ORIGINAL ARTICLE

Early versus delayed lower extremity amputations caused by firearm injury: A minimum 2-year follow-up

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ABSTRACT

BACKGROUND: High-energy casualties such as firearm injuries may result in extensive loss of soft tissue and bone in the lower extremities. Although the primary aim in these types of injuries is the preservation of the extremity, repeated surgical procedures for extremity salvage and subsequent restoration of function could have detrimental effects on the patient both physically and psychologically. The main aim of this study is to evaluate the physical and psychological outcomes of patients who underwent lower extremity amputation in the early period after a firearm injury compared with the results of patients who underwent amputation in the late period. We also evaluated the factors affecting the prognosis in patients undergoing late below-knee amputation (BKA).

METHODS: This retrospective study included patients who underwent BKA following a lower extremity injury caused by firearms between March 2017 and March 2022. Patients who underwent emergency BKA at the first center they were taken to immediately after the injury constituted the early amputation (EA) group. Patients who were transferred to our tertiary-level referral center for continuation of treatment after the first intervention at another center and later underwent BKA constituted the late amputation (LA) group. The patients were evaluated regarding age, gender, amputation side, presence of phantom limb pain (PLP), and post-traumatic stress disorder (PTSD).

RESULTS: Information was available from hospital records for a total of 35 patients; 16 in the EA group and 19 in the LA group. All patients were male. The mean age at the time of injury was 25.5±5.3 years (range, 20-45 years), and the mean follow-up period was 37±17 months (range, 25-72 months). In the comparison of PLP experienced, the difference between the groups was statistically significant, with PLP experienced by 1 (10%) patient in the EA group and by 9 (90%) in the LA group (p=0.010). PTSD was diagnosed in 3 (23%) patients in the EA group and 10 (77%) patients in the LA group (p=0.039).

CONCLUSION: Patients who underwent late BKA were found to be affected by PLP and PTSD at a higher rate. When deciding on extremity-preserving surgery for patients with severe open injuries to the lower extremity, it is crucial to consider the poor outcomes associated with late BKA. Patients should be thoroughly informed about these negative outcomes.

Keywords: Amputation; firearm injury; phantom limb pain; post-traumatic stress disorder.

INTRODUCTION

The type and severity of injuries caused by firearms vary depending on the energy released upon impact of the projectile and the specific body part affected, often resulting in extensive bone and soft tissue loss. Decisions regarding extremity preservation or amputation are typically made in a straightforward manner following initial evaluation in field hospitals situated in combat zones.[1] The prevalence of these injuries among a predominantly young patient group compounds the challenge for orthopedic surgeons in determining the most appropriate course, particularly regarding amputation.

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The most objective criteria for lower extremity amputation in cases of severe injury are transection of the tibial nerve and irreparable vascular damage.[2] With advancements in reconstructive techniques aimed at preserving limbs following explosive injuries,[3,4] it is generally preferred to avoid amputation whenever feasible, provided the vascular structures remain intact. However, inappropriate or repeated attempts at extremity salvage can have deleterious physical and psychological consequences for the patient, including an increased risk of sepsis and sepsis-related mortality.[5]

While challenges may arise with long-term prosthetic use, early amputation can offer rapid functional recovery, particularly with recent advancements in prosthetic technology.[6] Furthermore, advanced rehabilitation protocols play a key role in facilitating patients' reintegration into daily life post-amputation, significantly enhancing overall health, psychological well-being, and functional recovery.[7] The primary purpose of this study is to compare the early-stage physical and psychological outcomes among patients undergoing early versus late amputation following severe lower extremity injuries caused by firearms, and to investigate prognostic factors influencing outcomes.

MATERIALS AND METHODS

Approval for this retrospective study was granted by the Local Ethics Committee (decision no: 2024/159, dated: 19/03/2024). The study included 35 patients who had undergone below-knee amputation (BKA) following severe lower extremity injury caused by firearms between March 2017 and March 2022. The study's inclusion criteria encompassed patients who had undergone BKA following Gustilo-Anderson type 3a, 3b, or 3c open fracture resulting from firearm injuries. Patients were excluded from the study if they presented with close fractures or had undergone BKA due to another type of injury other than firearms.

