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Effect of Combination of Temporary Vascular Shunt and Prophylactic Fasciotomy on Limb Salvage after Lower Extremity Arterial Injuries among Yemeni Patients with War-Related Polytrauma

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ABSTRACT

Context and Aim: *In cases of severe lower extremity arterial injuries (LEAI), such as those resulting from combat-related injuries, the preservation of the affected limb is a significant challenge. The combination of a temporary vascular shunt (TVS) and prophylactic fasciotomy (PF) has emerged as a potential approach to improving limb salvage outcomes in these cases. In the context of the war in Yemen, we aimed to assess the effect of combination TVS and PF on limb salvage after LEAI in patients with war-related polytrauma (WRPT).*

Patients and Methods*: A retrospective study was conducted among patients with WRPT at Al Hazm Hospital in Al Jawf Governorate in northeastern Yemen. Cases identified as polytrauma with LEAI in which PF was used comprise the study. These cases were matched to patients, or a control group, injured during the same period having polytrauma with LEAI requiring major vascular intervention but managed without fasciotomy. The primary outcome was surgical amputation.*

Results*: Inclusion criteria were met in 39 cases, 18 (46.2%) had undergone fasciotomy, while the other 21 (53.8%) did not. Both study groups were entirely young (mean age 26.32 ± 5.01 years) males (100%). The overall amputation rate was 17.9% (7 of 39 cases), with 6 (28.57%) cases in the non-fasciotomy group and 1 (5.55%) case in the fasciotomy group. The difference in amputation rate was not statistically significant (p-value, 0.071). Likewise, the mechanism of injury, clinical findings on admission, arterial injuries, and types of surgical procedures were similar in both groups. By contrast, the fasciotomy group had a lower rate of limb infection than their non-fasciotomy counterpart (38.1% vs. 5.6%, respectively). The mortality rate in the hospital was 5.1% (2 of 39 cases), and all of them did not undergo fasciotomies.*

Conclusion*: The combination of TVS and PF was associated with significantly improved limb infection. While statistically unproven, this combination may also enhance limb salvage. Therefore, it should be performed in cases of WRPT.*

Keywords

Fasciotomy, Temporary Vascular Shunt, Military Trauma, Arterial Injury, War, Yemen.

Introduction

For military troops and citizens alike, war has terrible effects. Around 10% of war-related injuries have vascular lesions, with extremity injuries making up 75% of this total [1]. Estimates place the prevalence of LEAI among trauma patients between 1 and 4% [2-4]. Depending on the conflict, 9-13% of wounded cases in military practice experience vascular injury to the extremities, which is often caused by repeated perforating limb wounds from explosive devices [4,5]. Traumatic vascular injury, which frequently occurs during times of conflict and causes bleeding and ischemia, may affect the arteries and veins of the limbs [6]. Arterial injuries may also be accompanied by osseous, nerve, vein, and soft tissue injuries [7]. In addition, the injured are likely to become disabled or perhaps die if they are not given the right care [8].

Ideally, war-related injuries should be managed by surgeons with military surgery experience. As a matter of fact, civilian surgeons may find themselves trapped in wars practicing military surgery without any previous expertise or training in this field [3]. TVS has emerged as a potential intervention to mitigate the adverse effects of arterial injury and improve patient outcomes. This intervention involves the placement of a temporary shunt to restore blood flow to the injured extremity until a definitive repair can be performed [9]. TVS has gained attention due to its potential to minimize ischemic time, reduce limb loss, and improve overall patient survival rates [10]. While TVS can be beneficial in certain situations, there are also some disadvantages associated with this technique, such as shunt thrombosis, infection, and distal embolization. Additionally, CS remains the Achilles' heel of TVS [7,11,12].

