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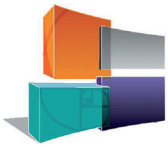

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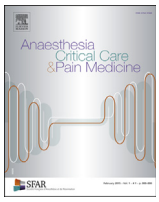

Review

Application of tourniquet in civilian trauma: Systematic review of the literature

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ABSTRACT

Introduction: The effectiveness of a tourniquet (TQ) in case of extremity haemorrhages is well recognised to prevent deaths on the battlefield. However, little is known about the usefulness of TQ in civilian trauma settings, including terrorist attack situations. The aim of this systematic review was to analyse the evidence-based medical literature in order to precise the use of TQ in the management of extremity haemorrhages in civilian setting.
Methods: Analysis of all studies published until 12/31/2016 on the Embase, Medline and Opengrey databases. To be included, studies had to contain descriptions, discussions or experiences of TQ application in civilian setting. The quality of the studies was evaluated using the PRISMA and the STROBE criteria.
Results: Of the 380 studies identified, 24 were included. The overall level of evidence was low. Three thousand and twenty eight TQ placements were reported. Most of them concerned the Combat Application Tourniquet CAT. Haemorrhages implied in the use of TQ were almost exclusively traumatic, most of the time regarding young men (27–44 years old). Effectiveness rates of TQ varied between 78% and 100%. Complications rates associated with the use of TQ remained low, even when used in elderlies or patients with comorbidities. Finally, caregivers reported a common fear of adverse effects, while reported complications were rare (< 2%).
Conclusion: This systematic review revealed TQ to be an effective tool for the management of extremity haemorrhages in civilian trauma, associated with few complications. Larger studies and dedicated training courses are needed to improve the use of TQ in the civilian standards of care.

1. Introduction

Both the Tactical Combat Casualty Care (TCCC) and the French Sauvetage au Combat (SC) rules aim to improve the survivability of combat casualties [1,2]. In their two guidelines, tactical tourniquet (TQ) is a cornerstone for the control of extremity haemorrhage, which is a major cause of preventable death on the battlefield [3]. Following the introduction of individual TQs in the US military,

Abbreviations: CAT®, Combat Application Tourniquet; EMS, Emergency Medical Services; GRADE, Grades of Recommendations, Assessment, Development and Evaluation acting group; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; SAMU, Service d'aide médicale d'urgence; STROBE, Strengthening the Reporting of Observational Studies in Epidemiology; TCCC, Tactical Combat casualty Care; TECC, Tactical Emergency Casualty Care; TQ, Tourniquet.

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between 2005 and 2007, the number of combat-related deaths from extremity haemorrhage decreased drastically by 85%, from 23.5 to 3.5 deaths per year [1]. Furthermore, patients with TQs did not present more complications and require more amputations than patients without TQs. Further studies by Kragh et al. showed an improvement in survival rate when TQs were placed early in the wounded, i.e. before the shock [2–4]. Civilian trauma may differ from military trauma, regarding the difference in implied mechanisms of injury, and the absence of combat environment. Moreover, it is supposed to be easier and faster to evacuate a casualty to the hospital in a civilian area than in a combat zone. However, in the worldwide context of terrorist attacks, civilian prehospital medical teams have to deal with situations which are similar to those encountered by military medical teams on the battlefield [5–8]. In addition, medical interventions in austere and wild environments may have common characteristics with combat trauma management [8,9]. Recommendations on Tactical Emergency Casualty Care (TECC) or Tactical Rescue were developed [10]. They are based on the TCCC guidelines and include some military medical equipment such as TQs or haemostatic agents. The terrorist attacks in Madrid in 2004, London in 2005 and 2017, Boston in 2013 and Paris in 2015, exposed the civilian area to real war conditions. The mechanisms of injury were similar as those faced by soldiers on the battlefield and most of the time included explosive devices, or gunshot wounds. In France, after the terrorist attacks in Paris of 2015, both military and civilian emergency medical services such as the Paris Fire Brigade Medical Emergency Department and the SAMU (Service d'aide médicale d'urgence) decided to improve the equipment of the rescue teams and prehospital medical teams for control of haemorrhages. Inspired by the French Military Medical Service experience in theatres of military operations, they completed the current equipment with a dedicated kit "Haemorrhage in Exceptional Situations". This kit includes TQs and haemostatic dressing [5,6]. Both the European and American guidelines for the management of traumatic haemorrhage in civilian settings endorse the pre-hospital use of TQ in the event of threatening extremity haemorrhage [9,10]. In France, first aid courses were recently modified [11]. Citizens may now be trained for control of extremity haemorrhages, including the use of TQ. Medical literature is large regarding the use of TQ in combat setting. However, similar evidence for TQ experience in the civilian setting remains unclear regarding its use rate, circumstances, benefits and complications. The aim of this study was to conduct a systematic review of the medical literature for the use of TQ in civilian setting, with special insights on its benefits and complications.

2. Methods

2.1. Search strategy

We performed a systematic literature search on PubMed and the Cochrane Database of Systematic Reviews and Embase with no regard to publication date in the past, until the 31 December 2016. First, medical subject headings terms were combined with non-indexed relevant search. Second, a systematic search of the grey literature was conducted using the Opengrey database, over the same period (Table 1). Moreover, the references from included papers were also checked for additional material not found on the original search.