The patients were stratified into two groups based on the timing of the amputation surgery: those undergoing surgery in the early phase and those in the late phase. The early amputation (EA) group consisted of patients classified as Gustillo-Anderson type 3c (Fig. 1a), who underwent immediate BKA at a field hospital following the initial injury (Fig. 1b) and subsequently receiving postoperative wound care, rehabilitation, at our tertiary-level referral center. The late amputation (LA) group consisted of patients presenting with open, multifragmentary fractures accompanied by substantial soft tissue loss, including periosteum but without vascular injury (Gustillo-Anderson type 3a, 3b). These individuals initially underwent wound debridement and temporary stabilization (Fig. 2a) at another medical facility before referral to our center, where X-rays were checked (Fig. 2b), further debridements and repeated examinations were carried out. BKA was eventually performed due to infection and unresolved soft tissue complications encountered during follow-up care.

Intravenous (IV) antibiotics were initiated upon the patients' arrival in the Emergency Department. All patients received standard antibiotic prophylaxis (first-generation cephalosporin, aminoglycoside, metronidazole) for a duration of 72 hours as part of open fracture management. Debridement procedures were conducted in the operating theater under either general or spinal anesthesia. A tourniquet cuff was applied to the extremity without inflation. Excision and removal of infected tissue and sequestered necrotic bone segments were performed. The bone ends were meticulously debrided using a curette and saline solution. Additionally, foreign bodies and any fascial tissue exhibiting signs of contamination or compromised vitality were excised. Debridement of necrotic soft tissues was carried out until encountering areas of active bleeding from small vessels, delineating a clear demarcation from viable tissue. Subsequent wound irrigation was conducted using physiological saline solution.

BKA was executed in cases where infection persisted despite

Figure 1. (a) Preoperative clinical appearance of an early below-knee amputation patient. **(b)** Postoperative clinical appearance of an early below-knee amputation patient. **(c)** Postoperative X-ray of an early below-knee amputation patient.

Figure 2. (a) Preoperative clinical appearance of a late below-knee amputation patient. **(b)** X-ray of a late below-knee amputation patient. **(c)** Postoperative clinical appearance of a late below-knee amputation patient.

successive debridement procedures for wounds with extensive soft tissue loss, accompanied by infection and severely fragmented fractures without arterial damage (Fig. 2c), and X-ray was checked postoperatively (Fig. 2d). The amputation site was normally positioned approximately 12-18 cm distal to the knee joint. Utilization of the posterior flap technique was favored when the integrity of the posterior muscles (the gastrocnemius and soleus) remained intact. Conversely, in instances of severe injury to the posterior tibial compartment musculature, the fish-mouth amputation technique was employed.

Following suture removal, elastic bandages were meticulously applied in a figure-of-eight configuration to mold the stump. To prevent the occurrence of a tourniquet effect from the bandages, they were periodically loosened for intervals of 15-20 minutes every 6-8 hours. With the exception of activities such as washing and allowing for aeration, continuous application of the bandages was advised for a duration of 24 hours until the permanent prosthesis was applied. Daily extremity inspection, trunk balance, and muscle strengthening exercises were recommended. Following the completion of stump maturation, the permanent prosthesis was applied. The patients continue to receive physical and psychological support at certain periods in the rehabilitation clinic of our center.

Patients underwent regular follow-up assessments every three months after discharge, during which pertinent data were documented. Hospital records of patients were analyzed regarding age, gender, the time from injury to amputation, Mangled Extremity Severity Score (MESS), fracture region and type, fracture fixation type, the total number of surgeries performed before amputation, the presence of phantom limb pain (PLP) after amputation, the presence of post-traumatic stress disorder (PTSD), and return to work.

Statistical Analysis

Data obtained in the study were analyzed statistically using IBM SPSS Statistics for Windows, version 21.0. Categorical data were stated as number (n) and percentage (%). In the comparisons of categorical variables, the Chi-square test was used. A value of $p<0.05$ was accepted as statistically significant.

RESULTS

Information was available from hospital records for a total of 35 patients, 16 in the EA group and 19 in the LA group. All patients were male. The mean age at injury was 25.5±5.3 years (range, 20-45 years), and the mean follow-up period was 37±17 months (range, 25-72 months). Of the 19 patients who underwent late BKA, foot amputation was performed initially, together with external fixation (EF) of the distal tibia fracture in 9 patients (47.37%), distributed as 5 Chopart, 3 Syme, and 1 Lisfranc amputations. Although the Mangled Extremity Severity Score value trended slightly higher in the EA group, no statistically significant difference was observed between the groups. Detailed information pertaining to bone fractures necessitating late amputation is delineated in Table 1.

