European Journal of Trauma and Emergency Surgery
https://doi.org/10.1007/s00068-021-01828-4

ORIGINAL ARTICLE

Prolonged tactical tourniquet application for extremity combat injuries during war against terrorism in the Sahelian strip

Alexandre Sabate-Ferris[1] · Georges Pfister[1] · Guillaume Boddaert[2,3] · Jean-Louis Daban[4] · Stéphane de Rudnicki[4] · Alexandre Caubere[5] · Thomas Demoures[6] · Stéphane Travers[7,3] · Fréderic Rongieras[8,3] · Laurent Mathieu[1,3]

Received: 31 August 2021 / Accepted: 1 November 2021

Abstract

Purpose This study reports on complications following extended tourniquet application in patients with combat extremity injuries treated by the French Military Health Service in the Sahelian strip.

Methods A retrospective review was performed in a French forward medical treatment facility deployed in Gao, Mali, between 2015 and 2020. All patients treated for an extremity injury with the application of at least one tourniquet for a minimum of 3 h were included. Prehospital data were injury pattern, associated shock, tourniquet location, and duration. Subsequent complications and surgical procedures performed were analyzed.

Results Eleven patients with a mean age of 27.4 years (range 21–35 years) were included. They represented 39% of all patients in whom a tourniquet was applied. They had gunshot wounds ($n=7$) or multiple blast injuries ($n=4$) and totaled 14 extremity injuries requiring tourniquet application. The median ISS was 13 (interquartile range: 13). Tourniquets were mostly applied proximally on the limb for a mean duration of 268 min (range 180–360 min). Rhabdomyolysis was present in all cases. The damage control surgeries included debridement, external fixation, vascular repair, and primary amputation. Ten injuries were complicated by compartment syndrome requiring leg or thigh fasciotomy in the field or after repatriation. Two severely injured patients died of their wounds, but the others had a favorable outcome even though secondary amputation was sometimes required.

Conclusions Extended and proximal tourniquet applications led to significant morbidity related to compartment syndrome and rhabdomyolysis. Hemorrhagic shock, mass casualty incident, and tactical constraints often precluded revising the temporary tourniquet applied under fire.

Keywords Compartment syndrome · Improvised explosive device · Gunshot · Military · Rhabdomyolysis · Tourniquet

Background

The widespread use of tourniquets for extremity hemorrhage and the application of early damage control resuscitation within Tactical Combat Casualty Care (TCCC) have decreased combat casualty mortality during the twenty-first century asymmetric conflicts [1–5]. US Army studies demonstrated that the use of a prehospital tourniquet was strongly associated with lifesaving in Iraq and Afghanistan and that no limbs were lost due to tourniquet use [2,

✉ Laurent Mathieu
laurent_tom2@yahoo.fr

1 Department of Orthopedic, Trauma and Reconstructive Surgery, Percy Military Hospital, Clamart, France

2 Department of Thoracic and Vascular Surgery, Percy Military Hospital, Clamart, France

3 French Military Health Service Academy, Ecole du Val-de-Grâce, Paris, France

4 Department of Anesthesiology and Intensive Care, Percy Military Hospital, Clamart, France

5 Department of Orthopedic and Trauma Surgery, Saint-Anne Military Hospital, Toulon, France

6 Department of Orthopedic and Trauma Surgery, Bégin Military Hospital, Saint-Mandé, France

7 Medical Department, Fire Brigade of Paris, Paris, France

8 Department of Orthopedic and Trauma Surgery, Edouard Herriot Hospital, Lyon, France

Published online: 14 November 2021

6, 7]. Thanks to short medical evacuation (medevac) delays in these theaters of operations, Kauvar et al. [7] reported a median tourniquet application duration of 60 min. As a result, they found that field tourniquet use could be associated with wound infection and neurologic compromise but not with limb loss.

During the current war against terrorism in the Sahel, the French Military Health Service (FMHS) faces challenging constraints that include the support of operations spread over five countries and a 5-million-square-kilometer area with an unavoidable lower concentration of helicopters and surgical capabilities than the Iraqi and Afghan conflicts [5]. In this theater, the median distance between the point of injury and Role 2 medical treatment facilities (MTFs) was 290 km, and the median time from injury to Role 2 MTFs was 130 min for alpha casualties [5]. In such a prolonged field care setting, combat medics must reassess a tourniquet for conversion to compressive dressing as soon as the tactical situation permits and, in theory, no more than 2 h after initial placement [8, 9]. However, in the Sahel, strong operational constraints, and extended forward medevacs by helicopter often lead to tourniquet use exceeding 2 h with subsequent complications [8]. It is well-established that tourniquets increase morbidity and mortality after more than 3 h of ischemia [6]. However, the occurrence of these complications after prolonged field application of military tactical tourniquets is not well studied [10–12].