2.2. Selection criteria

For the inclusion criteria, the manuscripts had to contain descriptions, discussions or experiences of TQ application in civilian settings. Articles had to be written in English or French, published before December 31st 2016. Case reports and narrative reviews were excluded. Two reviewers screened the titles of identified literature independently. Literature clearly not complying with the inclusion criteria was excluded. Abstract reading, and then full text reading of the uncertain papers, assessed their eligibility. Included articles had to be accepted by the two reviewers. In case of divergent opinions on an article, the opinion of a third reviewer was requested. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses [PRISMA] guideline was followed [12].

Table 1
Selection criteria in the different databases.

Embase (Ovid)	"Military"/exp OR military AND ("tourniquet"/exp OR tourniquet) AND civilian NOT [31–12–2016]/sd Civilian AND ("tourniquet"/exp OR tourniquet) AND ("trauma"/exp OR trauma) NOT [31–12–2016]/sd
Pubmed (Medline)	Military (MeSH) AND civilian (All Fields) AND tourniquet (MeSH) AND trauma(MeSH) Prehospital AND tourniquet (MeSH) AND civilian (All Fields) Tourniquet (MeSH) AND civilian (All Fields)
Opengrey	Tourniquet AND prehospital
Cochrane Database	Tourniquet AND prehospital

2.3. Data extraction and quality appraisal

Data extraction focused on identifying common themes in the articles. Quality was appraised using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies, and the Grades of Recommendations, Assessment, Development and Evaluation acting group (GRADE) were used to assess the level of evidence [13,14].

3. Results

3.1. Identification

The original search included 380 studies, of which 182 duplicates were excluded. Among the 198 studies identified, 84 were selected based on the title and 26 on the abstract. Finally, 24 articles were selected for inclusion in the analysis after full text reading (Fig. 1).

3.2. Quality appraisal

Studies designs included retrospective observational studies ($n = 18$), surveys ($n = 5$), and an analysis of online protocols ($n = 1$). Most of the manuscripts were from the USA ($n = 22$), another one from Canada and the last one from France. According to the GRADE recommendations, level of evidence of the included studies was low or very low because of their observational design and their small effectives. Using the STROBE criteria for quality appraisal revealed that none of the studies were constructed and reported with respect to all design aspects of an observational study (Fig. 2, Table 2): the 24 selected studies reached an average score of 15.6 points, out of 22 evaluation points.

3.3. Data extraction

Of the 24 studies, two were published before 2010: one in 2005 and another one in 2008 [15,16]; the 22 remaining studies were published between January 2013 and September 2016. The studies describe 3028 TQ placements, and a total 1761 people were questioned about TQ use.

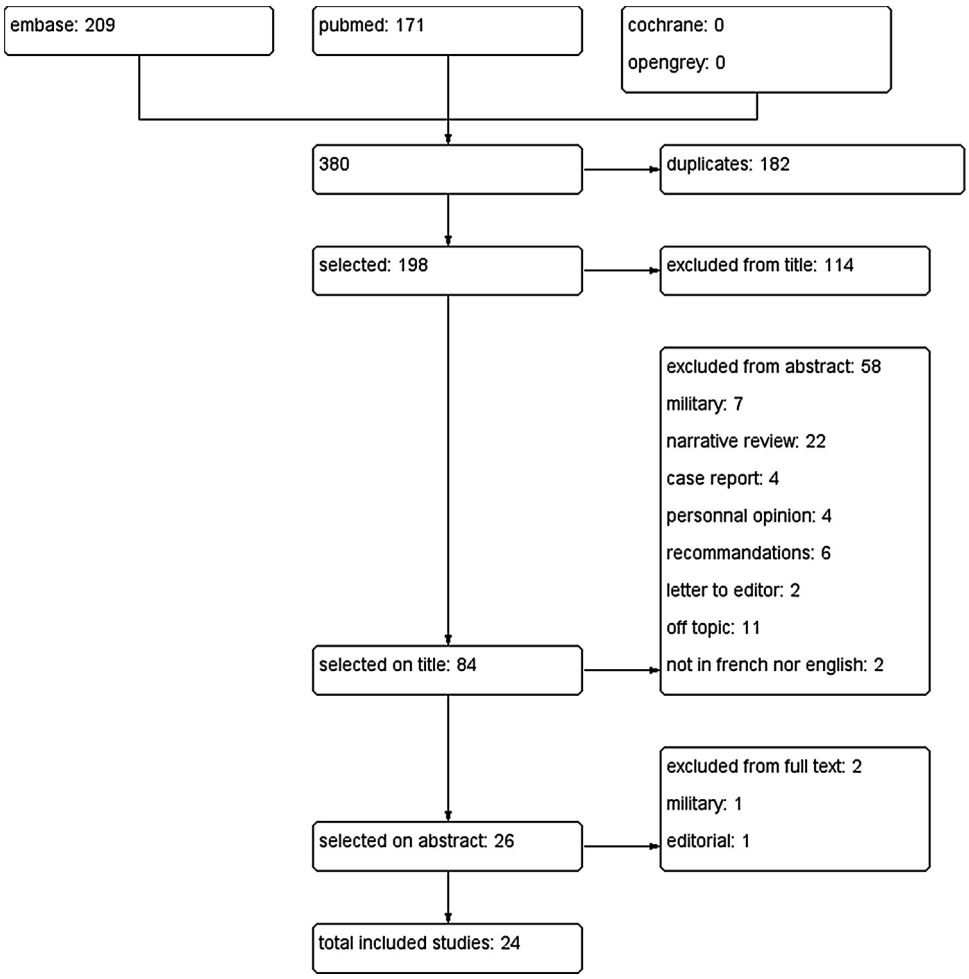

Fig. 1. Flow diagram of the systematic review.