In the comparison of PLP, a statistically significant difference was observed between the groups, with PLP reported by 1 (10%) patient in the EA group and 9 (90%) in the LA group ($p=0.010$). Similarly, PTSD was identified in 3 (23%) patients

Table 1. Fractures resulting in late amputation group

Fracture Region	n	%
Metatarsal fragmented fracture	5	26.5
Metatarsal+talus fragmented fracture	2	10.5
Calcaneus fragmented fracture	1	5.25
Calcaneus+talus fragmented fracture	3	15.75
Clavicle+talus+tibia distal fracture	1	5.25
Tibia distal fracture	1	5.25
Tibia distal+fibula distal fracture	2	10.5
Metatarsal+calcaneus+talus fracture	1	5.25
Tibia+fibula diaphysis fracture	1	5.25
Tibia shaft fragmented fracture	1	5.25
Tibia shaft+talus+calcaneus+metatarsal fracture	1	5.25

Table 2. Comparisons of the groups in respect of post-traumatic stress disorder, phantom limb pain, and return to work

	n	%	n	%	p*
Phantom Limb Pain					
Present	1	10	9	90	0.010
Absent	15	60	10	40	
Post-Traumatic Stress Disorder					
Present	3	23.1	10	76.9	0.039
Absent	13	59.1	9	40.9	
Return to Work Status					
Yes	5	55.6	4	44.4	0.700
No	11	42.3	15	57.7	

Chi-square test.

Table 3. Comparisons of phantom limb pain and post-traumatic stress disorder according to the interval between presentation at the clinic and the late below-knee amputation

	Interval between presentation at the clinic and the late below-knee amputation				
	<10 Days		≥10 Days		p*
	n	%	n	%	
Phantom Limb Pain					
Present	4	44	5	56	0.033
Absent	–	–	10	100	
Post-Traumatic Stress Disorder					
Present	4	40	6	60	0.087
Absent	–	–	9	100	

*Chi-square test.

Table 4. Comparisons of post-traumatic stress disorder, phantom limb pain, and return to work according to the number of debridements

	Number of Debridements ≤4		Number of Debridements ≥5		
	n	%	n	%	p*
Phantom Limb Pain					
Present	1	11.1	8	88.9	0.474
Absent	-	-	10	100	
Post-Traumatic Stress Disorder					
Present	1	10	9	90	0.330
Absent	-	-	9	100	
Return to Work					
Yes	-	-	4	100-	0.596
No	1	6.7	14	93.3	

*Chi-square test.

in the EA group and 10 (77%) in the LA group (p=0.039). In the LA group, 15 (57.7%) patients were unable to return to work, whereas 11 (42.3%) patients in the EA group faced similar challenges. Despite the higher incidence in the LA group, the difference did not attain statistical significance (p=0.700) (Table 2).

In the LA group, PLP was present in 4 patients (44%) who had a time interval of less than 10 days between injury and amputation, and in 5 patients (56%) with a time interval of more than 10 days. The difference between these subgroups was found to be statistically significant (p=0.033). PTSD was identified in 4 patients (40%) with a time interval of less than 10 days between injury and amputation, and in 6 patients (60%) with a time interval exceeding 10 days. Nevertheless, no statistically significant difference was discerned between the subgroups concerning PTSD (p=0.087) (Table 3). The patients were also evaluated regarding the impact of the number of debridement surgeries preceding the amputation on the presence of PLP, presence of PTSD, and return to work. Those who had fewer than 5 debridement procedures and those who had 5 or more debridement procedures did not differ significantly (Table 4).

DISCUSSION

Injuries leading to limb loss can result in significant functional deficits and psychological issues, particularly in young patients with high physical activity levels and expectations. Advances in prosthetic technology, structured rehabilitation processes, and psychological support programs aimed at improving body image and facilitating societal reintegration can partially restore losses. However, the ultimate outcome depends on various patient-specific factors. The most important factors influencing amputation outcomes are patient age and other demographics. Additionally, cosmetic appearance, localized stump pain or presence of phantom pain, level of disability, social support, and the patient's coping mechanisms with post-amputation challenges are also important factors affecting the outcomes.[8] Therefore, while extremity-preserving surgery might seem preferable, especially in younger patients, repeated surgeries for this purpose can impose additional burdens on the patient. Moreover, if the limb-sparing approach fails, the subsequent amputation surgery may potentially have a higher rate of complications. In this study, we aimed to explore the impact of the duration between firearm-induced lower extremity injury and subsequent amputation on the development of PLP, PTSD, and the ability to return to work.