This study sought to report on complications following extended tourniquet use in military patients treated by a French forward surgical team deployed in the Sahelian strip. The objectives were to analyze the context of these prolonged periods of tourniquet application and the further clinical course with the ultimate purpose of adapting battlefield medical support to this specific environment.

Patients and methods

A retrospective review was performed among patients managed in the French Role 2 MTF deployed in Gao, Mali, between 2015 and 2020 [13]. All patients treated for extremity injuries with the application of at least one tactical tourniquet for a minimum of 3 h were included. Patients in whom the tourniquet application duration was less than 3 h or those with incomplete prehospital data were excluded.

Eleven patients met the inclusion criteria during the period study (Fig. 1). They represented 39% of all patients who required prehospital tourniquet use. There were seven French servicemen and four local soldiers, all males, with a mean age of 27.4 years (range: 21–35 years). Seven presented with one or multiple gunshot wounds due to high-velocity bullets, and four were victims of improvised explosive devices (IEDs) used as roadside bombs (Table 1). They

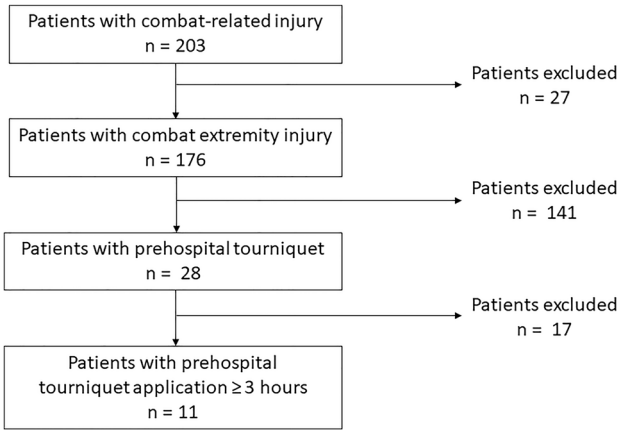

Fig. 1 Flow chart

received medical care in the field performed by a physician with a delay of less than 1 h. In all cases, the tourniquet was applied before the physician accessed the injury site, mostly by combat lifesavers, other combatants or by self-application. The physician sometimes added a second tourniquet when the bleeding was not controlled [5]. Only Combat Application Tourniquets (C-A-Ts) were used and systematically associated with a compressive dressing (Fig. 2) [10].

The baseline data and medical records were extracted from the OPEX database (FMHS) in the Gao Role 2 MTF and from the hospital electronic medical record system (Amadeus II, McKesson France) in Role 4 MTFs after the repatriation of French patients. Prehospital data were injury patterns and associated hemorrhagic shock and tourniquet location, number, and duration.

Primary treatment parameters included the presence of a shock and rhabdomyolysis and the injury severity score (ISS) at admission in the Gao Role 2 MTF. In unstable patients, the tourniquet was removed in the operating theater. The damage control surgeries performed to treat the main injury (requiring tourniquet application) and associated injuries were analyzed. In cases with acute compartment syndrome of the leg, fasciotomy was carried out using two surgical approaches (the "4 in 2" technique) or a single lateral approach (the "4 in 1" technique) depending on the surgeon's preference [14].

Definitive treatment of French soldiers was performed in Role 4 MTFs after repatriation to France by Falcon aircraft within 24 h [5, 13]. Local patients were fully managed in the field with a short-term follow-up since they were transferred early to local hospitals. Definitive treatment parameters included all secondary surgical procedures, including those to treat late complications. Only delayed skin closure or skin grafting after fasciotomy were not analyzed. Local and systemic complications were studied. Hospital and intensive care unit (ICU) lengths of stay were analyzed in