In the surgical management of military LEAI, early fasciotomy performed prophylactically to prevent the development of limb- or life-threatening CS is considered a crucial factor [13-19]. However, in patients with polytrauma, the problem of CS is still an issue. Delayed fasciotomy is a major risk factor for poor outcomes in patients with CS. For every hour that fasciotomy is delayed, the risk of muscle necrosis increases by 10% [20,21]. This is especially concerning for patients with polytrauma, who are often at high risk for CS and may be delayed in receiving surgery for a variety of reasons. One reason is that patients with polytrauma may have other life-threatening injuries that require immediate attention, such as abdominal bleeding or airway compromise (chest trauma). This can delay surgery for vascular repair, even if the patient is at high risk. Another reason is that these patients are often in shock, which can make it difficult to accurately assess the severity of their injuries and their risk for CS. Additionally, these patients may be transferred to different hospitals, or they may need to wait for specialized surgeons to become available. This can also lead to delays in surgery.

Yemen is witnessing a war as a result of a complex and ongoing conflict that began in 2014. The war involves multiple parties and has had a devastating impact on the country and its people [22]. This war has also had a significant impact on the healthcare system in the country and has resulted in a high number of casualties [23,24], including LEAI. Al Jawf Governorate holds strategic importance due to its location and proximity to the Saudi Arabian border. This governorate has been significantly affected by the war, and it has been the site of heavy fighting. It has witnessed military operations and airstrikes by various parties involved in the conflict. These operations have resulted in civilian casualties, damage to infrastructure, and the destruction of public facilities. In the context of the war in Yemen, LEAIs are most commonly caused by blast injuries and gunshot wounds. To date and to the best of our knowledge, there is no study published assessing the role of combination TVS and PF on limb salvage after LEAI in patients with WRPT in Yemen. Therefore, in this study, we compared the fasciotomy and non-fasciotomy groups to analyze the effect of fasciotomy as a previous intervention for limb salvage after LEAI in patients with WRPT in Yemen.

Patients and Methods

Study Design and Patients

A retrospective study was conducted at Al Hazm Hospital in Al Jawf Governorate in northeastern Yemen. All of the injured had polytrauma with a LEAI. Only cases with LEAI associated with other injuries that threat the life of the patient and were categorized as battle-related were included. Cases who sustained a LEAI in the setting of an immediate or traumatic (i.e., primary) amputation were excluded. Cases were classified as having undergone fasciotomy or not. Dates of injury were February 2020 through March 2022, and cases identified as polytrauma with a LEAI in which PF was used comprised the study. These cases were matched to patients, or a control group, injured during the same period having polytrauma with a LEAI requiring major vascular intervention but managed without fasciotomy (non-fasciotomy group).

Data Collection

From the medical files and clinical records of the hospital, cases and controls were reviewed, annotating demographics, features of injuries, presence of venous injury, ligation or repair of venous injury, hemodynamic status, ischemic time, surgical management of LEAI, and follow-up data regarding limb complications and outcomes, including wound infection, rate of amputation, and mortality. Subsequent data, including limb salvage, annotated complications, time of limb loss/complication, as well as the specific reason for the amputation, were recorded. Failure of limb salvage, amputation, or mortality was the primary endpoint evaluated.