3.4. Population

Patients who received a TQ were mostly men. Two studies including few patients (11 and 8 patients, respectively) involved only male population [15,17]. In their study about the victims of the Boston Marathon bombings, King et al. included the cases of 56 men, representing 37% of all the patients in the study [18]. In the other studies, the percentage of male population varied between 73% (59/81) for Sanko et al. and 90% (78/87) for Inaba et al. [8,9,21–32]. The mean age of the patients included in the studies analysed varied between 27 years old (no SD available) and 44 ± 21 years old. Only four studies provided information about extremity ages of the patients or their comorbidities [19,23,24,32] (Table 3). Finally, the 24 articles poorly described the comorbidities of casualties.

3.5. Injury mechanisms

In the 24 analysed articles, the mechanisms of injury requiring TQs were either traumatic or medical (Fig. 3, Table 4). Injuries were the most frequent reason of TQ application, involving blunt trauma (fall, road accident, work accident) and penetrating trauma (stabbing, shooting, or lacerations). Following blunt and penetrating traumas, medical issues were the third major reason for TQ application in the civilian setting. They concerned arteriovenous fistula haemorrhage or rupture of haemorrhagic varicose veins. Some reasons of TQ placement remained unspecified in four studies.

3.6. Types of TQ

Only 12 studies described the type of TQ used, which were of four main types: commercial TQs (similar to those used in military setting); pneumatic TQs, elastic TQs and improvised TQs [17–28]. Of the 12 retrospective studies, nine reported the preferential use of commercial TQs. The Combat Application Tourniquet (CAT® Resources, LLC, 483 Lakeshore Pkwy, Rock Hill, South Carolina, United States) was used in seven of the 12 studies (58%) [19–24,28]. Its use varied from 68% (59/87) for Inaba et al. to 100% for Zietlow et al. (n = 73), Scerbo et al. (n = 105), Leonard et al. (n = 61), Sanko et al. (n = 81) and Callaway et al. (n = 4). Only Dubose et al. described the preferred use of other TQs in 38% (18/47) of the cases, compared to CAT®, used in only 31% (15/47) of the cases. The study by Schroll et al. did not distinguish the different types of TQs used. Five studies reported the use of improvised TQs [17,18,20,21,27]. The study by Kue et al., about the Boston marathon bombings, was the only one that reported the use of an elastic TQ. At last, Passos et al. and Inaba et al. described the use of pneumatic TQs placed in the hospital setting (emergency room or operating room).

3.7. Implementation of the TQ

Several studies described the use of TQ by non-medical providers [18,20,22,24,26,28,30]. Callaway et al. reported four cases, in which law enforcement officers placed TQs before arrival

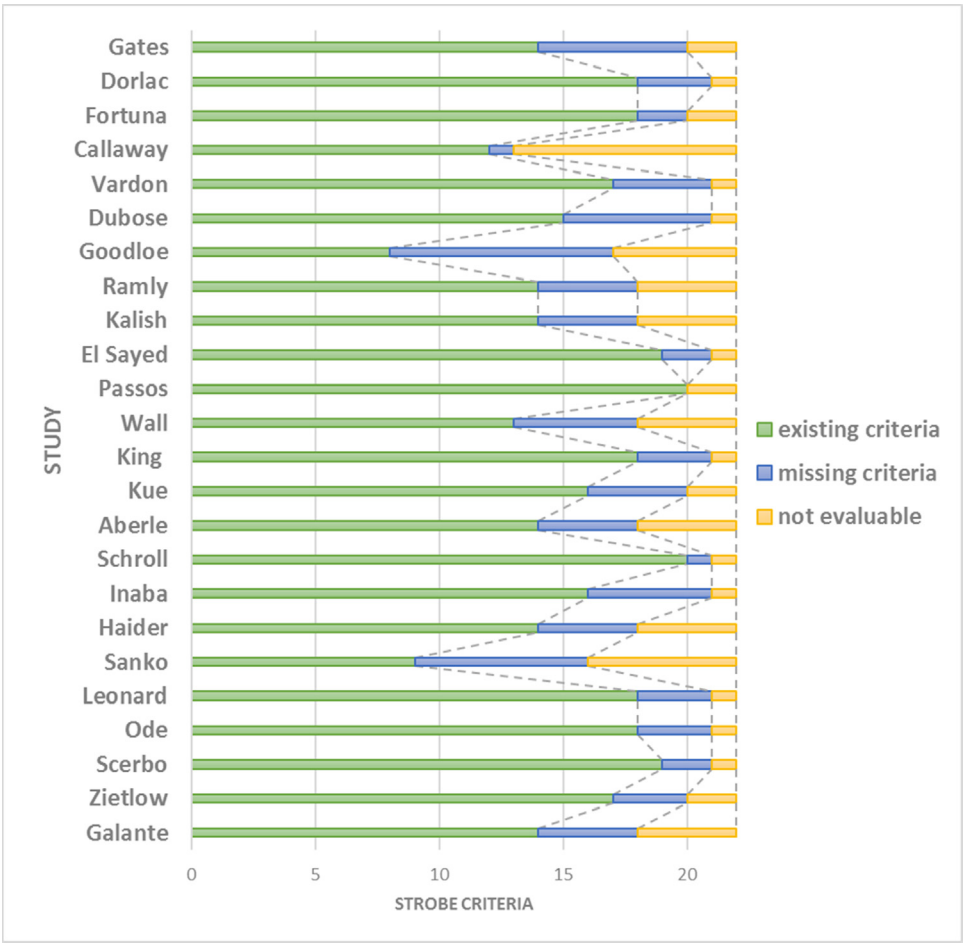

Fig. 2. Quality appraisal of the studies, using STROBE criteria.

of medical teams [28]. Among the TQs placed during the Boston bombings identified in the studies of King et al. and Gates et al., the majority of TQs, 17/27 (62%) and 21/26 (81%) respectively, were placed by non-medical personnel [18,30].