Table 1 Demographics, injury pattern, and prehospital data

Case	Age (years)	Mechanism	Injury	Hypovolemic shock	Tourniquet number	Tourniquet location	Tourniquet time (hours)
1	30	GSW	Open tibia fracture	No	2	Mid and distal thigh	4.5
2	26	IED	Open tibia fracture	No	1	Mid-thigh	4
3	35	IED	R tibia amputation	Yes	2	Prox. thigh	5
			L tibia amputation		1	Prox. thigh	5
4	21	IED	Open tibia fracture	Yes	1	Prox. thigh	4
5	30	GSW	L arm soft-tissue injury with palsy	Yes	1	Prox. arm	4
			R distal femur open fracture		2	Prox. thigh	4
6	28	IED	Proximal tibia amputation	Yes	2	Prox. thigh	4
7	22	GSW	Open femur fracture	No	1	Prox. thigh	3
8	27	GSW	Open femur fracture and arterial injury	Yes	2	Mid and distal thigh	6
9	23	GSW	Open tibia fracture	No	1	Prox. thigh	5
10	30	GSW	Leg soft tissue injury	No	1	Mid-thigh	4
11	29	GSW	R open tibia fracture	Yes	1	Prox. thigh	5
			L leg soft tissue injury	Yes	1	Prox. thigh	5

IED improvised explosive device, *GSW* gunshot wound, *L* left, *Prox.* proximal, *R* right

Fig. 2 Bleeding control for bilateral lower limb gunshot wounds using pressure dressings and three Combat Application Tourniquets (C-A-Ts) placed on the left proximal thigh

the acute period. Conversely, hospitalizations for secondary reconstructive procedures were not recorded. The final assessment focused on the main injury. Specific functional assessment was frequently difficult due to additional injuries on the same limb. Definitive management and final assessment were unknown in Case 9 because he was quickly lost to follow-up.

Results

Several patients had multiple injuries; there were 14 injuries requiring tourniquet application in this cohort: three traumatic amputations, eight open fractures, and three soft-tissue injuries. Seven patients presented with an initial hemorrhagic shock. Five injuries required two tourniquets to stop bleeding. Tourniquets were mostly applied on the proximal thigh (Table 1). The mean tourniquet application time was 268 min (range 180–360 min).

Five patients were still in shock upon their arrival in the Gao Role 2 MTF. Rhabdomyolysis was noticed in all cases. The median ISS was 13 (interquartile range: 13). The damage control procedures mostly consisted of debridement and temporary external fixation, but four amputations were carried out (Table 2). Vascular repair by veinous grafting was required in Case 8. In Case 5, arterial thrombectomy was also performed at the level of both tourniquets' application. One patient (Case 1) required an early revision with below-knee amputation because of acute ischemia related to popliteal pedicle thrombosis. Compartment syndrome occurred in 10 of the 14 injuries and required fasciotomy completion at the leg or thigh level (Fig. 3). The "4 in 1" technique was used in three patients to avoid tibia exposure. Associated procedures performed in three severe polytrauma patients are detailed in Table 2.

Upon arrival in Role 4 MTFs, a bilateral thigh fasciotomy was carried out in Case 3 after a severe compartment syndrome developed during medevac from Mali to France (Fig. 4). Secondary surgical procedures included definitive fracture stabilization, by external fixation or plating, and above-knee amputations due to extensive septic myonecrosis following late fasciotomy (Table 3). In Case 3, the transfemoral amputation had to be revised at a very proximal level upstream of the initial tourniquet site (Fig. 4). Infection

Table 2 Primary treatment parameters at the Role 2 MTF level

Case	Shock	RML	ISS	Injury treatment	Fasciotomy level and technique	Associated procedures
1	No	Yes	9	Debridement and Tibia EF → BKA	Leg (4 in 1)	–
2	No	Yes	9	Debridement and Tibia EF	Leg (4 in 2)	–
3	Yes	Yes	48	R knee disarticulation	–	Craniectomy
				L knee disarticulation	–	
4	Yes	Yes	17	Debridement and Knee spanning EF	Leg (4 in 1)	–
5	Yes	Yes	22	Brachial artery thrombectomy and Vein ligation	–	Laparotomy
				SFA thrombectomy, vein ligation and Knee spanning EF	Leg (4 in 2) and Thigh	
6	Yes	Yes	41	L knee spanning EF	–	R ankle disarticulation and R knee spanning EF
7	No	Yes	9	Debridement and Femur EF	Leg (4 in 1)	–
8	Yes	Yes	16	Debridement, femur EF, and SFA veinous grafting	Leg (4 in 2)	–
9	No	Yes	9	Debridement and Tibia EF	Leg (4 in 2) and Thigh	–
10	No	Yes	9	Debridement	Leg (4 in 2)	–
11	No	Yes	13	R BKA	Thigh	–
				L leg debridement	Leg (4 in 2)	

BKA below knee amputation, *EF* external fixation, *L* left, *R* right, *RML* rhabdomyolysis, *SFA* superficial femoral artery

