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ORIGINAL PAPER

Soft tissue coverage of war extremity injuries: the use of pedicle flap transfers in a combat support hospital

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Abstract

Purpose Definitive management of extremity injuries including soft tissue coverage is seldom achieved in battlefield medical treatment facilities due to limited resources and operational constraints. The purpose of this study was to analyse the French Army Medical Service experience performing such reconstructive surgery in a Combat Support Hospital (CSH) in Afghanistan.

Methods A clinical study was performed in the KaIA (Kabul International Airport) CSH from July 2012 to January 2013.

Results During this period 23 Afghan patients treated for soft tissue coverage of combat-related extremity injuries were included. They totalled 28 extremity injuries including 18 blast trauma (BT) and ten non blast trauma (NBT). Overall, 35 extremity pedicled flaps were performed. There were 26 fasciocutaneous flaps, eight muscle flaps and one composite flap. Soft tissue coverage was achieved on all patients reviewed with a mean follow-up of 59 days. Five postoperative complications occurred including two deep infections, one partial flap necrosis and two flap failures, without difference according to injury mechanism.

Conclusion Reconstruction of traumatic soft tissue defect can be achieved in CSHs for local nationals. Pedicle flap transfers provide simple and safe coverage for war extremity injuries in this challenging environment whatever the injury mechanism.

Keywords Afghanistan · Extremity trauma · Pedicled flap · Reconstruction · War surgery

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Introduction

During the current war in Afghanistan, widespread use of Improvised Explosive Devices (IEDs) resulted in new injury patterns with devastating wounds including high energy extremity trauma. Improvements in personal protective equipment and battlefield medical support have increased the survival rate, but reconstruction of extremity soft tissue and bone defects remains challenging, even for deployed military casualties benefiting from sequential management. Primary cares are based on Trauma Damage Control Orthopaedic (TDCO) procedures for live and limb salvage, prior to early intercontinental medical evacuation to major military hospitals for definitive treatment by multidisciplinary surgical teams with access to state-of-the-art techniques [1, 2].

Afghan military or civilian casualties also benefit from TDCO procedures in NATO (North Atlantic Treaty Organization) Medical Treatment Facilities (MTFs). Next, most of these patients are transferred to local hospitals for definitive treatment. Unfortunately, limited resources of these hospitals make complex reconstructive procedures difficult or impossible to achieve, with a high rate of secondary amputations [3–5]. That is the reason why definitive treatment of local nationals is sometimes achieved in Combat Support Hospitals (CSHs, echelon 3 MTF) which represent the highest level of medical care in Afghanistan [3, 4]. Extremity reconstructive surgery is performed on the battlefield by orthopaedic surgeons deployed at the Kabul International Airport (KaIA) CSH since 2009.

The purpose of the present study was to report soft tissue coverage using pedicled flaps performed on Afghan patients at the KaIA CSH. Demographics, mechanisms of injury, type of wounds, initial management, flap coverage and timing of reconstruction were analysed.

Methods

Patients were selected among casualties treated at the KaIA CSH between July 2012 and January 2013. Inclusion criteria were: Afghan military or civilian patients, combat-related injuries and traumatic extremity wounds requiring flap coverage. Many patients received care in Forward Surgical Teams (FSTs, echelon 2 MTF) or local hospitals prior to their admission at the KaIA CSH. Surgical procedures performed in these facilities were also analysed, except for patients referred for late reconstruction.

Patients were first treated by marginal Debridement and Irrigation (D&I), possibly repeated every two or three days until the wounds appeared clinically clean and ready for closure. Topical Negative Pressure Wound Therapy (TNPWT) was applied as often as possible before coverage. The timing of flap coverage depended on the injury severity, wound contamination and associated injuries. Three different periods were considered: early (<five days), subacute (five days–three months), and chronic period (>three months) [2]. Each reconstructive procedure was performed by two orthopaedic surgeons using local or distant pedicle flap transfers only. Coverage of massive soft tissue loss was achieved by combined pedicled flaps as described previously [6–8].