3.8. Injuries location

Injuries location was specified in 13 studies (Fig. 4). For all but two studies, all TQ were used for extremity injuries [31,32]. El Sayed et al. described the chief complaint anatomic location reported by dispatch for EMS activations with TQ use. In 20% of cases (350/2048), EMS was called because of general bleeding, whereas bleeding from the head (unspecified) occurred in 10% (183/2048) and other bleeding in 3% of cases (50/2048) [31]. Goodloe et al. did not specify injury location for 25% of patients (26/106) [32]. Dorlac et al. reported autopsy files of patients who died from peripheral haemorrhage, with 10 deaths from haemorrhage of the lower limbs on 14 patients in total (71% of cases); no TQ was used in this study [16].

Seven of the 13 studies found a majority of TQs placed on the upper limbs: 54/105 (51%) for Scerbo et al., 32/61 (52%) for Leonard et al., 64/81 (79%) for Sanko et al., 62/87 (71%) for Inaba et al., 53/98 (54%) for Kue et al., 698/2048 (40%) for El Sayed et al., 80/106 (75%) for Goodloe et al. In five other studies, TQs were placed mainly on the lower limbs: 27 (100%) for King et al., 9/11 (82%) for Kalish et al., 3/4 (75%) for Callaway et al., 26 (100%) for Gates et al. and (100%) for Fortuna et al. One study found as many TQs placed on the lower limbs as on the upper limbs [22]. For the studies by King et al., and Gates et al., who were interested in TQs during the Boston bombings in 2013, 100% of TQs (n = 27, and 26, respectively) were placed on the lower limbs. Finally, Fortuna et al. only focused on injuries located below the knee, and consecutively all the TQs reported in this study were placed on the lower limbs.

3.9. Vascular wounds

Ten studies detailed the proportion of vascular wounds [15,17–21,26–29]. The percentage of vascular wounds was described in eight studies, varying between 42% (11/27) for King et al. and 100% for Passos et al. (n = 8), Dubose et al. (n = 47) and Fortuna et al. (n = 25). Three articles indicated a majority of injuries implying arterial wounds [19,21,27].

3.10. Indication of TQ use

Whether TQ use was justified or not was reported in only three studies [18–20]. Scerbo et al. carried out a retrospective observational study. They analysed the cases of pre-hospital TQ use in Texas, between 2008 and 2013. For 105 patients, 90% (94/105) of the TQs were found to be relevant, with an absolute indication in 89% of cases (84/94), and a relative indication in 11% of cases (10/94). All non-appropriate uses of TQ (10%, i.e. 11/105) concerned the pre-hospital setting. Ode et al. achieved also a retrospective study of prehospital use of TQ between 2012 and 2013 in North Carolina. In this study, 62% of the TQs (15/24) were placed appropriately, and 16% (4/24) were delayed. TQs placement was judged non-indicated in 20% of cases (5/24). Late TQ placement was associated with a higher frequency of shock

Table 2
Quality appraisal of the studies, using STROBE criteria.

	Articles											
	Galante	Zietlow	Scerbo	Ode	Leonard	Sanko	Haider	Inaba	Schroll	Aberle	Kue	King
TQs applied	–	73	105	24	61	81	–	87	197	–	98	27
Title and abstract	O	O	O	O	O	O	O	O	O	O	O	O
Study's design	R	R	R	R	R	R	R	R	RC	P/S	R	R
Informative and balanced summary	✔	✔	✔	✔	✔	NE	✔	✔	✔	✔	✔	✔
Introduction												
Background/rationale	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔
Objectives	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔
Methods												
Study design	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔	✔
Setting	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔	✔
Participants	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Variables	NE	✔	✔	✔	✔	✔	NE	✔	✔	NE	✔	✔
Data sources/measurement	NE	✔	✔	✔	✔	✔	NE	✔	✔	NE	✔	✔
Bias		✔										
Study size	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Quantitaive variables	NE	NE	✔	✔	✔		NE	✔	✔	NE	NE	✔
Statistical methods	✔		✔	✔			✔	✔	✔	✔		✔
Results												
Participants	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔
Descriptive datas	✔	✔	✔									
Outcome datas	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Main results	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Other analysis		✔	✔	✔	✔		✔		✔	✔		✔
Discussion												
Key results	✔		✔	✔	✔	NE			✔		✔	
Limitations	✔	✔	✔		✔	NE			✔	✔	✔	
Interpretation	✔		✔	✔	✔	NE	✔	✔	✔	✔	✔	✔
Generalisability	✔	✔	✔	✔		NE	✔	✔	✔	✔	✔	✔
Other information												
Funding		✔		✔	✔			✔	✔			✔