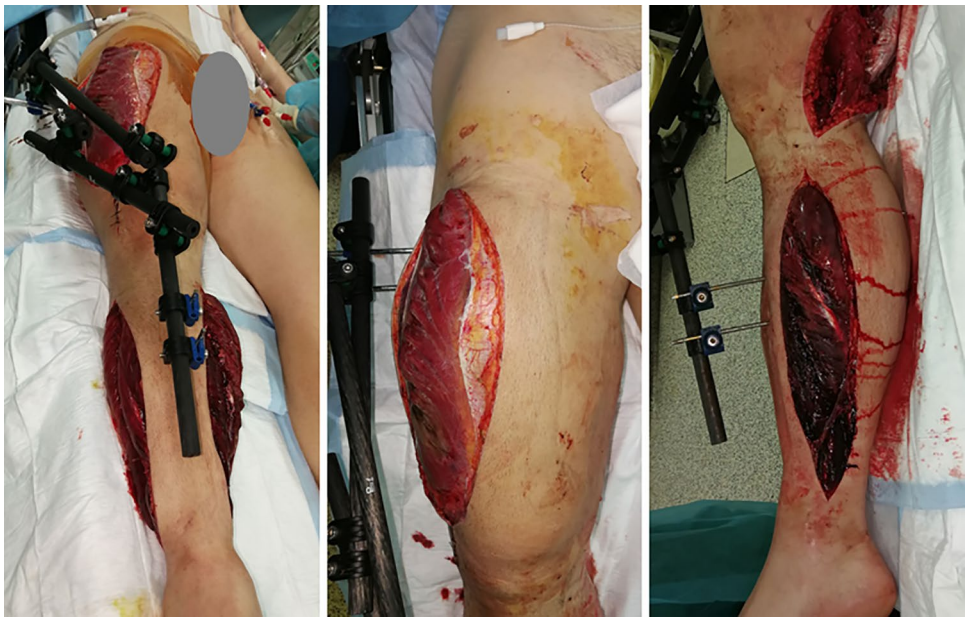

Fig. 3 Combined leg and thigh fasciotomies together with temporary external fixation in Case 5

of the primary veinous graft required revision of the femoral artery by-pass using allograft in Case 8.

The mean hospital length of stay was 40.5 days (range 8–67 days) for French patients but only 8.5 days (range 2–14 days) for local patients fully managed in the field. After repatriation, four French patients were admitted to ICU for an average of 25 days (range 8–45 days) and received ventilation therapy for a mean duration of 13 days (range 8–27 days). The three most severely injured patients (Cases 3, 5, and 6) had persistent severe rhabdomyolysis with acute renal failure for which iterative dialysis sessions were needed. Case 5 required only 24 h of continuous renal replacement therapy (CRRT), but cases 3 and 6 required intermittent hemodialysis during 18 and 2 days, followed by 4 and 6 days of CRRT, respectively. Tolerance to dialysis sessions was good is all patients. Nevertheless, the condition of two patients (Cases 3 and 6) worsened to septic shock then to multiple organ failure with a fatal outcome.