Variables for the study included age and gender of patients, mechanism and site of injury, associated fractures or neurovascular injuries, and Injury Severity Score (ISS). The severity of open diaphyseal long bone fractures were recorded based on the Gustilo classification [9]. Data collected during initial management included the number of D&I procedures, the use of TNPWT, and means of bone stabilization. Reconstructive data included the coverage timing, the type of tissue transfer (fasciocutaneous, muscle or composite) and the flap description. Postoperative complications were analysed as deep infection or partial necrosis when return to the operating theatre was needed for debridement and washout, and as flap failure when a revision coverage procedure was required [10]. Two groups were considered for analysis according to injury mechanism: Blast Trauma (BT) caused by various explosive devices and Non Blast Trauma (NBT) due to gunshots, fragments and motor vehicle crashes.

A study database was created using Excel (Microsoft, Redmond, WA). Statistical analysis for demographic data or selected variables included means and standard deviations. Median and quartiles (first and third) were calculated for ISS analysis. Dichotomous variables were compared using the Fisher's exact test, and the Student's t test was used for comparison of quantitative variables. A p value of ≤ 0.05 was considered significant.

Results

Of the 27 patients who underwent flap reconstructive procedures during the study period, 23 were included in this cohort and were reviewed with a mean follow-up of 59 days [range, 12–152 days]. There were 21 males and two females with a mean age of 25.8 years [range, six to 55 years]. Nine patients were soldiers or policemen and 14 were civilians, including four children under the age of 15 years. Almost half of the patients were injured by IEDs (Fig. 1). Among the 16 patients wounded by explosive devices, 13 sustained a real blast injury due to explosive forces and were included in the BT group. The three other patients were victims of isolated fragments, and as such were included in the NBT group.

Twenty patients were referred for recent injuries and three for late reconstructions. They totalled 28 extremity injuries: 19 patients had one injury, three patients had two injuries and one patient had three injuries. All multiple injured patients were in the BT group. The sites of injuries in order of incidence were: leg (12 cases), hand (eight cases), elbow/forearm (four cases) and ankle/foot (four cases). There were 18 open fractures (including one tibia septic non union) and ten soft tissue defects exposing tendons, joints or neurovascular structures. With the exclusion of the patients referred for late reconstruction, the median ISS was 19 [quartiles, 12–26] and seemed to be higher in the BT

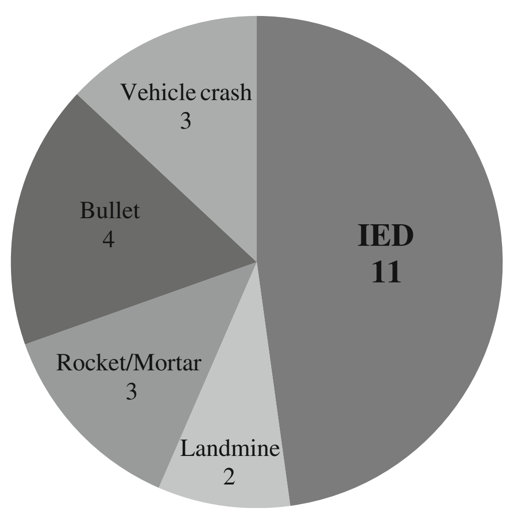

Fig. 1 Distribution of injury mechanisms

group, but with it was only a statistical trend (25 versus 16, $p=0.09$).

Prior to reconstruction, an average of three D&I procedures per injury [range, one to nine] were performed in the whole cohort. TNPWT was applied on 11 injuries for a mean duration of 6.5 days [range, two to 22 days]. Eleven of the 18 open fractures required external fixation, but splinting or K-wires were preferred for hand fractures. External fixation was also used to protect flap pedicles (Fig. 2). In five open fractures with bone loss a cement spacer was applied to prepare secondary bone reconstruction. There was no significant difference in initial management according to injury mechanism (Table 1).