	Articles											
	Wall	Passos	El Sayed	Kalish	Ramly	Goodloe	Dubose	Vardon	Callaway	Fortuna	Dorlac	Glass
TQs applied	–	8	2048	11	–	106	47	–	4	25	–	26
Title and abstract	O	O	O	O	O	O	O	O	O	O	O	O
Study's design	R	R	R	R	P	R	R	P/S	R	R	R	R
Informative and balanced summary	✔	✔	✔	NE	✔	NE	✔	✔	✔	✔	✔	✔
Introduction												
Background/rationale	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Objectives	✔	✔	✔	✔		✔	✔	✔		✔	✔	
Methods												
Study design	✔	✔	✔	✔	✔		✔	✔	NE	✔	✔	✔
Setting		✔	✔	✔	✔		✔	✔	✔	✔	✔	✔
Participants	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Variables	NE	✔	✔	✔	✔			✔	NE		✔	NE
Data sources/measurement	NE	✔	✔	NE	✔			✔	✔	✔	✔	
Bias		✔							NE			
Study size	NE	NE	NE	NE	NE		NE	NE	NE	NE	NE	NE
Quantitaive variables	NE	NE	✔	NE	✔			✔	NE	NE	✔	
Statistical methods		✔	✔					✔	NE	✔		✔
Results												
Participants	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔
Descriptive datas	✔	✔	✔									
Outcome datas	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Main results	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Other analysis		✔	✔	✔	✔		✔		✔	✔		✔
Discussion												
Key results	✔	✔	✔	✔	✔	NE	✔	✔	✔	✔	✔	✔
Limitations		✔	✔	✔	✔	NE	✔	✔	✔	✔	✔	
Interpretation	✔	✔	✔	✔	✔	NE	✔	✔	✔	✔	✔	✔
Generalisability	✔	✔	✔	✔	NE	NE	✔	✔	✔	✔	✔	✔
Other information												
Funding	✔	✔			✔		✔	✔	✔	✔		

O: observational study; R: retrospective study; S: survey; P: prospective study; NE: not evaluable.

(88% vs. 60%), a lower arterial pH (7.21 ± 0.19 vs 7.38 ± 0.13) and a more frequent use of blood products (71% vs. 40%). The study by King et al. about the victims of Boston Marathon bombings found that 100% use of TQs was appropriated. In this study, TQs were used for management of traumatic amputations (16/27, 59%), major cutaneous defects (6/27, 22%) and vascular wounds (5/27, 18%).

3.11. TQ efficiency

Eight studies reported TQ efficiency [18,22–26,28,32]. Efficiency was defined as the stop of bleeding after TQ placement. The lowest efficacy rate was 78% or less (21/27) in King et al. study. In this multicentre study, one hospital centre reported the replacement of

Table 3
Comorbidities and ages.

	Age (years)			
	<18	>50–65	Total ages (%)	Comorbidities
Scerbo (19)	NA	NA	20	NA
Leonard (23)	8	12	20	43%
Sanko (24)	NA	NA	NA	21% renal failure 17% diabetes 16% arterial hypertension
Goodloe (32)	NA	10	10	NA

NA: not available.

all improvised TQs (six TQs) by CAT® TQs. Other studies reported a rate of efficacy between 84% (90/106) for Goodloe et al., and 100% (4/4) for Callaway et al.

3.12. Injury score

Seven studies (43%) reported the patient's Injury Severity Score [17–21,23,25]. These scores ranged from 8,3 for Inaba et al., to 15 for Passos et al.

3.13. Side effects and complications associated with use of TQ

Eight studies evaluated the side effects and complications associated with the use of TQ [15,17,19,23,25,26,28]. The incidence of complications following the use of TQ in trauma varied between none (0%) for Ode et al., and Callaway et al., and 25% (64/197) for Schroll et al. (Fig. 5). Acute complications implied compartment syndromes, requiring discharge fasciotomies between 2% (2/105) for Scerbo et al. and 18% (2/11) for Kalish et al.; ischemia-reperfusion in 4% (7/197) for Schroll et al.; rhabdomyolysis in 2% of cases for Leonard et al. (1/61); and renal failure between 2% (2/87) for Inaba et al. and 3% (3/105) for Scerbo et al. Later complications concerned nerve palsy between 1% (1/95) for Kue et al., and 6% (12/197) for Schroll et al.; infections between 7% (4/61) for Leonard et al., and 9% (17/197) for Schroll et al.; and deep venous thrombosis in 9% (9/105) for Scerbo et al. Amputations were either the reason for the use of a TQ, or one of the consequences of the initial injury. Thus, amputations rates were reported between 12% (7/61) for Leonard et al. and 59% (16/27) for King et al. None of those studies established a clear relation between these complications and the isolated placement of the TQ. The authors discussed the fact that the initial trauma could have been, per se, responsible for each of the complications. Solely, Kue et al. reported two complications (2/98 or 2%) that could be directly attributed to TQ. In one patient, a wound of the intima of the superficial femoral artery might have been attributed to a wrong placement of a TQ. In another patient, a case of nerve palsy could have been the consequence either of the TQ, or of the initial injury.

Table 4
Injury mechanisms.

