REVIEW ARTICLE

Tourniquet use in out-of-hospital emergency care: a systematic review

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Objective. Uncontrolled bleeding from serious injuries continues to be one of the main causes of preventable deaths outside hospitals. Tourniquets could be useful for quickly stemming blood flow and prevent exsanguination, although evidence supporting their use and effectiveness in civilian accidents is limited. To analyze the effectiveness of tourniquets for stopping bleeding in out-of-hospital emergencies and to explore factors associated with effectiveness.

Methods. We undertook a systematic review of the literature in Spanish and English. Search protocols to identify studies that evaluated the use of various devices and their effectiveness in stemming arterial blood flow. We included studies published between 2011 and 2016 in which tourniquets were used to prevent massive blood loss.

Results. We included 17 articles. Tourniquets were effective in stopping massive bleeding in all studies. Pain, the most frequently described adverse effect, was observed in 420 patients (35.7%). Delayed application of a tourniquet was associated with more negative outcomes.

Conclusions. Tourniquets are effective for stopping massive blood loss. There are few complications, most of which are attributable to the critical state of patients rather than to application of the tourniquet. A tourniquet should be applied in major trauma cases in civilian settings if massive, life-threatening bleeding cannot be stopped with direct pressure.

Keywords: Tourniquets. Hemorrhage. Exsanguination. Emergency medical services.

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Utilización del torniquete en la asistencia extrahospitalaria: revisión sistemática

Objetivo. La hemorragia no controlada producida por un traumatismo grave sigue siendo una de las principales causas de muerte evitable en el entorno extrahospitalario. En estas situaciones, los torniquetes podrían ser una herramienta rápida y útil para detener el sangrado exanguinante, aunque existe evidencia limitada en cuanto a su utilización y efectividad en el entorno civil. Analizar la efectividad del torniquete para detener las hemorragias en situaciones de urgencia extrahospitalaria y los factores relacionados.

Método. Revisión sistemática de la bibliografía en español e inglés. Se elaboraron protocolos de búsqueda para localizar estudios que valoraran la utilización de los distintos dispositivos y la efectividad en la detención del flujo arterial. Se incluyeron estudios publicados entre 2011 y 2016, con utilización del torniquete en hemorragias exanguinantes.

Resultados. Se analizaron 17 artículos. En todos los estudios se observó que el torniquete fue efectivo en la detención de la hemorragia, siendo el dolor el efecto adverso más frecuentemente descrito (35,7% de los casos). El retraso en su aplicación es un factor determinante que afecta negativamente a la efectividad.

Conclusiones. Los torniquetes son efectivos deteniendo la hemorragia exanguinante. Sus complicaciones son escasas y la mayoría son atribuibles al estado crítico de los pacientes y no a su colocación. A nivel extrahospitalario, el torniquete debería utilizarse en pacientes con traumatismo mayor si la presión directa no es suficiente para controlar una hemorragia exanguinante que amenace la vida.

Palabras clave: Torniquetes. Hemorragia. Exanguinación. Servicios médicos de emergencia.

Introduction

Traumatic aetiology is the sixth leading cause of death and the fifth leading cause of moderate and severe disability globally, as well as the leading cause of death and disability in people under 35 years of age[1,2].

Tourniquets can first be defined as strips of cloth tied tightly around the limbs to stop bleeding by compressing the arteries that supply the area of injury[3]. Tourniquets work properly when compression of limb tissues stops arterial blood flow and the distal pulse is not present[4]. Union hemorrhage is defined as bleeding from a joint of the torso to the extremities, specifically, the base of the neck, shoulder, armpit, perineum, buttocks, buttock area, and groin. For this type of bleeding, limb tourniquets cannot be applied as they cannot control the bleeding. For this reason, junctional tourniquets have been developed, which have proven to be effective in controlling bleeding in the joint area[5].