Ten reconstructions were achieved in the acute period, 15 in the subacute period and three in the chronic period (late reconstruction) without difference between groups. An overall of 35 extremity flaps was performed. Eight patients underwent multiple flap reconstruction for multiple injuries or extremely large wounds requiring two simultaneous flaps for coverage (Tables 2 and 3). There were 26 fasciocutaneous flaps, eight muscle flaps, and only one composite latissimus required for both soft tissue coverage and functional reanimation of elbow flexion. Tibia coverage was mostly achieved by classic fasciocutaneous flaps at the distal third and muscle flaps at proximal levels, but two longitudinal medial skin defects were covered by local bipedicled translated flaps (Fig. 3). Most of the hand reconstructions were performed using local flaps in patients of the BT group victims of multiples fragments wounds.

At the last follow-up, soft tissue coverage was achieved in all patients with complete wound healing. Five patients had postoperative complications without difference according to injury mechanism (Tables 2 and 3). Deep infections were metacarpophalangeal arthritis and tibia osteomyelitis due to *Staphylococcus aureus* in both cases. The arthritis required iterative D&I procedures associated with antibiotics, but the osteomyelitis was managed successfully by antibiotic therapy only. A groin flap partial necrosis was caused by a technical fault (suture under tension) and was salvaged by skin grafting. Flap failures were distal partial necrosis requiring new coverage, by medial gastrocnemius flap at the proximal tibia and lateral supramalleolar flap at the distal tibia.

Table 1 Comparison of injury initial management

Parameter	BT group (18 injuries)	NBT group (10 injuries)	*P* value
D&I procedures, *n*	57	25	0.6
TNPWT, *n*	8	3	0.7
External fixation, *n*	5	6	0.3
Cement spacer, *n*	3	2	1
Days to flap, mean [range]	15 [3–46]	23 [2–81]	0.3

BT blast trauma, *NBT* non blast trauma

Discussion

Soft-tissue coverage of war extremity injuries in echelon 3 MTFs is a practice seldom analysed in the literature [3, 4, 11]. Marchaland et al. [3] reported the use of pedicled flaps to cover bone exposure of the leg in such conditions in Afghanistan and Ivory Coast. Recently, Klem et al. [4] reported the US military experience performing free flaps in a combat zone, with 21 extremity flaps performed during a 30-month period in both Iraqi and Afghan theatres. The high number of flaps performed in this six-month study can be explained by the location of the KaIA CSH in the centre of Kabul, which is responsible for a specific patient recruitment compared to other NATO CSHs. If war casualties are