Injury mechanism (%)					
	Blunt	Penetrating	Other		
			Medical		Other
			Arteriovenous Fistula	Hemorrhagic varice	
Galante	–	–	–	–	–
Zietlow	50	43	7		
Scerbo	49.5	49.5			
Ode	32	44	16	4	
Leonard	51	38	10		
Sanko	11	63	25		1
Haider	–	–	–	–	–
Inaba	33.3	66.7			
Schroll	36	56			7
Aberle	–	–	–	–	–
Kue	7	67	24		
King	100				
Wall	–	–	–	–	–
Passos	62	38			
El Sayed	51	32.6			11
Kalish		100			
Ramly	–	–	–	–	–
Goodloe		58.5	13		
Dubose	–	–	–	–	–
Vardon	–	–	–	–	–
Callaway		100			
Fortuna	48	44			
Gates	100				
Dorlac		100			

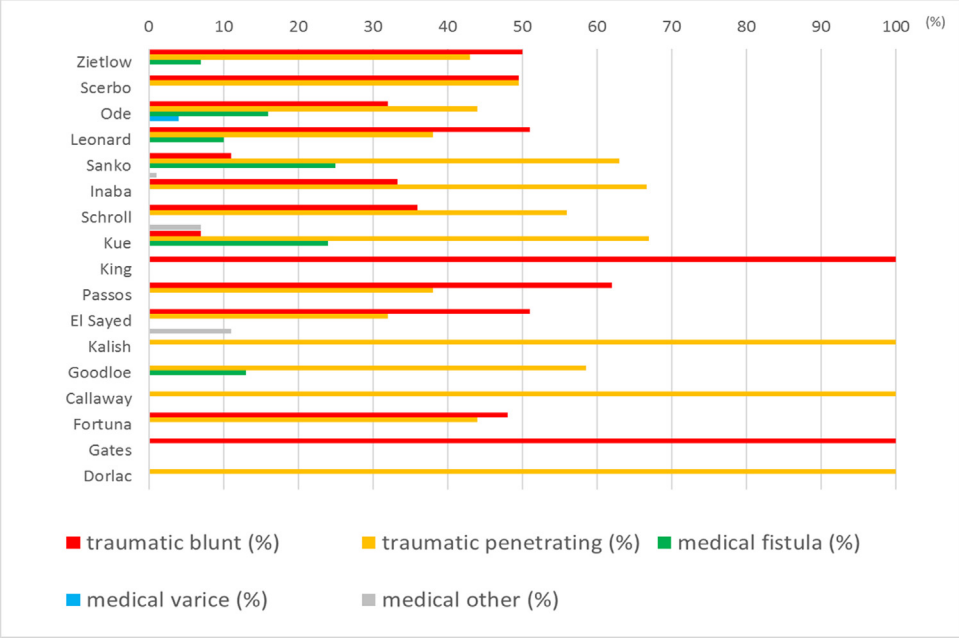

Fig. 3. Injury mechanisms.

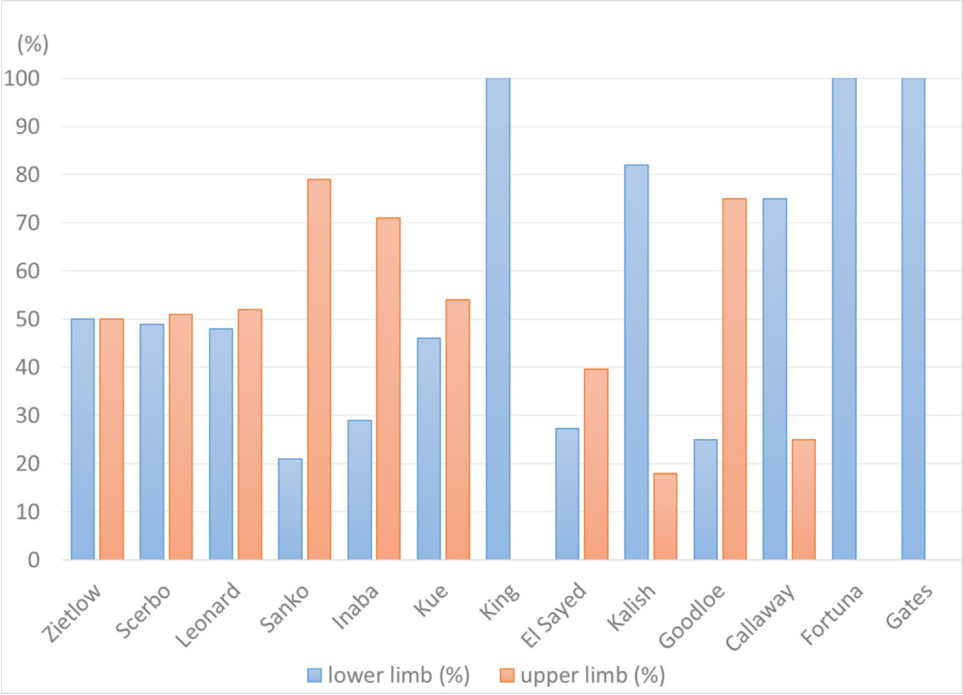

Fig. 4. Injury locations.