Surgical Management and Outcome

First, all our cases had a previous intervention with TVS at the battle site or in the hospital. Additionally, all of them had a previous intervention at the battle site, including compression, tourniquet, or ligation/clampage, and were then admitted to the hospital. Cases were evaluated in the emergency services. The evaluation of the arterial injury was mostly undertaken by physical examination. Indications for vascular surgical intervention were defined as follows: signs of leg ischemia, reduced or absent distal pulse, arterial bleeding, expanding hematoma, pulsatile hematoma, and the presence of a thrill/murmur. The exposure of interest was lower extremity fasciotomy performed after the initial vascular limb salvage procedure, with follow-up for non-fasciotomy extremities beginning on completion of the limb salvage procedure. The operative exploration of our cases differed. When it came to bullet-related injuries, exploration was carried out according to standard arterial exposure. PF was performed due to two main factors. First, the presence of a LEAI in combination with another life-threatening injury to the patient, as a life-threatening injury to the patient takes additional time that could affect limb salvage. Another factor was the high-energy nature of the injuries in our cases, as they were WRPT. After hemodynamic stabilization and wound decontamination in cases of severe tissue loss due to explosive devices, an exploration was performed to expose and repair the vascular structure as soon as possible. After completing the treatment of the accompanying and life-threatening injury as well as improving the condition of the patient, arterial restoration and repair were carried out. With the exception of extensive muscle and soft tissue damage, systemic heparinization was carried out. To remove any thrombus, proximally and distally, Fogarty catheters were frequently utilized. Primary repair or end-to-end anastomosis was preferred, but where it was not possible, the greater saphenous vein of an uninjured leg was used for an interposition graft. Polypropylene sutures were used for anastomosis. Concomitant vein injuries were repaired whenever possible. All cases with associated orthopedic injuries underwent reduction of bone fracture and immobilization by external fixation only. After surgical intervention, the decision for secondary amputation was made in the event of a weak or faint pulse, an existing massive infection, massive soft tissue loss, coldness of the extremity, or other life-threatening condition. Limb-related complications were defined as limb ischemia after the development of CS, foot drop, a documented soft tissue infection, a documented soft tissue necrosis, or amputation. Limb salvage was defined as the maintenance of a viable limb with adequate perfusion. The primary outcome was surgical amputation. The secondary outcome was limb complications.

Statistical Analysis

We first stratified cases into two analytic cohorts based on whether they had undergone fasciotomy or not. We performed all statistical analysis without regard to the matching between the fasciotomy and control groups because the matched sets were not identified. We expressed qualitative data as frequencies and percentages. A Shapiro-Wilk test confirmed that all continuous variables were normally distributed. Accordingly, we summarized continuously distributed variables by means and standard deviations (SD). We compared the fasciotomy and control groups with the Chi square test or Fisher's exact test as appropriate. We used the Student's t-test to compare continuous variables among both groups of the study. All statistical testing was two-sided with a significance level of 5%, and we used the Statistical Package for Social Science Analysis (SPSS, Inc., Chicago, Illinois, USA) version 28.0 throughout.

Results

Ninety-one cases of WRPT were transferred to our center. Forty-four cases without injuries threatening the life, as well as eight cases in which primary amputation had been performed, were excluded from final analysis. Therefore, the study's inclusion criteria were met in 39 cases. Table 1 represents the frequencies and percentages of previous interventions on admission among the studied cases. The distribution of cases according to the compression, TVS, tourniquet, and ligation/clampage groups was 24 (61%), 6 (15.3%), 5 (12.8%), and 4 (10.2%), respectively.

Table 1: Distribution of previous interventions on admission among studied cases (n= 39).

Previous interventions	Frequency (%)
Compression	24 (61)
TVS	6 (15.3)
Tourniquet	5 (12.8)
Ligation/Clampage	4 (10.2)

Table 2 clearly demonstrates the distribution of injuries' locations among the studied cases. The majority of injuries, 46.15% (n = 18), were lower extremity fractures, followed by abdomen and pelvic injuries (n = 11, 28.20%), chest injuries (n = 7, 17.94%), and head and neck injuries (n = 3, 7.69%).

Table 2: Distribution of the location of injuries among studied cases (n = 39).

