive rehabilitation protocols tailored to extremity trauma patients.

Keywords: Extremity trauma, limb salvage, trauma management, vascular injury

ÖZ

Giriş: Ekstremite travmaları, travma kaynaklı morbidite ve mortalitenin önemli bir nedeni olup, tüm travma yatışlarının %70'ine kadarını oluşturabilmektedir. Ekstremite travmalarına eşlik eden vasküler yaralanmalar, akut ekstremite iskemisi, kompartman sendromu ve uzuv kaybı gibi ciddi komplikasyonlara yol açabileceğinden dolayı önemli zorluklar teşkil etmektedir. Bu nedenle, tanının hızlı bir şekilde konulması ve cerrahi müdahalenin zamanında gerçekleştirilmesi hasta sonuçlarının iyileştirilmesinde hayati öneme sahiptir.
Yöntem: Bu retrospektif kohort çalışmasında, 2018-2023 yılları arasında bir üçüncü basamak hastanede vasküler ekstremite travması nedeniyle tedavi gören 85 hasta incelenmiştir. İzole yumuşak doku yaralanması veya kronik yaralanması olan hastalar çalışmaya dahil edilmemiştir. Demografik veriler, yaralanma mekanizmaları, klinik bulgular, görüntüleme yöntemleri, cerrahi müdahaleler ve sonuçlar gibi veriler toplanmıştır. Birincil sonuçlar arasında uzuv kurtarma ve mortalite oranları yer alırken, ikincil sonuçlar komplikasyonlar ve fonksiyonel iyileşme değerlendirilmiştir.
Bulgular: Kohortun ortalama yaşı 33,7 olup, hastaların %87,1'i erkekti. En sık karşılaşılan yaralanma alt ekstremite yaralanmaları olup, travmaların %31,8'i ateşli silah yaralanmalarıydı. Hastaların %90,6'sı travmadan sonraki ilk 6 saat içinde başvurmuş ve %55,3'ünde hemodinamik instabilite tespit edilmiştir. Olguların %91,8'inde cerrahi müdahale gerekli olmuş, en sık kullanılan yöntemler interpozisyon ven grefti ve primer onarımlar olmuştur. Uzuv kurtarma oranı %92,9 olarak bulunurken, hastaların %15,3'ünde iskemik ve nekrotik komplikasyonlar tespit edilmiştir. Hemodinamik olarak stabil hastalarda iyatrojenik travma oranı anlamlı derecede yüksek bulunmuştur (%18,4'e karşı %4,3, p=0,007).
Sonuç: Ekstremite travmalarında erken cerrahi müdahale, yüksek uzuv kurtarma oranları ve olumlu sonuçlar için kritik öneme sahiptir. Önemli bir komplikasyon oranı görülmesine rağmen, zamanında yönetim olumsuz etkileri azaltabilmektedir. Gelecekteki çalışmalar, uzun dönem fonksiyonel sonuçları iyileştirme ve ekstremite travmalarına yönelik kapsamlı rehabilitasyon protokolleri geliştirme üzerinde yoğunlaşmalıdır.

Anahtar Kelimeler: Damar yaralanması, ekstremite kurtarılması, ekstremite travmaları, travma yönetimi

Introduction

Extremity traumas, encompassing both upper and lower limb injuries, represent a significant portion of trauma cases worldwide and remain a leading cause of morbidity and mortality. Based on the World Health Organization (WHO), trauma is one of the most critical public health challenges, with over five million deaths annually attributed to injuries, and millions more suffering long-term disabilities (1). Among these, extremity trauma is particularly prevalent, accounting for up to 70% of all trauma admissions in emergency

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departments globally (2). The mechanisms of such injuries vary widely, ranging from road traffic accidents and falls to violence-related incidents such as gunshot and stab wounds, each presenting unique challenges in clinical management (3).