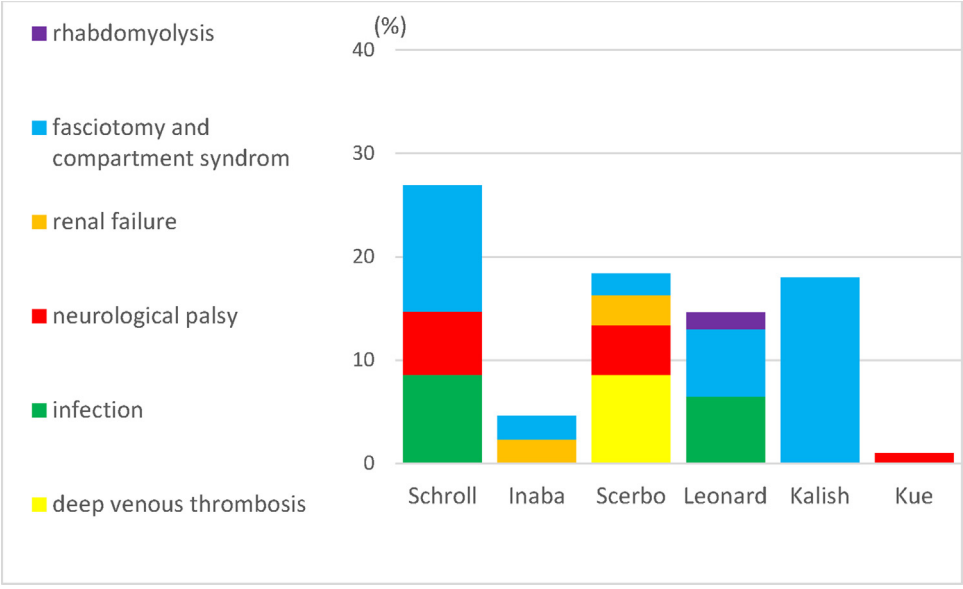

Fig. 5. Side effects and complications in relation with TQ.

4. Discussion

4.1. Main results

Our review highlights the current questions about the application of TQ in civilian trauma. Of the 24 analysed studies, 22 were published after 2010, of which 16 since 2015. However, most available studies are retrospective, with a low level of evidence. Our analysis showed that several US civilian trauma care standards have already integrated the application of a TQ use: Iowa, Minnesota, Wisconsin [22,23], Texas [19,25], Charlotte [28], North Carolina [20], California [21], Los Angeles [21,24], Boston [15,18,30,33] and Houston [16]. TQs were used in several situations, a priori without fear regarding the age or comorbidities of the patient. Apart from terrorist attacks, TQs were mainly applied by medical staff. But several studies showed that bystanders or non-physician caregivers also used TQs [18,28,30]. TQs involved quite homogeneous types of injuries and locations. TQs were mainly used for extremity Injuries. In most of cases, TQs were applied efficiently, with an efficacy rate varying from 78% for King et al. to 100% for Callaway et al. [18,28]. No study has described the use of a second tourniquet in case of failure of a first one. There was no data on the pain caused by TQ, and if pain was a reason for TQ failure. Surveys advocated multiple reasons for refusal of TQs use: the fear of adverse effects and complications, the difference in characteristics of injuries encountered in civilian and military settings, or the impression of lack of proven benefits for the use of TQ, in comparison with other devices such as

haemostatic dressings or manual compression [34–36]. Conversely, our analysis showed that training may significantly change knowledge and skills for TQ application. Indeed, Aberle et al. showed that staff trained for use of TQ was more likely to use it and less feared complications, in comparison with untrained staff [36]. However, in the study by Wall et al., 37% (n = 40/107) of those trained for TQ placement did not understand the need to interrupt arterial flow, but also venous flow. Such results advocated for the need to train medical teams facing haemorrhagic injuries [37]. Moreover, TQ was still considered as a second-line strategy. Only 39% (n = 474) of those interviewed by Aberle et al. reported that the TQ was the most effective technique for saving lives, in case of life-threatening haemorrhage [36]. In 2012, 46% (n = 82) of French EMS were equipped with TQs [38]. In 2015 in the USA, 36% of EMS (n = 15) had a protocol for the use of TQ in the management of haemorrhagic trauma [39].

Several data regarding TQ application should be interpreted carefully. A precise definition of TQ exposure time was rarely specified. Indeed, the moment of TQ application and the moment of TQ removal were probably different from one study to another. Moreover, the management of extremity injuries changed recently, including the use of TQ. The study by Dorlac et al. illustrated how extremity injuries were managed before the use of TQs, the usefulness of TQs for management of extremity haemorrhage and its ability to save lives in civilian settings [16]. Indeed, the lack of TQ in this study demonstrated the evolution of medical practices. From 1994 to 1999, at the time of data collection, recommendations for prehospital management of extremity haemorrhage were based on direct compression of the wound [40], and the use of a TQ was limited to cases of traumatic amputation, with uncontrollable bleeding. A similar study conducted more recently could have provided different data regarding the use of TQ.

In their study on the placement of 2048 TQs, El Sayed et al. analysed the predictive factors for TQ use in civilian prehospital setting [31]. TQs were mainly used in male patients, presenting trauma haemorrhage, implying gunshot wound. Predictive factors for TQ use were: extremity injuries, gunshot wounds, work accidents, and "haemorrhage problems". Identification of such predictive factors showed that TQ could be applied in several situations. Galante et al. and Aberle et al. surveys revealed that the fear of complications limited the use of TQ in civilian trauma [34,36].