In the military context, the current indication for the use of the emergency tourniquet is its application in a limb wound to which pressure can be applied and where the personnel who place it value it as a life-threatening hemorrhage[6]. In this scenario, the application

of the tourniquet is the initial and primary method for the control of severe bleeding. In contrast, the use of tourniquets by civil emergency medical services (EMS) is not widespread[6]. In different countries, civilian EMS use direct pressure, compressive bandages, bandages, and limb elevation to treat extreme bleeding, using tourniquets as a last resort[7,8]. This practice is supported by different clinical practice guidelines, which recommend its use when all the classic methods of halting bleeding have failed, due to the limited evidence of its use in the civilian population[9,10]. Different reasons have been described, such as the variability in its use between different international EMS or that its overuse, in substitution of the basic bleeding control methods, could cause greater morbidity and mortality[11].

The use of tourniquets has been associated with a number of muscular, cardiac and neurovascular complications[8,12] that could have life-threatening consequences[6,13]. There are no published data on the prevalence of tourniquet use applicable to our environment[14], although the main commercial tourniquets currently in use have been identified (Table 1)[4,5,15].

Its use in the military environment has extensive experience, together with the use of haemostatic agents[8,16,17]. Although the designs and application protocols for tourniquets have been progressively improved, there is controversy in the civil pre-hospital setting regarding their application. Risks due to inappropriate use, lack of training of professionals or maintenance of prolonged tourniquet times could have led to negative results that favoured their lack of use[18].

Therefore, the objective of this systematic review is to analyze the effectiveness of a tourniquet in stopping bleeding in out-of-hospital emergency situations, as well as to identify associated factors that favour or diminish this effectiveness.

Table 1. Types of tourniquets marketed

Type of tourniquet	Description	Image and additional information
CAT (Combat Application Tourniquet) Limb tourniquet	It has a strap that must be securely fastened to the end before attaching the plastic reel. The strap is secured on itself with velcro, and there is a locking point for the reel. The strap should go through the buckle differently if used for the upper or lower extremity[4].	www.EMSWorld.com
MET (Emergency & Military Tourniquet) Limb tourniquet	It is an open loop system composed of a strong belt and aluminum reel. It has two fixing points to lock the reel, one that is adjustable and another with velcro[4].	www.savelives.com
EMT (Emergency Medical Tourniquet) Limb tourniquet	It is a pneumatic tourniquet similar to a pressure cuff that is easily applied and, unlike a blood pressure cuff, the pneumatic bladder in EMT is reinforced to prevent air loss when inflated, allowing the pressure in the limb to be maintained once it is blocked[4].	www.delfimedical.com
SWAT-T (Stretch Wrap and Tuck Tourniquet) Limb tourniquet	Elastic band that is applied by wrapping the device around the extremity and pressing through the total stretch of the band[4].	www.EMSWorld.com
SOFTT (Special Operations Forces Tactical Tourniquet) Limb tourniquet	It's an open loop system with a metal reel. It has a narrow strap and a metal "crocodile" clip to secure the strap. Once the reel is applied there are two plastic fixing points[4].	www.tacmedsolutions.com
SOFTT-W (Special Operations Forces Tactical Tourniquet-Wide) Limb tourniquet	It has a wider strap than the SOFTT and the clip and locking system were replaced by a detachable buckle[4].	www.EMSWorld.com
CRoC (Combat Ready Clamp) Junctional tourniquet	It is a small bucket with an aluminium structure to exert mechanical pressure directly on the wound or indirectly on the groin area to stop bleeding[15].	www.EMSWorld.com
JETT (Junctional Emergency Treatment Tool) Junctional tourniquet	It consists of a belt system, with two trapezoidal pressure pads and threaded pullers in a T shape[15].	www.EMSWorld.com
SJT (SAM Junctional tourniquet) Junctional tourniquet	It is composed of a belt and two pneumatically inflatable bags. It serves to stabilize pelvic fractures and to control joint bleeding in the axillary and inguinal area[15].	www.EMSWorld.com
AAT (Abdominal Aortic Tourniquet) o AAJT (Abdominal Aortic and Junctional Tourniquet) Junctional tourniquet iTClamp Hemorrhage Control System Junctional hemorrhage	It is a pneumatic belt that is placed around the abdomen with the inflated part over the navel, the buckle is manually closed down and tightened with the reel located in the front of the device[15].	www.EMSWorld.com
iTClamp Hemorrhage Control System Junctional hemorrhage	A mechanical clamp with several small needles that seals a wound by firmly approaching the edges of the wound[6].	www.EMSWorld.com