Location of injury	Frequency (%)
Head and neck	3 (7.69)
Chest	7 (17.94)
Abdomen and pelvic	11 (28.20)
Lower extremities fractures	18 (46.15)

Thirty-nine cases were divided into two groups: those in which fasciotomy was performed prophylactically on admission (fasciotomy group, n = 18) and those in which fasciotomy was not performed (n = 21) (Table 3). Both study groups were entirely young (mean age 26.32 ± 5.01 years) males (100%). In comparing demographic characteristics, the fasciotomy group was significantly older (p-value, 0.024). By contrast, the mechanism of injury was similar in both groups. Similarly, all clinical findings on admission (mean hematocrit level and mean systolic blood pressure (SBP)), as well as the incidence of concomitant vein injury, bone fracture, major soft tissue disruption, nerve injury, mean mangled extremity severity score, mean duration of ischemia, associated bone injury, and foot drop due to initial injury, were similar in both groups. The overall amputation rate was 17.94%. There was a total of 7 amputations, with 6 (28.6%) in the non-fasciotomy group and 1 (5.6%) in the fasciotomy group. The difference in amputation rate was not statistically significant; however, limb infection was significantly lower in the fasciotomy group than their non-fasciotomy counterpart (38.1% vs. 5.6%, respectively; p-value,

Table 3: Demographics, injuries' characteristics, and outcomes among studied cases (n = 39).

	Overall (n= 39)	Non-fasciotomy group (n=21)	Fasciotomy group (n=18)	P-value
Age, mean (SD)	26.32 (5.0)	24.5 (3.8)	28.33 (5.5)	**0.024***
Male gender, n (%)	39 (100)	21 (53.9)	18 (46.1)	
Mechanism of injury, n (%)				
Gunshot	19 (48.7)	9 (42.9)	11 (61.1)	0.256
Explosive	20 (51.3)	12 (57.1)	7 (38.9)	
Clinical findings on admission				
Hematocrit %, mean (SD)	29.12 (4.24)	29.8 (3.63)	28.7 (4.5)	0.792
SBP (mmHg), mean (SD)	92.47 (9.1)	94.9 (9.2)	91.6 (8.8)	0.532
Injured vascular structure, n (%)				
Arterial	25 (64.10)	13 (61.9)	12 (66.7)	0.757
Arterial and vein	14 (35.90)	8 (38.1)	6 (33.3)	
Bone fracture, n (%)	18 (46.2)	10 (47.6)	8 (44.4)	0.843
Major soft tissue disruption, n (%)	9 (23.1)	5 (23.8)	4 (22.2)	0.605
Major nerve injury, n (%)	6 (15.4)	4 (19.0)	2 (11.1)	0.410
Mangled extremity severity score, mean (SD)	7.17 (1.75)	6.45 (1.67)	7.44 (1.82)	0.207
Duration of ischemia, hours, mean (SD)	5.37 (1.91)	5.95 (1.92)	4.84 (1.84)	0.157
Associated bone injury, n (%)	18 (46.2)	10 (47.6)	8 (44.4)	0.843
Wound infection, n (%)	9 (23.1)	8 (38.1)	1 (5.6)	**0.019***
Foot drop, n (%)	6 (15.4)	4 (19.0)	2 (11.1)	0.410
Amputation, n (%)	7 (17.9)	6 (28.6)	1 (5.6)	0.071
Mortality, n (%)	2 (5.1)	2 (9.5)	0 (0)	0.283

* Significant difference (p-value < 0.05)

Table 4: Distributions of arterial injuries and types of surgical interventions among studied cases (n= 39).

	Overall (n= 39)	Non-fasciotomy group (n=21)	Fasciotomy group (n=18)	P-value
Artery injured, n (%)				
Femoral arteries and SFA	19 (48.7)	10 (47.6)	9 (50.0)	0.882
Popliteal artery	12 (30.8)	4 (22.2)	8 (38.1)	0.236
Crural arteries	12 (30.8)	7 (38.9)	5 (23.8)	0.252
Arterial procedure, n (%)				
End to end anastomosis	12 (30.8)	8 (38.1)	4 (22.2)	0.236
Saphenous vein interposition	15 (38.5)	8 (38.1)	7 (38.9)	0.959
Primary rapier	8 (20.5)	4 (19.0)	4 (22.2)	0.558
Autogenous plasty of an artery defect	4 (10.3)	3 (14.3)	1 (5.6)	0.364
Vein injuries, n (%)				
Vein repair	7 (17.9)	3 (14.3)	4 (22.2)	0.153

(a) (b) (c) (d)

Figure 1: The etiologies of the amputation: (a). Graft thrombosis; (b). Ischemia reperfusion; (c). concomitant injuries; and (d) massive soft tissue loss in the lower limb.