In high-energy trauma settings, the potential for concomitant vascular injury is a crucial consideration, as it can significantly affect limb viability and patient outcomes. Vascular injuries associated with extremity trauma can lead to devastating consequences, including acute limb ischemia, compartment syndrome, and, ultimately, limb loss if not promptly identified and managed (4). The presence of hard signs of vascular injury, such as pulsatile bleeding, expanding hematoma, and absent distal pulses, often necessitates immediate surgical exploration. In contrast, soft signs require a more nuanced approach involving advanced imaging modalities to confirm the extent of the injury. The timely and accurate diagnosis of these injuries is critical, as delays in treatment are associated with increased rates of amputation and mortality (5).

The management of extremity trauma involves a multidisciplinary approach including initial resuscitation, surgical intervention, and comprehensive postoperative care. The choice of surgical technique, such as primary repair, interposition vein grafting, or fasciotomy, is dictated by the type and severity of the injury. Early surgical intervention has been shown to improve outcomes significantly, particularly in cases of vascular injury where time to surgery is a critical determinant of limb salvage (6). Despite advances in surgical techniques and perioperative care, complications such as ischemia, necrosis, infection, and chronic pain remain significant concerns, often leading to prolonged hospital stays and repeated interventions (7).

Recent studies have highlighted the importance of a standardized approach to managing extremity trauma, emphasizing early identification of vascular injuries, appropriate surgical planning, and the use of advanced imaging techniques to guide treatment decisions (7). However, significant variability remains in clinical practice, particularly regarding the optimal timing of surgical intervention and the management of complications. Additionally, there is a paucity of data on the long-term functional outcomes of patients surviving extremity trauma, particularly in resource-limited settings where access to rehabilitation services may be restricted (7).

Given these gaps in the literature, this study aims to provide a comprehensive analysis of extremity trauma management in a tertiary care setting, focusing on the incidence and types of injuries, clinical presentations, surgical interventions, and outcomes, including limb salvage rates, complications, and long-term functional recovery. By examining a diverse cohort of patients over five years, we seek to identify key factors influencing outcomes and propose evidence-based recommendations for improving trauma care. The findings of this study will contribute to the growing body of evidence on extremity trauma and inform clinical guidelines, ultimately enhancing patient care and reducing the burden of trauma-related disabilities.

Methods

This retrospective cohort study was conducted in the cardiovascular surgery clinic of a tertiary university hospital between January 2018 and December 2023. The local ethics committee reviewed and approved the study protocol, and informed consent was obtained from all patients or their legal representatives. The study adhered to the ethical principles outlined in the Declaration of Helsinki.

Study Population

The study included a total of 85 patients presenting with extremity trauma. Inclusion criteria encompassed patients presenting with acute extremity trauma, defined as any injury involving the upper or lower extremities resulting from blunt, penetrating, or mixed mechanisms. Patients with major vascular injuries involving large vessels such as the aorta, vascular involvement of thoracic or abdominal organs, isolated soft tissue injuries without vascular involvement, chronic injuries, or those refusing to give consent were excluded from the study. Demographic data, including age, gender, and injury characteristics were obtained from electronic medical records of the hospital.

Clinical Assessment and Data Collection

Upon arrival at the emergency department, the trauma team thoroughly assessed all patients. This assessment included a detailed history, physical examination, and the evaluation of hemodynamic status. The clinical presentation was classified based on hard signs (e.g., pulsatile bleeding, absent distal pulses, cold, and pale limbs) and soft signs (e.g., non-pulsatile hematoma, reduced sensation) of vascular injury. The hemodynamic status was categorized as stable or unstable based on the initial vital signs and

the need for resuscitation.

The collected data included the time to clinical presentation defined as the interval between the injury and the initial presentation to the trauma center. It also included information about the mechanism of the injury (such as gunshot wounds, road traffic accidents, and stab wounds), as well as specific causes and related details about the injuries.