Method

Once the area of uncertainty concerning the use of tourniquets in out-of-hospital areas was detected, a search and review protocol was drawn up in September 2016. In order to carry out this protocol, a team of reviewers was created following the recommendations of both the Cochrane Collaboration[19] and the Joanna Briggs Institute[20].

Once the review team was established, all participants approved the protocol in October 2016. Following the protocol, a search of the available literature in English and Spanish was conducted through the Medline, Scopus and Science Direct databases. The search started from a clinically answerable question in PICO format (Table 2)[3] and from this, search strategies were designed, as shown in Table 3.

Inclusion criteria were: scientific literature published between 2011 and 2016; research designs for clinical trials, systematic reviews or analytical observational studies (cohorts and case-control); sample of studies composed of adults and use of tourniquet in emergency or exsanguinating situations. On the other hand, studies using surgical tourniquets were excluded.

The choice of articles, variables and methodological quality was made by two reviewers, with the rest of the researchers intervening in the disagreements. Finally, an inverse search was performed, reviewing tertiary sources (Cochrane Library, clinical practice guidelines) and grey literature manually (Tactical Combat Casualty Care Guide) to verify if there were other papers that had not been found in the initial search.

After selecting the studies, a previously designed extraction template was used to obtain the following data: author, country and date, type of study, methodological quality, type of scenario, sample size, tourniquet model, effectiveness, survival, adverse effects and mean duration of tourniquet application. Effectiveness was defined as the ability to stop the blood flow in the limb in which the device was applied[21,22]. Survival was defined as no death during hospital admission[11].

The selection of articles, variables and methodological quality was done by two reviewers, with the rest of researchers intervening in the disagreements.

To evaluate the methodological quality of the articles we used the Critical Reading Cards (FLC 2.0) developed by Osteba, Servicio de Evaluación de Tecnologías Sanitarias. The FLC 2.0 contemplates the evaluation criteria of the main recognized tools according to the research design that evaluates each card (Cochrane, PRISMA, and AGREE among the most important). In this regard, the review team also observed the risk of bias, in addition to the methodological quality of the studies. These files are validated by the eight agencies of the RedETS (Red de Agencias de Evaluación de la Tecnología Sanitaria de España) and contemplate the evaluation of the biases of the different methodological designs[23]. In addition, they facilitate homogeneity in the evaluation among reviewers. The critical reading was carried out in pairs, with a third reviewer intervening in case of discrepancy.

Table 2. Structure of the PICO question

P (patient)	Adult patient with exanguinant hemorrhage.
I (intervention)	Use of the tourniquet to stop the bleeding.
C (comparison)	Does not exist.
O (results)	Containment of bleeding, reduction of side effects.

Table 3. Search strategies applied

Database	Search Strategy
Medline	((("Tourniquets"[Mesh]) AND "Hemorrhage"[Mesh]) OR "Exsanguination"[Mesh]) NOT "Arthroplasty, Replacement, Knee"[Mesh] ("Tourniquets" [Mesh]) AND "Emergency Medical Services" [Mesh] ("Tourniquets/utilization"[Mesh]) AND "Emergency Medical Services"[Mesh] "from 2011 to 2016" AND "humans" AND "languages: Spanish and English"
Science Direct	("Tourniquets" AND "Hemorrhage") OR ("tourniquets" AND "Emergency Medical Service") ("Tourniquets" AND "Utilization") "from 2011 to 2016" AND "Nursing and Health Professions" AND "Journal"
Scopus	("Tourniquets" AND "Exsanguination") OR ("Tourniquets" AND "Emergency Medical Services") ("Tourniquets" AND "Emergency Medical Services" AND "Utilization") ("Tourniquets" AND "Utilization") "from 2011 to 2016" AND "languages: Spanish and English" AND "Article and Review"