0.019). The mortality rate in the hospital was 5.12% (n = 2), and all of them did not undergo fasciotomies.

Distributions of arterial injuries and types of surgical procedures were described in Table 4. In comparison, there were no differences between the two groups.

The etiologies of the amputation were shunt or graft thrombosis in 3 (42.8%) cases (Figure 1a), ischemia reperfusion in 2 (28.5%) cases (Figure 1b), concomitant injuries in 1 (14.3%) case (Figure 1c), and massive soft tissue loss in 1 (14.3%) case (Figure 1d).

Discussion

The management of war-related arterial injuries is complex and challenging due to the high-energy nature of the injuries, often-severe concomitant injuries, and the limited resources that may be available in a combat setting [1,25-29]. The combination of a TVS and PF has emerged as a potential approach to improving limb salvage outcomes in cases of severe LEAIs, such as those resulting from trauma or combat-related injuries. During the war in Yemen, we encountered these types of injuries frequently. In fact, the preservation of the affected limb is a significant challenge in these cases.

The hospital where the injured individuals are treated is located in Al Hazm, Al Jawf Governorate, in northeastern Yemen, along the border with Saudi Arabia. The hospital lacks advanced technical facilities and is just a secondary healthcare center, which creates certain constraints and challenges, particularly in diagnoses. Doppler ultrasonography and computed tomography angiography, the gold standard for diagnosis, were infrequently employed; instead, physical examinations were the primary means of making diagnoses [30].

Before the wars in Iraq and Afghanistan, the majority of war-related injuries were caused by gunshot wounds. However, after that, it became clear that powerful, lethal weapons that were developed in tandem with technological breakthroughs were now responsible for most of these injuries [26]. High-power and destructive weapons play a significant role in the complexity of war-related LEAIs. These weapons are designed to increase the number and energy of casing fragments, leading to multiple penetrating wounds [31]. This is why vascular injuries are often associated with multiple trauma, leading to high mortality unless prompt and appropriate surgical management is made. Preventing amputation is mostly dependent on an expeditious initial intervention. In all our cases, local medical teams have conducted the initial patient interventions in regions close to the various war areas. After medical or surgical intervention, the injured were transferred and brought to our healthcare facility by a military ambulance team. In this study, we compared fasciotomy and non-fasciotomy groups to analyze the effect of PF after LEAI in cases with polytrauma. Both study groups were entirely young (mean age 26 years) males (100%).

A number of studies have demonstrated the benefits of PF in cases with LEAI. For example, a 2012 review of the National Trauma Data Bank found that PF was associated with a decreased risk of amputation in cases with LEAI [18]. The optimal timing of fasciotomy after LEAI is a matter of debate. However, most experts agree that fasciotomies should be performed as soon as possible after injury, ideally within 6 hours. This is because the risk of muscle necrosis and other complications increases with time. In our cases, the rate of amputation in the fasciotomy group was lower than that in the non-fasciotomy group (5.55% vs. 28.57%, respectively); however, this difference did not achieve statistical significance. In cases of LEAI, such as severe fractures or crush injuries, there is a risk of increased pressure within the affected compartment. This increased pressure can compromise blood flow to the muscles and nerves, leading to tissue damage and potentially limb-threatening complications. Performing PF can help alleviate this pressure and restore blood flow to the affected area. By releasing the constricting fascia, fasciotomies can prevent or minimize tissue ischemia and reduce the risk of complications such as muscle necrosis, nerve damage, and limb loss [18]. However, a number of reports indicated that greater limb injury complexity was associated with fasciotomy [19,21]. It is important to note that fasciotomies are not without risks. They are invasive procedures that carry the potential for complications such as infection, bleeding, and wound healing problems. Therefore, the decision to perform a PF should be carefully considered by a multidisciplinary team of healthcare professionals, including vascular surgeons, orthopedic surgeons, and trauma specialists.