Imaging and Diagnostic Methods

Diagnostic imaging was used based on clinical need. All patients had X-rays to check for fractures and foreign objects. Computed tomography angiography was used to look for suspected vascular injuries, especially in cases where clear signs were not present. Duplex ultrasonography was used for patients suspected of having venous injuries or when immediate surgery was not needed. In unstable patients or those needing cardiopulmonary resuscitation, diagnosis relied only on physical examination. The choice of imaging was based on the patient's condition and available resources, as the emergency department physicians decided.

Surgical Interventions and Management

In cases of confirmed vascular injury or when conservative management was insufficient, surgery was necessary. The surgical procedure was determined based on the nature and severity of the injury. Options included interposition vein grafts, primary repair, fasciotomy, or a combination of these, as well as limb amputation when necessary. All surgeries took place in a dedicated cardiovascular surgery operating room equipped with full resuscitation capabilities and were performed by an experienced vascular team. Trauma teams were called in when required. The timing of surgery was recorded as either "less than six hours" or "more than six hours" post-injury, depending on the clinical urgency.

The type of anesthesia used, the length of the surgery, and any complications during surgery were carefully documented. After the surgery, standard trauma care procedures were followed, which included anticoagulation therapy, infection prevention, and close monitoring for signs of compartment syndrome or ischemia.

Outcome Measures

The study's main goals were to determine the rates of saving limbs, mortality, and the occurrence of major complications such as ischemia, necrosis, and infections. Secondary goals included the length of hospital stay, rates of readmission due to complications, and the need for blood transfusion. Long-term outcomes were evaluated using follow-up notes at the first, third, sixth, and 12th months after the discharge. Standardized scoring systems were used to assess full functional recovery and the presence of functional disabilities.

Statistical Analysis

Descriptive statistics were used to summarize patient demographics, injury characteristics, and clinical outcomes. Continuous variables were expressed as mean ± standard deviation (SD) based on data distribution, while categorical variables were presented as frequencies and percentages. Comparisons between groups were performed using the chi-square test for categorical variables and the independent t-test for continuous variables. A p-value of <0.05 was considered statistically significant. All analyses were conducted using the Statistical Package for Social Sciences (SPSS) for Windows, software (version 29.0, IBM Corp., Armonk, NY, USA).

Results

Demographics and Injury Characteristics of Patients

The study included a total of 85 patients with extremity trauma. The mean age of the patients was 33.7 years, ranging from four to 84 years. Among the patients, 87.1% were male (n=74) and 12.9% were female (n=11). Most injuries affected the lower extremities, with the left lower extremity being the most frequently affected area (36.5%, n=31), followed by the right lower extremity (34.1%, n=29). In comparison, injuries to the upper extremities were less common, with 20% (n=17) involving the right upper extremity and 9.4% (n=8) affecting the left upper extremity (Table 1).

When examining the causes of injury, the most frequent reasons were gunshot wounds (31.8%, n=27), road traffic accidents (29.4%, n=25), and stab wounds (23.5%, n=20). Gunshot wounds stood out as the primary cause of injury (Table 1).

Of the gunshot-related injuries, 61.53% were shotgun and 38.46% were gunshot. Shotgun injuries had more extensive tissue damage and multiple vascular injuries than gunshot injuries and generally required more aggressive vascular repair and debridement.

Clinical Presentation and Hemodynamic Status

The majority of patients (90.6%, n=77) arrived at the healthcare facility within 6 hours of the injury. Upon admission, 55.3% (n=47) of patients were hemodynamically unstable, while 44.7% (n=38) were hemodynamically stable. In hemodynamically unstable patients, the rate of combined (arterial + venous) injuries was significantly higher compared to stable patients (59.6% vs 28.9%; p=0.013). Among the hemodynamically unstable patients, the most frequently observed hard signs were pulsatile bleeding (59.8%, n=49), absence of distal pulses (22.0%, n=18), and cold, pale extremities (18.3%, n=15). On the other hand, soft signs were found in 37.6% of the cases (n=32), with non-pulsatile hematoma and neurological deficits being the most common findings. The findings were similar in patients presenting with hard and soft signs. In hemodynamically stable patients, the incidence of iatrogenic trauma was significantly higher compared to unstable patients (18.4% vs 4.3%; p=0.007). (Table 1)