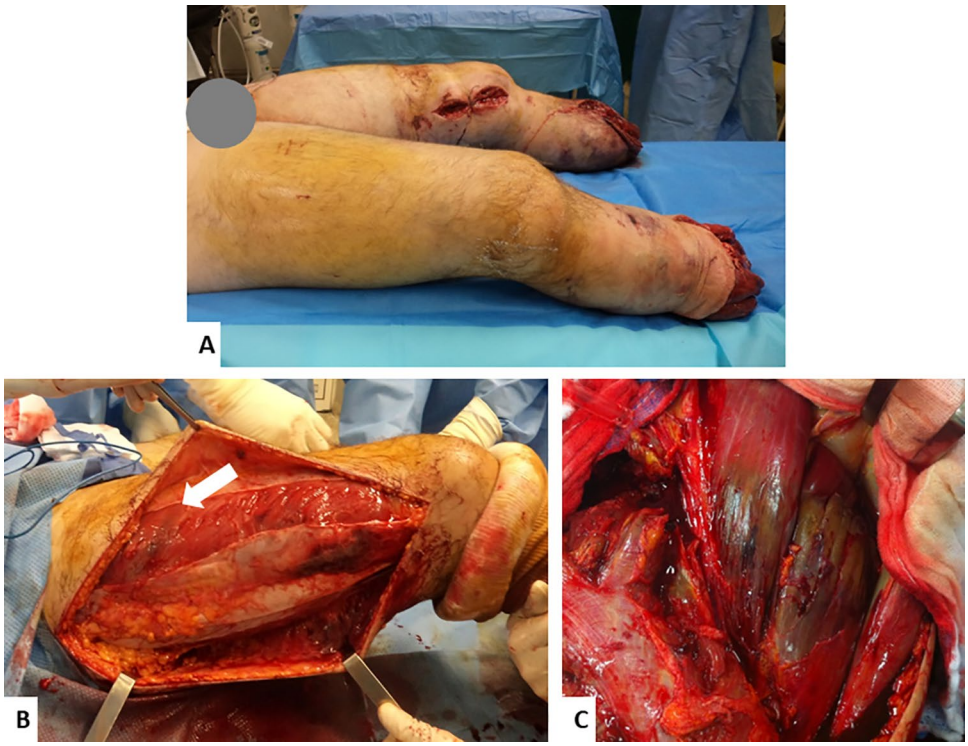

Fig. 4 Bilateral thigh compartment syndrome following proximal tourniquets application in Case 3 (**A**). Clinical aspect after fasciotomy completion: the arrow indicates muscle injury at the tourniquet site (**B**). Secondary muscle necrosis at the tourniquet site (**C**)

Table 3 Definitive treatment, complications, and final assessment at the last follow-up

Case	Surgical procedures	Local complications	Systemic complications	Last follow-up (months)	Final assessment and ongoing care
1	Stump closure	–	–	18	Prosthetic fitting
2	DPC and Definitive EF → Bone grafting	–	–	36	Bone union
3	R thigh fasciotomy → Distal AKA → Prox. AKA	Septic myonecrosis	Severe rhabdomyolysis, septic shock, MOF → Death	–	–
	L thigh fasciotomy → Distal AKA → Prox.l AKA	Septic myonecrosis		–	–
4	DPC and Tibia plating	–	–	42	Bone union
5	Neurolysis and DPC → HO excision	HO	Severe rhabdomyolysis, septic shock	21	Persistent motor deficit at the hand
	AKA → Delayed stump closure → HO excision	Septic myonecrosis, multiples HO		21	Prosthetic fitting
6	–	–	Severe rhabdomyolysis, septic shock, MOF → Death	–	–
7	DPC and Femur plating	–	–	2	Self–rehabilitation and bone healing in progress
8	DPC, definitive femur EF and SFA revision repair by allograft	Veinous graft infection	–	10	Bone union with LLD
9	NA	NA	NA	NA	NA
10	AKA	Septic myonecrosis	–	1	No prosthetic fitting
11	Stump closure	–	–	1	No prosthetic fitting
	DPC	–	–	1	Self–rehabilitation

AKA above knee amputation, *DPC* delayed primary closure, *EF* external fixation, *HO* heterotopic ossification, *L* left, *LLD* lower limb discrepancy, *MOF* multiple organ failure, *NA* not available, *Prox.* proximal, *R* right, *SFA* superficial femoral artery

Other French patients had a favorable outcome with satisfying bone union and prosthetic fitting (Table 3). Owing to the lack of long-term follow-up, functional assessment was limited in local patients (Cases 7, 9, 10, and 11) for whom physical therapy or rehabilitation was also impossible in such an austere setting.

Discussion

This review demonstrates that tourniquets continue to save lives on modern battlefields but lead to serious complications in cases of prolonged application. Prehospital challenges during the current French military operations conducted in the Sahelian strip were already studied by Travers et al. [5]. However, this is the first study dedicated to the issues related to tactical tourniquet use in this specific context. Unlike in the Iraqi and Afghan theaters, battlefield medical support in the Sahel is challenged by prolonged evacuation times with distances between the point of injury and surgical teams frequently exceeding 1000 km [5]. As a result, extended tourniquet use represents a significant part of all tactical tourniquet applications in this specific context of care. We found that the use beyond 3 h was associated with local and systemic complications threatening the limb and possibly life. The occurrence of compartment syndrome and severe rhabdomyolysis in polytraumatized patients seemed to be pejorative in this series.