We have reported that limb infection was significantly lower in the fasciotomy group than their non-fasciotomy counterpart. Our findings are contrary to those of Kauvar et al. [19]. The reason for the limb infection rate not being higher in the fasciotomy group in our cases is likely attributed to a number of reasons. First, PF reduces the amount of time that the tissues are deprived of oxygen and nutrients, which makes them less susceptible to infection. Second, PF relieves pressure on the tissues, which can also help reduce the risk of infection. Third, PF allows for better drainage of fluids and pus from the wound, which can also help to prevent infection. Fourth, PF involves the removal of dead or necrotic tissue, which can serve as a breeding ground for bacteria. By removing this tissue promptly, the risk of infection is significantly reduced. Fifth, PF allows for thorough cleaning and irrigation of the wound, reducing the bacterial load present in the injured area. This helps prevent the growth and spread of bacteria, minimizing the risk of infection. Finally, PF may also help to improve the blood supply to the wound, which can also help to reduce the risk of infection. In addition to these factors, PF may also help to reduce the risk of wound infection through several other mechanisms, such as reducing the risk of CS. CS can lead to tissue death and infection [17,20]. Other mechanisms include reducing the need for further surgery, which can also increase the risk of infection, and allowing for earlier wound closure, which can also help reduce the risk of infection. While PF is an effective way to reduce the risk of wound infection in cases with war-related LEAIs, it is important to note that it is not a guarantee. There are a number of other factors that can contribute to wound infection, such as the severity of the injury, the patient's overall health, the timely administration of antibiotics, and the type of bacteria present in the wound. The procedure can be complex and time-consuming, and there is a risk of bleeding, infection, and nerve damage. However, the benefits of PF generally outweigh the risks [18]. Proper postoperative care, including infection prevention measures, is still necessary to ensure optimal outcomes.

Limitations

Our study has several limitations that should be considered when interpreting its findings. First, given that our study was based on a single secondary healthcare center's experience, widespread extrapolation may be limited. Additionally, we studied only cases with WRPT, which limits the generalizability of our findings. Second, wound infection is not specific to the lower limbs and may include abdominal wounds that may have been used to gain proximal control during intraoperative management of extremity trauma. Third, long-term follow-up on these cases was not available. Finally, due to the retrospective design of our study and the limitations of the database, we were unable to ascertain whether the initial revascularization was successful and whether there was any delay in revascularization that may have influenced patient outcomes. Likewise, due to the inherent limitations of the database, we were unable to complete assessments regarding return to normal activities, employment, and other quality of life measures after limb salvage. Nonetheless, our observational study provides the first meaningful assessment of PF outcomes following LEAI in cases with WRPT in Yemen. More extensive and collaborative studies are required to support our findings.

Conclusion

The combination of TVS and PF was associated with significantly improved limb infection. While statistically unproven, this combination may also enhance limb salvage. Therefore, it should be performed in cases of WRPT. Larger studies to determine any other possible benefits of this combination are needed. The presence of vascular surgeons within a military surgical team is recommended. Our findings support further prospective studies to refine clinical recommendations regarding patient selection for PF in the setting of LEAI.

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Information Disclosure

First, we performed our study in accordance with the Declaration of Helsinki. Ethical review and approval were obtained from the administration and research ethics committees of the hospital. Since the data collection was based on a retrospective chart review, obtaining informed consent from participants was not necessary. However, we were careful to ensure that the data collected was de-identified and anonymized to protect the privacy and confidentiality of participants. Additionally, we collected and used only the data necessary for the study. It was important for us to use the data collected only for its intended purpose, and we adhered to relevant data protection regulations.

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