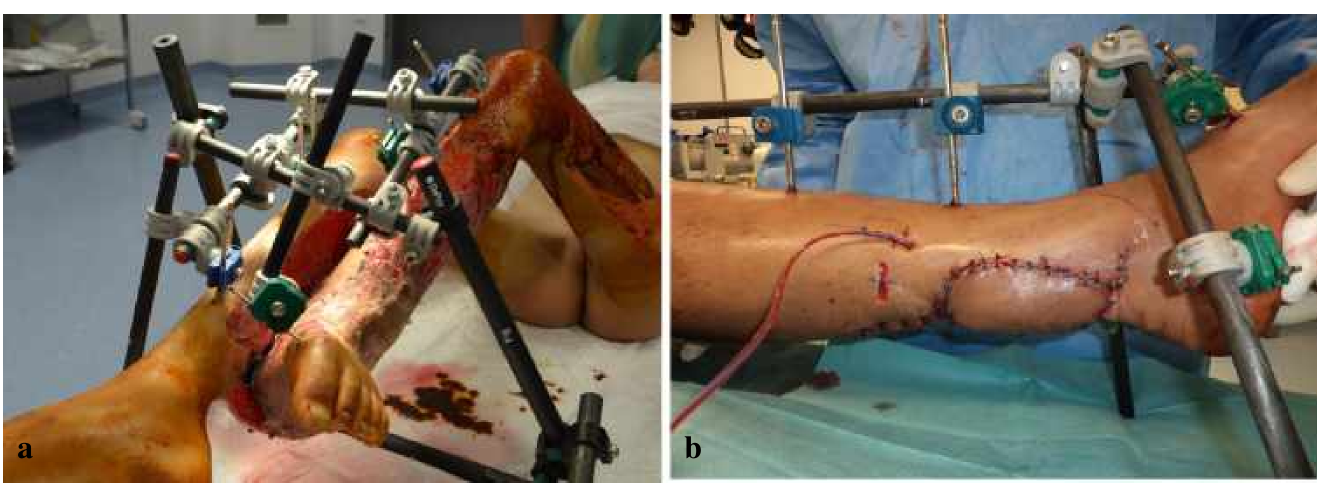

Fig. 2 Use of external fixation to protect two simultaneous cross-leg flaps in a ten-year-old girl (**a**) and to avoid pressure over an Achilles tendon coverage (**b**)

Table 2 Injury characteristics and flap reconstruction in the blast trauma (BT) group

Patient	Site of injury	Associated fracture	Associated injury	Days to flap	Flap type	Flap description	Complication
1	Leg	Tibia G3b	Patellar tendon	4	Muscle	Medial gastrocnemius	–
					Muscle	Lateral gastrocnemius	–
	Hand	–	Extensor tendon	4	Fasciocutaneous	Local rotational	Deep infection
2	Hand	–	Extensor tendon	8	Fasciocutaneous	Local translated	–
	Hand	First metacarpal	Extensor tendon	8	Fasciocutaneous	Skin island (Kite)	–
	Elbow	–	–	10	Fasciocutaneous	Radial forearm	–
3	Hand	–	Thumb finger tip loss	3	Fasciocutaneous	Reverse skin island	–
4	Forearm	Ulna shaft	Ulnar nerve	46	Fasciocutaneous	Groin	–
	Hand	Proximal phalanx	Extensor tendon	46	Fasciocutaneous	Local rotational	–
5	Hand	Proximal phalanx	Volar bundles	–	Fasciocutaneous	Local rotational	–
6	Leg	Tibia G3b	–	44	Fasciocutaneous	Local translated	–
7	Leg	–	Achilles tendon	4	Fasciocutaneous	Lateral supramalleolar	–
8	Leg	L bifocal tibia G3b	–	3	Muscle	Soleus	–
					Fasciocutaneous	Sural	–
	Leg	R bifocal tibia G3b	–	5	Muscle	Soleus	–
					Fasciocutaneous	Sural	–
9	Elbow	–	Ulnar nerve	5	Fasciocutaneous	Lateral arm	–
10	Leg	Tibia G3b	–	3	Muscle	Hemi-soleus	Flap failure
11	Leg	–	Fibular tendons	22	Fasciocutaneous	Lateral supramalleolar	–
12	Foot	Calcaneus	–	21	Fasciocutaneous	Sural	–
13	Hand	Metacarpal	Extensor tendon	21	Fasciocutaneous	Groin	Partial necrosis

G3b/3c type 3b/3c of Gustilo classification [9]

classically transferred from FSTs or directly admitted from the battlefield for initial management, Afghan patients may be referred for reconstructive surgery from low-resources medical facilities within the capital. Achieving definitive treatment of these patients, requiring serial surgical procedures and extended hospitalization, is always challenging in a CSH with limited resources and operational constraints [3]. In this cohort, all extremity flap transfers were performed by orthopaedic surgeons trained in reconstructive surgery because of the lack of a plastic surgeon at the KaIA CSH. Flap coverage

Table 3 Injury characteristics and flap reconstruction in the non blast trauma (NBT) group