TCCC is performed by nonmedical personnel (all service members or combat lifesavers) and medical personnel (combat medic or paramedic) to avoid preventable deaths on the battlefield [1, 3]. Controlling bleeding from an extremity is one of the first TCCC priorities that often requires tourniquet application [1]. Using this tactic, Brodie et al. [15] reported a survival rate of 87% in a population of 1375 wounded American soldiers engaged in Iraq and Afghanistan. Although a tourniquet is an efficient live-saving procedure on the field, improper or prolonged placement can lead to serious complications, including nerve palsy, rhabdomyolysis, limb ischemia, compartment syndrome, and tourniquet-induced reperfusion injury [11, 16]. These complications are time dependent. The time management and tourniquet placement are major issues, and regular reassessment is critical within the prolonged field care [6, 9, 12, 17]. The need for a tourniquet should always be questioned by forward medical teams considering the time to medevac to the nearest surgical unit [8]. In cases of prolonged application, it is important to keep in mind three practical questions (Fig. 5): (1) Is the tourniquet effective? (2) Is the tourniquet useful? (3) Is the tourniquet close enough to the injury (to limit unnecessary tissue ischemia)?

In this series, tourniquet application longer than 3 h was consistently associated with early complications, mostly compartment syndrome, rhabdomyolysis, and vessel thrombosis at the tourniquet site. Our findings differ from Dayan et al. [11] and Kragh et al. [18], who reported favorable

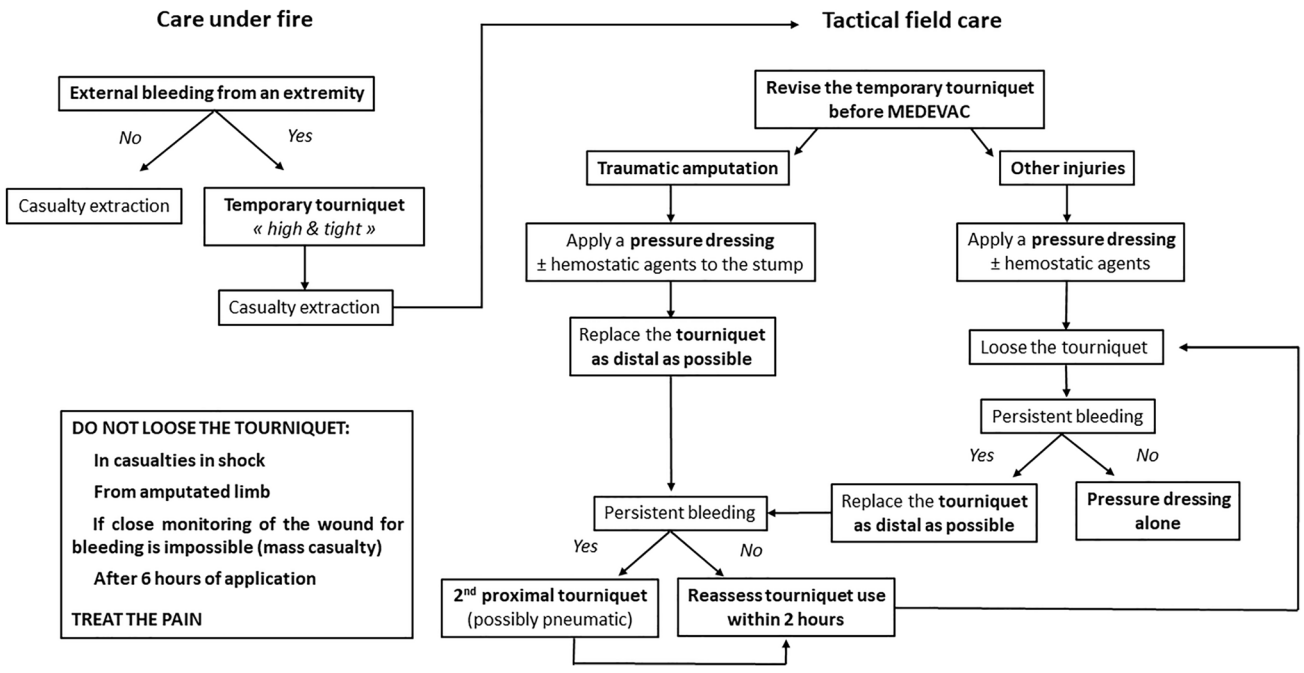

Fig. 5 Decision-making algorithm to control bleeding from an extremity in a prolonged battlefield care setting (adapted from French Military Health Service recommendations)