An important parameter explored in this study was the correlation between the time to amputation and the incidence of PLP, in which patients experience painful sensations arising from the absent limb. After amputation, the burning, tingling pain felt in the missing limb was first described as "phantom limb pain" by the French military surgeon Ambroise Paré. Various studies have reported an incidence of phantom pain in up to 85% of amputees. Furthermore, approximately half of the patients continue to experience pain within five years post-amputation.[9]

Just as with other chronic pain disorders, the reasons for PLP are complex and the condition is affected by a complex interplay of somatic, psychological, and social factors.[10] Although the etiopathology of phantom pain is not fully understood, it is believed to involve peripheral, spinal, and cortical mechanisms. Specifically, maladaptive reorganization of the region in the cerebral cortex that represents the amputated limb, sensitization of the peripheral and central nervous systems, and loss of inhibition play significant roles in the pathophysiology.[11,12] Recent evidence, supported by functional neuroimaging studies, indicates the presence of aberrant peripheral signals that are amplified as a result of central reorganization.[13]

A key finding of our study is that a delay in the duration between initial injury and amputation exceeding 10 days was associated with a significant increase in PLP frequency, possibly attributed to prolonged inflammatory processes at the injury site. Studies conducted with animal models have demonstrated that nociceptor activation, triggered by soft tissue and nerve damage, initiates inflammatory processes that lead to persistent pain.[14-16] The inflammatory process and intense stimulation of nociceptors induced by severe trauma cause changes in higher-order neurons that carry pain signals. Subsequently, peripheral neural sensitization and central synaptic plasticity contribute to the development of issues such as neuroma pain, residual limb pain, and phantom sensation/pain.[17] The remodeling of the peripheral and central nervous systems is also related to the intensity and duration of nociceptor activation. Therefore, limb-salvaging approaches that do not remove the inflammatory focus, additional tissue damage caused by repeated surgical interventions, or infections arising during the treatment process prolong the nociceptor-activating inflammatory process. When these interventions fail and amputation is ultimately performed, a strong foundation for the development of phantom pain may be established.[17] Some prospective studies have shown that the severity of pain before amputation increases the risk of developing phantom pain, particularly within the first two years post-amputation.[18,19] The increase in pain severity due to additional surgeries performed during the period leading up to the final amputation may also explain the higher incidence of phantom pain in the LA group. However, no significant correlation was discerned between the number of pre-amputation surgeries and phantom pain development.

Patients in the EA group exhibited a comparatively lower incidence of PLP, suggesting a potential benefit associated with expedited surgical intervention. When it is considered that the MESS values were similar in both groups, it can be concluded that late amputation is more likely to yield to PLP.

In our study, it was found that patients who underwent late amputation developed PTSD more frequently compared to those who underwent early amputation. The relationship we

established between the timing of amputation and the development of PTSD has been demonstrated in previous studies as well. The Military Extremity Trauma Amputation/Limb Salvage (METALS) Study reported that 38.3% of military personnel who underwent amputation or limb salvage surgery following severe lower extremity injury developed depressive symptoms, and 17.9% developed PTSD. It was found that patients who underwent amputation had a lower incidence of developing PTSD.[20] Melcer et al. reported that patients who underwent early amputation following severe lower extremity combat injuries experienced lower rates of PTSD, substance abuse, and mood disorders in the short and medium terms compared to those who underwent late amputation or successfully underwent limb salvage surgery.[21,22] However, they defined the distinction between early and late amputation as within 90 days post-trauma, whereas we made the distinction based on whether the amputation was performed at the battlefield hospital at the first encounter or later at our center. A possible reason for the decreased incidence of PTSD when amputation is performed straightforwardly could be that the more predictable clinical and rehabilitation course follows amputation surgery; however, in the limb salvage approach, the uncertainty and the longer adaptation process, along with additional complications, might challenge the patient's physical and mental resilience. Additionally, previous cross-sectional studies have indicated that the presence of anxiety and depression may be predictors for the development of phantom pain.[23] The higher prevalence of PTSD in the LA group observed in this study may partly elucidate the increased PLP frequency within this cohort.

Several limitations warrant consideration, primarily the retrospective design and the variability in surgical techniques employed across different surgeons. Moreover, the relatively short follow-up duration and the lack of standardized rehabilitation and psychological support programs represent limitations. Finally, a larger number of patients in the early and the late amputation groups is needed to confirm our comparative results. As far as we know, our study is the first to investigate the relationship between the time elapsed until amputation following lower extremity injuries due to firearm explosions and the occurrence of PLP and PTSD. The confirmation of our results in larger patient groups and longer follow-up periods could assist clinicians in selecting the optimal treatment when deciding between limb-sparing surgery and early amputation options during initial evaluation, highlighting the potential for higher rates of various complications associated with delayed amputation.