Patient	Site of injury	Associated fracture	Associated injury	Days to flap	Flap type	Flap description	Complication
1	Elbow	Humerus G3c	Brachial artery Flexor muscles	81	Composite	Latissimus	–
2	Foot	–	–	–	Fasciocutaneous	Medial plantar	–
3	Leg	Tibia G3b	–	2	Fasciocutaneous	Sural	–
					Fasciocutaneous	Local rotational	Flap failure
4	Hand	Middle phalanx	Extensor tendon	15	Fasciocutaneous	Local rotational	–
5	Ankle/foot	Malleolar	Achilles tendon	22	Fasciocutaneous	Saphenous/cross-leg	Deep infection
					Fasciocutaneous	Sural/cross-leg	–
6	Leg	–	–	2	Fasciocutaneous	Sural	–
7	Leg	Tibia septic non union	–	–	Muscle	Soleus	–
					Muscle	Tibial anterior	–
8	Leg	Tibia G3b	Bone loss	8	Muscle	Medial gastrocnemius	–
9	Leg	Infected tibia G3b	–	15	Fasciocutaneous	Local translated	–
					Fasciocutaneous	Local translated	–
10	Leg	Tibia G3a	–	42	Fasciocutaneous	Sural	–

G3b/3c type 3b/3c of Gustilo classification [9]

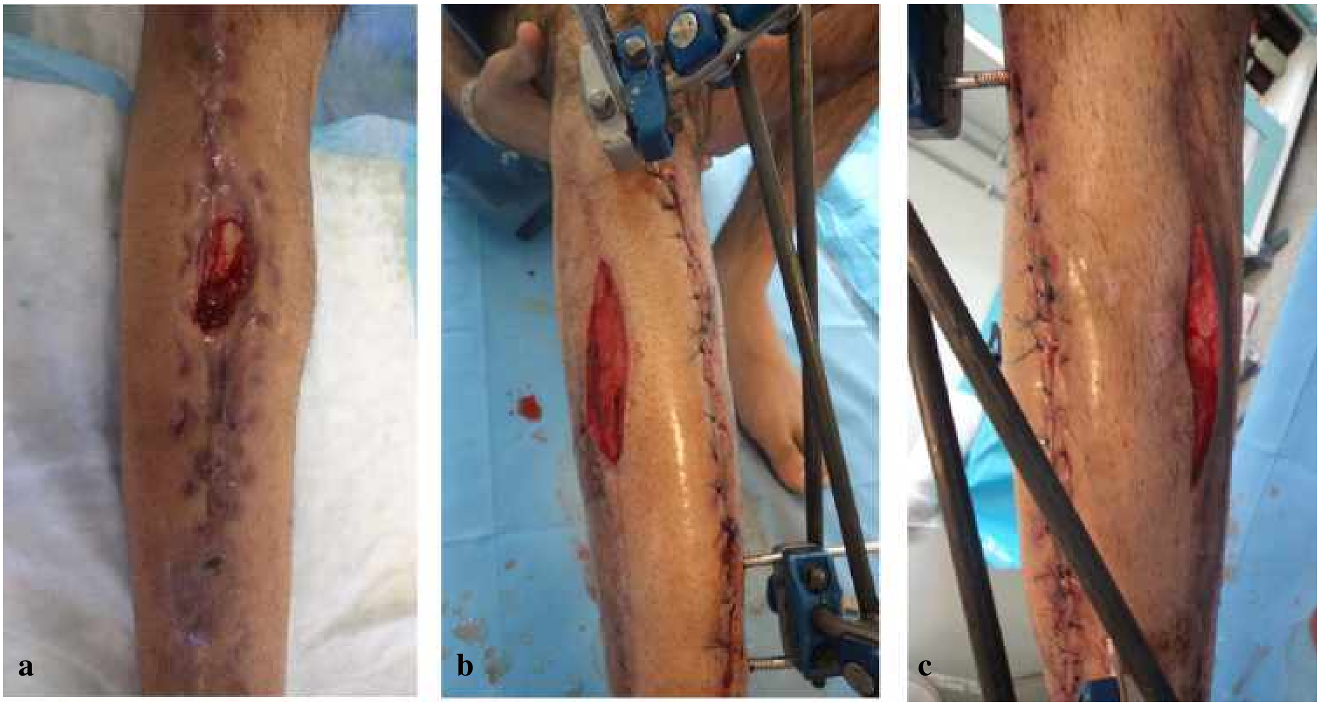

Fig. 3 Delayed coverage of an infected middle third open tibia fracture (**a**) by two simultaneous local bipedicled translated flaps: lateral (**b**) and medial (**c**)