functional evolution after tourniquet application exceeding 12 h. The limited complications observed by these authors may be explained by improper or inefficient arterial occlusions due to the use of improvised tourniquets or by limb cooling to improve tolerance to ischemia [11, 18]. In this cohort, military tactical tourniquets were exclusively used, applied by trained personnel, and reassessed by combat medics. Considering the high incidence of complications, we can assume that most of these C-A-Ts were efficient. This was the result of the battlefield care training program developed by the FMHS for any deployed medical and nonmedical personnel (Fig. 5). Only the tourniquet placed at the arm level did not lead to a compartment syndrome, probably because of a self-application [8]. This patient had an elbow and hand palsy that was probably due to a missile nerve injury rather than the tourniquet. Similarly, leg compartment syndrome in Case 8 was more likely due to the femoral artery injury rather than to the two tourniquets that were applied as recommended as distally as possible. Because of logistical constraints and because hypothermia is part of the lethal triad, limb cooling was not an option in this cohort, where most patients present with an initial hypovolemic shock [8]. Instead, fluid resuscitation was needed to treat the shock and the rhabdomyolysis. This treatment could have increased local tissue edema and intramuscular pressure before the fasciotomy was completed [18]. Rhabdomyolysis was an important issue in this series that required early and adapted resuscitation. Early renal dialysis might have been beneficial for polytrauma patients with severe rhabdomyolysis, but it could only be performed after evacuation out of the combat zone.

Our results are in line with Travers et al. [5], who found that a total of 31 tourniquets were placed on 18 casualties during French military operations in the Sahel between 2013 and 2018. For most casualties, tourniquet removal could only be performed in a Role 2 MTF after a median time of 90 min (range 62–262 min). Rhabdomyolysis and compartment syndrome were described for 4 casualties with a tourniquet time longer than 2 h [5]. The absence of tourniquet conversion to pressure dressing in this cohort was explained by the presence of a hemorrhagic shock in most patients. Shock is, in fact, an absolute contraindication to tourniquet loosening [1, 12, 17]. Loss of consciousness in patients with head trauma (Cases 3 and 6) was also a relative contraindication in the previous edition of the French TCCC. In other patients, the tourniquet was maintained because of persistent bleeding after the loosening attempt or when close patient monitoring was impossible during tactical field care (Fig. 5). This situation was frequent after IED attacks on vehicles resulting in several casualties for whom initial management was also challenged by the risk of a second attack on the rescue team. In addition, we found that most tourniquets were applied at a proximal level, sometimes far from the injury. Extended proximal placement is questionable as several patients developed a thigh compartment syndrome following injuries at the lower leg level. Once again, hemodynamic instability, mass casualty incident and various tactical constraints explained that the temporary tourniquet placed "high and tight" above the wound under enemy fire could not be revised before medevac to forward surgical teams as recommended by the TCCC. Even though these compartment syndromes increased the morbidity of the injuries, the mortality in this cohort cannot be directly related to prolonged tourniquet use. The two patients who died of their wounds had, in fact, a very high ISS due to multiple associated blast injuries, especially to the lungs and head.

The limitations of this study first include its retrospective nature and the small cohort. Only tourniquets still applied at the patients' arrival in the Role 2 MTFs were included. Temporary tourniquets removed early in the combat zone and converted to a simple or pressure dressing were excluded. Thus, it is likely that the overall number of tourniquet applications was underestimated, and the proportion of prolonged applications was overestimated. Our analysis was then limited by the lack of precision of certain data collected during battlefield care. Finally, as mentioned above, it was sometimes impossible to distinguish between complications related to initial injuries and those related to the use of a tourniquet.

Conclusion

Prolonged tourniquet use represents a significant part of all tactical tourniquet applications within military operations conducted in the Sahel. Hemorrhagic shock, mass casualty incidents, and tactical constraints often precluded revising temporary tourniquets applied under fire. Extended proximal applications led to significant morbidity related to compartment syndrome and rhabdomyolysis.

To limit the occurrence of such complications in a prolonged field care setting, combat caregivers must remember few basic key points: (1) Temporary proximal tourniquets placed under fire save lives but must be revised at the earliest time possible before medevac; (2) Every effort should be made to convert tourniquets in less than 2 h if bleeding can be controlled by other means (knowing that hemostasis is often obtained by spontaneous vessel clotting); (3) If they are necessary, tourniquets must be applied as distally as possible; (4) Appropriate pressure dressings should be sufficient below the knee and below the elbow; 5) Close wound monitoring for bleeding is imperative after tourniquet loosening [1, 9, 12, 17]. However, it must be stressed that no patient should exsanguinate from an extremity injury because of the hesitance of a caregiver to use a tourniquet due to fear of potential complications. In cases of extended tourniquet

application, initial fluid resuscitation should consider the rhabdomyolysis, and fasciotomy of the whole limb should be considered.