Table 1. Demographic and Injury Characteristics of Hemodynamically Stable and Unstable Patients

	HD Stable (n=38)	HD Unstable (n=47)	*p*-value
Age (years)	34.76±20.52	32.85±14.46	0.629
Gender			
Male	32 (84.2%)	42 (89%)	0.530
Related Extremities			
Right Upper Limb	11 (28.9%)	7 (14.8%)	0.293
Left Upper Limb	4 (10.5%)	3 (6.4%)	
Right Lower Limb	10 (26.3%)	19 (40.4%)	
Left Lower Limb	13 (34.2%)	18 (38.3%)	
Mechanism of Injury			
Gunshot Wounds	8 (21.1%)	19 (40.4%)	**0.007***
Road Traffic Collusion	8 (21.1%)	7 (14.9%)	
Stab Wounds	4 (10.5%)	11 (23.4%)	
Industrial or Heavy Machinery Trauma	3 (7.9%)	3 (6.4%)	
Blunt Injury	1 (2.6%)	0 (0.0%)	
Fall	1 (2.6%)	3 (6.4%)	
Glass-related Injury	6 (15.8%)	2 (4.3%)	
Iatrogenic Trauma	7 (18.4%)[a]	2 (4.3%)[b]	

*The p-value (p=0.007) indicates a statistically significant linear relationship between the injury mechanism and hemodynamic status. HD: Hemodynamically

In our cohort, multisystemic involvement was observed in 41.66% of patients with orthopedic injuries and 35.48% of patients with thermal or non-thermal nerve injuries, emphasizing the importance of a multidisciplinary approach in managing such complex traumas.

Surgical Interventions and Outcomes

Surgical intervention was performed on 91.8% of patients (n=78). The most common procedures were interposition vein grafts (52.9%, n=45), primary repairs (24.7%, n=21), and fasciotomies (22.4%, n=19). The vast majority of surgeries (97.6%, n=83) were done within the first 6 hours following the injury, highlighting the urgency of surgical intervention in traumatic vascular injuries. Limb salvage was achieved in 92.9% (n=79) of cases. Amputation was necessary for severe ischemia or non-viable limbs, and the decision was made either during the initial surgical procedure or during subsequent interventions following the first operation (Table 2).

Table 2. Distribution of Surgical Procedures Performed in Hemodynamically Stable and Unstable Patients

	HD Stable (n=38)	HD Unstable (n=47)	*p*-value
Interposition Vein Graft	18 (47.4%)	27 (57.4%)	0.213*
Interposition ePTFE Graft	1 (2.6%)	4 (8.5%)	
Primary Vascular Repair	17 (44.7%)	11 (23.4%)	
Ligation	1 (2.6%)	2 (4.3%)	
End-to-end Suturing	0 (0.0%)	1 (2.1%)	
Patch-plastic Repair	1 (2.6%)	0 (0.0%)	
Thrombectomy	0 (0.0%)	2 (4.3%)	

* The p-value (p = 0.213) indicates no statistically significant difference between the hemodynamically stable (HD Stable) and hemodynamically unstable (HD Unstable) groups regarding the distribution of surgical procedures.

Complications and Hospital Course

In 15.3% of cases (n=13), complications were observed, with the most common being ischemia (30.8%, n=4), necrosis (23.1%, n=3), and infections (15.4%, n=2). The average hospital stay was 8.5 days, ranging from 1 to 37 days. Additionally, 15.3% of patients (n=13) were readmitted due to the need for additional surgical procedures or infection management (Table 3).