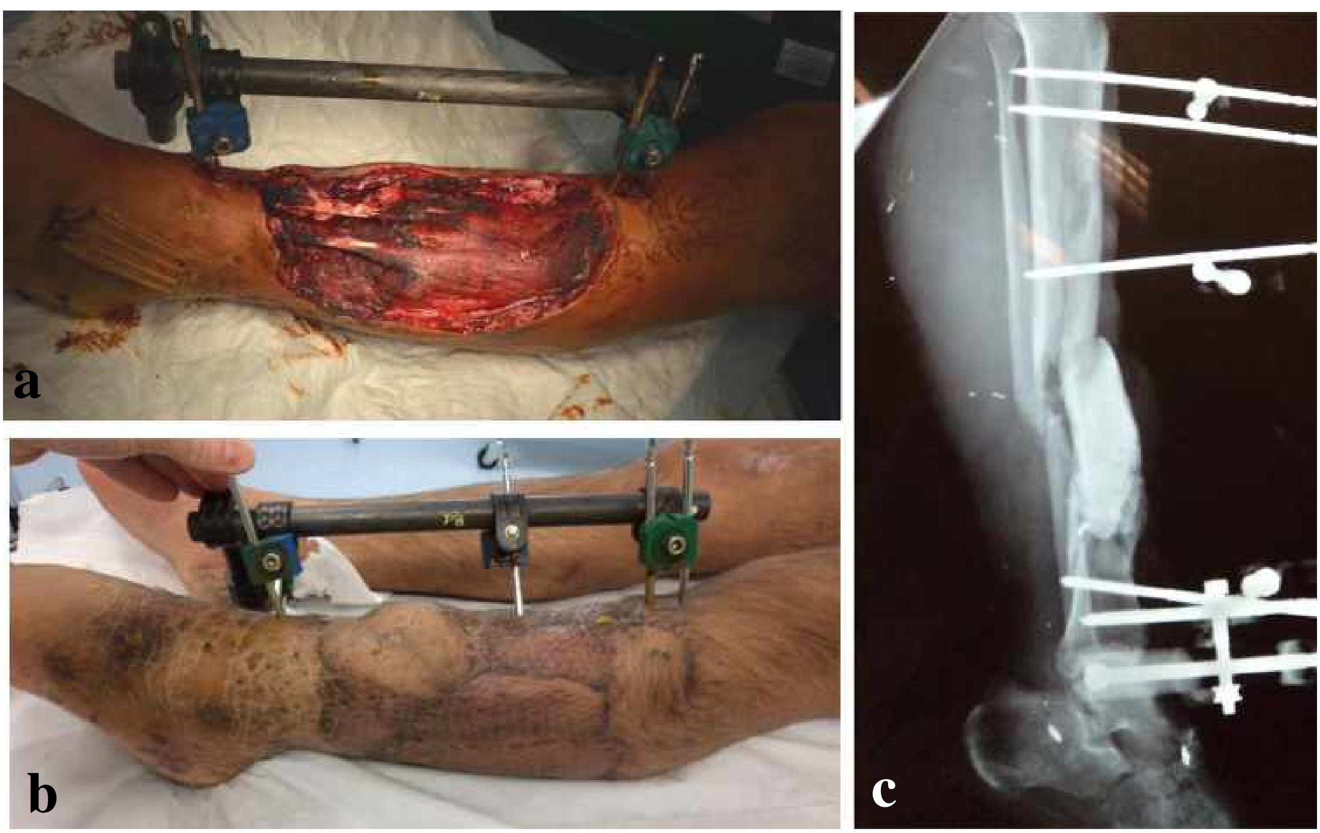

Fig. 4 Example of Gustilo 3b tibia fracture caused by 12.7-mm bullet. Aspect after initial debridement and external fixation (**a**); coverage successfully achieved by three combined pedicled flaps (**b**); however, a secondary amputation should be considered due to multi-drug resistant deep infection and massive bone defect (**c**)

could often be provided in the acute or early subacute period like in civilian practice. That way, this review is distinguishable from previous studies describing advanced reconstruction of combat wounds in occidental casualties [1, 2, 7, 10].