Interestingly, only one study in the 24 of our review noted complications possibly due to TQ use [33]. These two complications reported by Kue et al. concerned 2% of all complications (n = 2/98). Other retrospective studies did not succeed to determine whether these complications were related to the TQ application or to the initial injury. These data were consistent with those from military setting, reporting a low rate of complications associated with TQ use [3,41]. Finally, these results were also consistent with common surgical practices, where a TQ could be left in place for two hours in lower limb, with no fear of complications [42]. In urban environment, hospital structures were accessible easily and quickly. The TQ application time and the potential complications associated were thus limited. In civilian population, TQ might also be used in patients of extreme ages or with comorbidities. The current recommendations for the use of TQ in civilian trauma do not specify how to deal with such patients [43]. Nevertheless, according to four studies of our review, patients of extremity ages represent between 10 and 20% of patients who had a TQ [19,23,24,32]. In addition, comorbidities were rarely described. In our review, there was no statistically significant association between age or presence of comorbidities, and complications associated with the use of TQ. Such data, however being limited, might encourage the use of TQ in such patients.

Civilian recommendations for mass casualty incidents suggest, with a low level of evidence, the use of commercial TQs first, and improvised TQs as a last resort [43]. Military data showed that improvised TQs were less effective than dedicated TQs (efficiency rate of 25% to 43%, respectively, depending on the width of the improvised TQ, vs. 79% for the CAT®), and caused more complications (rate of complications of 80% vs. 21% respectively) [4]. In our review, both efficacy and complication rates were similar for commercial and improvised TQs. However, King et al. reported an efficacy rate of less than 78% for the use of improvised TQs in the Boston Marathon bombing. Six of the 78 TQs (8%) were ineffective because being only venous TQs, and were replaced on arrival to the ED. Finally, in this study, TQs were applied in 66% of cases by non-medical staff (n = 51) [18]. Our analysis did not find any data evaluating whether the application of TQs by non-medical staff was justified, or if it led to more complications than by medical staff. These data emphasised the need to train the population to efficiently use TQ. Initiatives to train the general population are multiple and can be easily disseminated by Internet. For example, in November 2016, the UK military and civilian medical professionals launched citizenAID™, a free website and smartphone application dedicated to the first aid measures in case of terrorist attack. This application proposes simple and easy algorithms for management of mass casualty incident, including the use of TQ before EMS arrival [44,45].

In their retrospective study (2010–2013) evaluating the characteristics of patients who presented with a TQ at hospital admission, Schroll et al. compared the characteristics of civilian and military casualties [25]. Their results showed several statistically significant differences. Military casualties were younger, presented with more severe injuries, and the time for prehospital transport was longer. Mortality rates and secondary amputations were higher. These data emphasized the fact that these two populations are different. Data obtained in the military population cannot be directly applied to civilian trauma. The early placement of a TQ in military casualty, before the onset of shock, was associated with a decreased risk of mortality [2]. Our review in the civilian setting, with shorter prehospital evacuation times, did not report such a finding [46].

Despite these differences observed between civilian and military setting, military trauma knowledge acquired during the last decade has been incorporated into civilian guidelines [9]. The recommendations from the US National Trauma Care System integrate definitively the scientific advances made over the past decade in military trauma care [47]. The current notion of focused empiricism encouraged these advances. Focused empiricism is part of a learning process that involves determining whether empirical gaps in care exist, and if so, how to address them to the best. The concept is an integral and pivotal component of the Military Health System's requirements-driven approach to trauma care evaluation and improvement. Focused empiricism is a useful and necessary feature of a learning trauma care system in both military and civilian settings, particularly in urgent circumstances when rapid advances in care are required. Evidence and insights derived from the military's use of this approach led to the generation and modification of clinical practice guidelines, the identification of questions requiring further research, and the transfer of innovative care practices to the civilian sector.

4.2. Limits

This systematic review presents several limitations. First, it was based on the analysis of retrospective studies, with a low level of evidence. The STROBE scale used for the evaluation of the quality of the articles was not fully adapted to the analysis of all the selected articles. Nevertheless, it was applied correctly for most of them and implied validated criteria. Second, literature that was not available in French or English was excluded. However, the low number of

studies involved ($n = 2$) could not compromise the quality of the analysis.

Despite these limitations, this study presented strength points. Two reviewers independently selected and evaluated the quality of the articles. Above all, the study of the grey literature, combined with that of the usual databases, led to an exhaustive search of the current data. Finally, the methodology used for the analysis of the studies (STROBE scale) was robust and largely acknowledged [14].

4.3. Future research

Our systematic review showed that the use of TQ was efficient in different cases of extremity haemorrhages in civilian setting. The overall complication rates were low. Nevertheless, only few data were available. Moreover, most of the studies implied a low level of evidence. Especially, data regarding the safety of TQ, as well as a better description of its use in patients of extremity ages or with comorbidities, were missing. Further studies are needed to provide more details regarding these points. A larger training of actors involved in trauma management would be implemented in order to fully integrate the use of TQ in civilian setting.

5. Conclusion

This systematic review reported 24 studies concerning the application of TQ in civilian setting. This is a highly up to date topic, 22 articles out of 24 being published since 2014. TQ saved lives, with few associated complications. However, the level of evidence for available studies was low and doubts persisted regarding the complications associated with the use of TQ, and its specific use in patients of extremity ages or with comorbidities. Nevertheless situations in which a TQ could be applied to stop extremity haemorrhage are numerous in civilian setting, including the growing threat of terrorist attacks, and more generally mass casualty incidents. Prehospital civilian EMS should adopt an easy use of TQ, following a dedicated training. Finally, further studies are mandatory to detail the indications of TQ and to promote its application in civilian setting.

Disclosure of interest

The authors declare that they have no competing interest.

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