Table 3. Complication Rates in Hemodynamically Stable and Unstable Patients Following Surgical Intervention

	HD stable	HD Unstable	*p*-value
No Complication	35 (92.1%)	37 (78.7%)	0.14
Compartment Syndrome	0 (0.0%)	2 (4.3%)	
Reperfusion Injury	0 (0.0%)	4 (8.5%)	
Bleeding on Surgical Site	1 (2.6%)	0 (0.0%)	
Disseminated Intravascular Coagulation	1 (2.6%)	0 (0.0%)	
Hematoma	0 (0.0%)	1 (2.1%)	
Ischemia	1 (2.6%)	0 (0.0%)	
Necrosis	0 (0.0%)	1 (2.1%)	
Osteomyelitis	0 (0.0%)	2 (4.3%)	

Blood Transfusion and Long-Term Outcomes

64.7% of patients (n=55) required a blood transfusion, with an average transfusion volume of 3.2 units per patient. In long-term follow-ups, 87.1% of patients (n=74) achieved full recovery without significant disability, while 12.9% (n=11) continued to experience functional disability due to nerve damage or other reasons.

Discussion

The current study provides valuable insights into the demographic characteristics, injury mechanisms, clinical presentations, surgical interventions, and outcomes of patients with extremity trauma. Our findings highlight several critical aspects of trauma care aligning with and expanding upon the existing literature, suggesting areas for continued improvement and future research. This discussion will contextualize our results within the broader scientific discourse, drawing comparisons with similar studies and emphasizing the implications for clinical practice.

In this cohort of 85 patients, the predominance of male patients (87.1%) and a mean age of 33.7 years reflect a demographic profile commonly reported in trauma studies worldwide. For instance, a systematic review by Kataria et al. (2023) noted that males are disproportionately affected by trauma due to greater involvement in high-risk activities such as driving, manual labor, and sports (8). Our findings are consistent with those of Sharifian et al. (2024), who also reported a high incidence of extremity injuries among young adult males, particularly in urban settings. The similar distribution of demographics highlights the persistent vulnerability of young males to trauma, suggesting the need for preventive strategies focused on this demographic. The observed gender disparity may be attributed to behavioral and sociocultural factors, necessitating targeted public health interventions to mitigate risks among these high-risk groups (4).

The distribution of injury mechanisms in our study, particularly the high incidence of gunshot wounds (31.8%), road traffic collisions (29.4%), and stab wounds (23.5%), mirrors global patterns reported in trauma literature. Gunshot wounds as a leading cause of injury are consistent with findings from urban trauma centers in the United States and South Africa, where firearm-related violence is prevalent. For instance, studies from the US urban centers have shown that firearms are responsible for a significant proportion of trauma cases, with over 80% of firearm-related injuries requiring hospitalization and a mortality rate of 10-13% depending on the number and severity of gunshot wounds (9-12). Our results also align with data from the WHO Global Status Report on Road Safety (2018), highlighting road traffic accidents as a leading cause of worldwide morbidity and mortality. The prevalence of violent injury mechanisms underscores the necessity for violence prevention programs and stricter firearm control measures to reduce trauma incidence.

Shotgun injuries usually lead to greater soft tissue damage and vascular disruption than gunshot injuries, necessitating more aggressive surgical repair or debridement and reconstructive procedures.

The substantial proportion of injuries resulting from violent mechanisms underscores the urgent need for comprehensive violence prevention programs and stricter firearm control policies, as advocated by recent public health studies (1, 9).

Clinically, the majority of our patients (90.6%) presented within 6 hours of injury, reflecting a commendable response time critical for favorable outcomes in trauma care. This is in line with the principles of damage control surgery and early resuscitation, which emphasize the importance of prompt surgical intervention to mitigate the effects of hemorrhagic shock and minimize secondary complications (13). The relatively high rate of hemodynamic instability (55.3%) upon admission in our cohort emphasizes the severity of injuries managed in this setting and necessitates preparedness for rapid intervention. The presence of hard signs of vascular injury, such as pulsatile bleeding (59.8%) and absent distal pulses (22.0%), necessitated immediate surgical exploration, which is consistent with current guidelines for managing vascular trauma (14).