The goal of definitive treatment for combat-related extremity trauma is to retain or restore limb function by achievement of soft tissue healing and fracture union [10]. The first step is to obtain wound decontamination which is difficult, if not impossible, in current war wounds due to explosive devices [2]. Penetrative injuries caused by blast are often multiple and highly contaminated by inclusion of fragments or debris embedded deeply into soft tissues beyond the level of impact. Furthermore, micro-anatomic structures of the surrounding tissues may be broken by the pressure wave which compromises soft tissue coverage [11]. Destruction of perforators or distant island of necrotic tissue may limit the local pedicle flaps use, and microscopic vessels trauma far from the "zone of injury" may lead to thrombosis of microvascular anastomoses in free flaps [10, 11]. Finally, systemic failures in multiple-injured patients also contribute to local ischemia of the traumatized tissues and delay the timing of reconstruction after management in the intensive care unit (ICU).

Ideal management with early debridement and coverage within five or seven days could be achieved in ten patients [12, 13]. With the exclusion of the late reconstructions, the average time for coverage was 17.8 days for both groups. Despite the absence of intercontinental evacuation this time period is similar to those of studies concerning coalition casualties: 21 days for Tintle et al. [1] and 19.8 for Burns et al. [10]. Delayed reconstructions in the subacute period were mainly due to heavily contaminated wounds from IEDs requiring meticulous repeated marginal debridements preserving potentially viable surrounding tissues [4, 11, 14]. TNPWT was mostly applied in the BT group and for patients managed in the acute period [1, 2]. Conversely, indications for TNPWT were limited for patients referred secondary with wounds already infected. Late patient transfers from local hospitals and/or serious associated injuries requiring prolonged stay in ICU have also contributed to delayed soft tissue coverage.

Choice of reconstructive procedures was based on the judgement of both orthopaedic surgeons, according to their experience and available resources in terms of surgical equipment and hospitalization beds. The simplest and least morbid solution for coverage was selected to ensure an optimal outcome [1, 3, 4]. Free flaps were never chosen because of low training and expertise in free tissue transfers among surgical teams. Furthermore, free flaps require lengthy operative times which can jeopardize the operational activity of a CSH if a mass casualty situation occurs [15]. Our experience demonstrated reasonably low flap failure and infection rates with the exclusive use of pedicled flap in this particular setting, without any difference according to injury mechanism. Even in occidental reconstructive surgery units, coverage of war wounds is mostly achieved by pedicled tissue transfers [1]. Burns et al. [10] reported a lower amputation and re-operation rate for patients with combat-related type 3 open tibia fractures treated with rotational coverage compared to those treated with free flaps.

Coverage of massive soft tissue defects can also be achieved by simultaneous distant pedicled flap as an alternative to free transfers [6–8]. Tintle et al. [7] supported that distant pedicled flaps are sometimes preferable because their vascular supplies are obtained outside of the "zone of injury". Simultaneous transfers were used successfully in this cohort with both distant and local pedicled flaps. However, we caution against the use of multiple local pedicled flaps for coverage of type 3 open tibia fractures combining massive soft tissue and bone loss (Fig. 4). We agree with Pollack at al. [16] that the use of local rotational flaps in severe lower extremity trauma may lead to high failure rates due to unrealized large zones of injury involving the rotated tissue. Multiple local flap coverage may be a salvage procedure, but with a high risk of infective complication and secondary septic non union whose treatment is particularly challenging in deteriorating settings. Early amputation should be considered in these situations, especially in cases of postoperative infection or flap complication [3, 17, 18].

Conclusion

Despite limitations including absence of functional outcome and bone healing assessment, the present study demonstrates that soft tissue coverage of combat-related extremity injuries can be easily performed for local casualties in a CSH. Pedicle flap transfers provide simple and safe coverage in this challenging context whatever the injury mechanism.

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Conflict of interest The authors declare that they have no conflict of interest.

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