The most important finding of this study is that the time from initial trauma to amputation is an important factor increasing the likelihood of PTSD or PLP development, and this should be taken into consideration when making the decision about extremity-protective surgery. Despite the critical role of amputation as a life-saving intervention following trauma, it significantly impacts physical capabilities, social integration, confidence levels, psychosocial dynamics, and occupational opportunities. Patient responses to limb loss are multifaceted, with some experiencing functional, social, and psychological challenges, while others adapt following a period of adjustment.

CONCLUSION

In conclusion, our findings highlight significantly reduced frequencies of PLP and PTSD development with early BKA, emphasizing the therapeutic benefits of early amputation in cases of severe lower extremity injuries. The adverse outcomes associated with delayed amputations, particularly beyond 10 days post-trauma, underline the importance of informed decision-making regarding extremity salvage surgery and necessitating comprehensive patient education on the potential drawbacks of delayed amputation.

Ethics Committee Approval: This study was approved by the Gülhane Training and Research Hospital Ethics Committee (Date: 19.03.2024, Decision No: 2024-159).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Ateşli silah yaralanmasına bağlı erken ve gecikmiş alt ekstremite amputasyonları: Minimum 2 yıllık takip

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AMAÇ: Ateşli silah yaralanmaları gibi yüksek enerjili yaralanmalar, alt ekstremitelerde aşırı yumuşak doku ve kemik kaybına neden olabilir.Bu tür yaralanmalarda öncelikli olarak ekstremitenin korunması hedeflense de,ekstremitenin kurtarılması ve fonksiyonun restorasyonu için tekrarlanan cerrahi işlemler hastaya hem fiziksel hem de psikolojik açıdan zarar verici sonuçlar doğurabilmektedir.Çalışmanın temel amacı ateşli silah yaralanması sonrası erken dönemde alt ekstremite amputasyonu yapılan hastaların fiziksel ve psikolojik bulguları ile geç dönemde amputasyon yapılan hastaların sonuçlarının değerlendirilmesidir. Ayrıca geç diz altı amputasyon uygulanan hastalarda prognozu etkileyen faktörleri de değerlendirilmiştir.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmaya Mart 2017 ile Mart 2022 tarihleri arasında ateşli silahlara bağlı alt ekstremite yaralanması sonrası diz altı amputasyon uygulanan hastalar dahil edildi. Yaralanmanın hemen ardından götürüldükleri ilk merkezde acil diz altı amputasyon uygulanan hastalar erken amputasyon grubunu oluşturdu.Başka bir merkezde yapılan ilk müdahalenin ardından tedavilerinin devamı için üçüncü basamak sevk merkezimize nakledilen ve daha sonra diz altı amputasyon uygulanan hastalar geç amputasyon grubunu oluşturdu. Hastalar yaş, cinsiyet, amputasyon tarafı, fantom uzuv ağrısı varlığı ve travma sonrası stres bozukluğu açısından değerlendirildi.

BULGULAR: Toplam 35 hastanın bilgileri hastane kayıtlarından elde edildi; Erken amputasyon grubunda 16, Geç amputasyon grubunda ise 19. Hastaların tamamı erkekti. Yaralanma anında ortalama yaş 25.5±5.3 yıl (aralık, 20-45 yıl) ve ortalama takip süresi 37±17 ay (aralık, 25-72 ay) idi. Yaşanan fantom uzuv ağrısı karşılaştırıldığında gruplar arasındaki fark istatistiksel olarak anlamlıydı; Erken amputasyon grubunda 1 (%10) hastanın, Geç amputasyon grubunda ise 9 (%90) hastanın fantom uzuv ağrısı yaşadığı görüldü (p=0.010). Erken amputasyon grubunda 3 (%23) hastada, Geç amputasyon grubunda ise 10 (%77) hastada Travma sonrası stres bozukluğu tanısı konuldu (p=0.039).

SONUÇ: Geç diz altı amputasyon uygulanan hastaların Fantom uzuv ağrısı ve Travma sonrası stres bozukluğundan daha yüksek oranda etkilendikleri belirlendi. Alt ekstremitede ciddi açık yaralanması olan hastalarda ekstremite koruyucu cerrahiye karar verirken geç diz altı amputasyon ile ilişkili kötü sonuçların dikkate alınması çok önemlidir. Hastalar bu olumsuz sonuçlar konusunda iyice bilgilendirilmelidir.

Anahtar sözcükler: Ateşli silah yaralanması; amputasyon; fantom uzuv ağrısı; travma sonrası stres bozukluğu.

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