The high rate of multisystemic involvement, including orthopedic and nerve injuries, highlights the need for a collaborative approach among vascular, orthopedic, and neurosurgical teams to optimize outcomes in extremity trauma patients.

The high rate of surgical intervention (91.8%) in our cohort, with interposition vein grafts and primary repairs being the most frequently performed procedures, reflects the complexity of managing extremity trauma, particularly when major vascular structures are involved. These findings are comparable to those of Feliciano et al. (2013), reporting similar surgical approaches in their analysis of vascular injuries (15). The frequent use of interposition vein grafts (47.4% in stable and 57.4% in unstable patients) underscores

the critical role of vascular grafting techniques in limb salvage efforts, particularly in complex trauma cases. The success of limb salvage in 92.9% of cases in our study is noteworthy and compares favorably with limb salvage rates reported in other contemporary trauma series (16). However, the 7.1% rate of amputation, although relatively low, underscores the challenges of managing severe vascular injuries and the critical importance of timely, definitive surgical care to optimize outcomes.

Complications were observed in 15.3% of our patients, with ischemia and necrosis being the most common. This complication rate is comparable to the one reported by Kontopodis et al. (2024), identifying similar postoperative complications in patients with complex extremity trauma (17). These findings underscore the importance of meticulous intraoperative technique and vigilant postoperative monitoring to promptly identify and address complications. Additionally, the significantly higher rate of iatrogenic trauma in hemodynamically stable patients (18.4% vs 4.3%; p=0.007) warrants attention. This finding may suggest that stable patients are subjected to more extensive diagnostic or interventional procedures, potentially increasing their risk of iatrogenic injury. Identifying the factors contributing to this higher rate of iatrogenic trauma could guide procedural refinements aimed at minimizing such complications. Moreover, our data indicate that a significant portion of patients required blood transfusions (64.7%), reflecting the substantial blood loss often associated with severe extremity trauma. This aligns with studies by Kontopodis et al. (2024), which underscore the necessity of robust transfusion protocols and the management of coagulopathy in trauma patients (17).

Long-term follow-up in our study revealed that while 87.1% of patients achieved full recovery, a notable 12.9% experienced functional limitations, primarily due to nerve damage or prolonged ischemia. These findings highlight the potential for significant long-term morbidity following extremity trauma, even in cases where initial limb salvage is successful. This is consistent with the work of Kontopodis et al. (2024), reporting persistent functional impairments in a subset of trauma survivors (17). The observed functional impairments underscore the importance of post-discharge rehabilitation and long-term follow-up to address residual disabilities and optimize recovery. Such outcomes underscore the need for comprehensive rehabilitation programs tailored to the needs of extremity trauma patients to enhance functional recovery and quality of life.

Conclusion

In summary, this study offers a comprehensive analysis of extremity trauma management, highlighting the importance of early diagnosis, prompt surgical intervention, and vigilant monitoring to optimize limb salvage and reduce complications. Our findings underscore the high success rate of limb salvage (92.9%) achieved through interposition vein grafts and primary repairs, alongside the challenges posed by complications such as ischemia and necrosis. The significantly higher rate of iatrogenic trauma in hemodynamically stable patients also suggests areas for targeted procedural improvements. These insights align with best practices in trauma care and emphasize the need for tailored rehabilitation programs to address long-term functional limitations. Future research should consider multi-center trials to validate these findings across diverse populations and explore novel strategies in trauma management further enhancing patient outcomes. By integrating these insights into clinical practice, we can advance the care of extremity trauma patients, ultimately improving both immediate and long-term outcomes.

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