These principles based on the military practice could be applied to civilian prehospital care units, in their daily practice or in disaster situations such as building collapse or terrorist attack [19, 20]. They should be taught to any caregiver working in these units or in emergency departments.

Acknowledgements The authors thank all battlefield caregivers who took part in the Barkhane operation and managed the patients featured in this study.

Declarations

Conflict of interest The authors declare that they have no conflict of interest, and no source of funding.

Ethical approval The views expressed in this paper are those of the authors and do not reflect the official policy or position of the French Military Health Service.

References

1. Tactical Combat Casualty Care And Wound Treatment. Subcourse MD0554_Edition 2000. http://www.operationalmedicine.org/Army/MD0554_200.pdf. Accessed 7 Aug 2021
2. Beekley AC, Sebesta JA, Blackbourne LH, Herbert GS, Kauvar DS, Baer DG, et al. Prehospital tourniquet use in Operation Iraqi Freedom: effect on hemorrhage control and outcomes. J Trauma. 2008; 62(2 Suppl): S28–37.
3. Eastridge BJ, Mabry RL, Seguin P, Cantrell J, Tops T, Uribe P, et al. Death on the battlefield (2001–2011): implications for the future of combat casualty care. J Trauma Acute Care Surg déc. 2012;73(6 Suppl 5):S431-437.
4. Butler FK. TCCC updates : two decades of saving lives on the battlefied: Tactical Combat Casualty Care turns 20. J Emerg Med. 2021;60(1):98–102.
5. Travers S, Carfantan C, Luft A, Aigle L, Pasquier P, Martinaud C, et al. Five years of prolongied field care : prehospital challenges during recent military operations. Transfusion. 2019;59(S2):1459–66.
6. Kragh JF, Walters TJ, Baer DG, Fox CJ, Wade CE, Salinas J, et al. Survival with emergency tourniquet use to stop bleeding in major limb trauma. Ann Surg. 2009;249(1):1–7.
7. Kauvar DS, Miller D, Walters TJ. Tourniquet use is not associated with limb loss following military lower extremity arterial trauma. J Trauma Acute Care Surg. 2018;85(3):495–9.
8. Caubère A, de Landevoisin S, Schlienger G, Demoures T. Tactical tourniquet: surgical management must be within 3 hours. Trauma Case Rep. 2019; 22:100217.
9. Drew B, Bird D, Matteucci M, Keenan S. Tourniquet conversion: a recommended approach in the prolonged field care setting. J Spec Oper Med. 2015;15(3):81–5.
10. Kragh JF Jr, Dubick MA. Bleeding control with limb tourniquet use in the wilderness setting: review of science. Wilderness Environ Med. 2017;28(2S):S25–32.
11. Dayan L, Zinmann C, Stahl S, Norman D. Complications associated with prolonged tourniquet application on the battlefield. Mil Med. 2008;173:63–6.
12. Doyles GS, Taillac PP. Tourniquets: a review of current use with proposal for expanded prehospital use. Prehosp Emerg Care. 2008; 12:241–56.
13. Hofmeister EP, Mazurek M, Ingari J. Injuries sustained to the upper extremity due to modern warfare and the evolution of care. J Hand Surg Am. 2007;32:1141–7.
14. Masquelet AC. Acute compartment syndrome of the leg: pressure measurement and fasciotomy. Orthop Traumatol Surg Res. 2010;96:913–7.
15. Brodie S, Hodgetts TJ, Ollerton J, McLeod J, Lambert P, Mahoney P. Tourniquet use in combat trauma: UK military experience. J R Army Med Corps. 2007;153:310–3.
16. Clasper JC, Brown KV, Hill P. Limb complications following prehospital tourniquet use. J R Army Med Corps. 2009;155:200–2.
17. Richey SL. Tourniquets for the control of traumatic hemorrhage: a review of the literature. World J Emerg Surg. 2007;2:28.
18. Kragh JF, Baer DG, Walters TJ. Extended (16-hour) tourniquet application after combat wounds: a case report and review of the current litterature. J Orthop Trauma. 2007;21:274–8.
19. Barnard LM, Guan S, Zarmer L, Mills B, Blackwood J, Bulger E, et al. Prehospital tourniquet use: an evaluation of community application and outcome. J Trauma Acute Care Surg. 2021;90:1040–7.
20. Borgers F, Van Boxstael S, Sabbe M. Is Tactical Combat Casualty Care in terrorist attacks suitable for civilian first responders? J Trauma Acute Care surg. 2021. https://doi.org/10.1097/TA.0000000000003337.