Results

The initial search resulted in 751 articles from Medline, Science Direct and Scopus. After eliminating duplicates (356 articles), and after reading titles and abstracts, 372 were excluded because they were not related to the emergency tourniquet (Figure 1). Twenty-three full-text articles were analyzed. Finally, 17 articles were considered valid, as 6 articles were discarded after a more detailed critical reading and were determined to be descriptive studies. Table 4 summarizes the main characteristics of the 17 studies analyzed (Table 4)[5,11,21,22,24-36]. The majority were from the United States (10), and the rest from the United Kingdom (3), Canada (2), Turkey (1) and Holland (1). Studies ranged from 10 to 4,297 patients (5,654 in total), and were published between 2011 and 2016. With regard to the type of design, the same number of publications with experimental design as observational (7) were found, with a clearly higher number than the systematic reviews (3).

In all publications the efficiency of the tourniquet could be appreciated, although only in 7 of them it was evaluated quantitatively[21,25-27,30,32,34]. We observe that limb tourniquets were effective between 69-97%[26,27,30,32,34]. The Emergency Medical Tourniquet (EMT) model showed greater effectiveness over the Combat Application Tourniquet (CAT), since EMT was able to stop arterial flow in patients with a body mass index

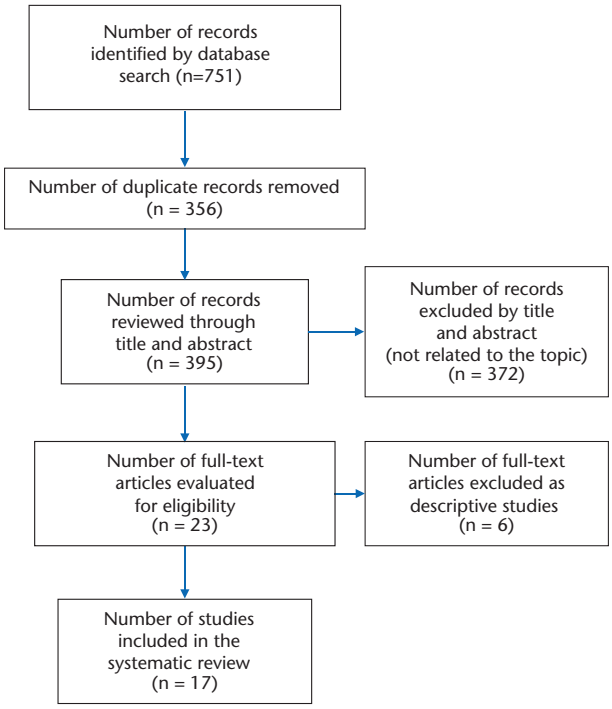

Figure 1. Flowchart for study selection.

and a higher mean arterial pressure compared to the CAT device[29]. Regarding the union models, Combat Ready Clamp (CRoC) and SAM Junctional tourniquet (SJT) were the best rated and their effectiveness ranged from 77-87%[21,25].

Different factors associated with the effectiveness of the tourniquet have been described, such as the severity and location of the lesion27, its correct and rapid application30,32 and the time between the lesion and the application of the tourniquet[26,31,34,36].

In 11 studies (64.7%)[21,22,24,25,30-36] adverse effects related to the application of the tourniquet were described, although they were not permanent, except in cases in which the use of the tourniquet was not performed correctly. The most frequently reported adverse effect was pain, as it was identified in 420 patients (35.7%) and evaluated in 7 studies (41.2%)[21,22,24,25,30,32,33]. Differences were observed between different models of tourniquets in terms of the pain perceived by the volunteers to whom they were applied. Different studies determined that the CAT model produced more pain than the other models evaluated, the Special Operations Forces Tactical Tourniquet (SOFTT), Special Operations Forces Tactical Tournique- Wide (SOFTT-W) and Stretch Wrap and Tuck Tourniquet (SWAT-T)[22,30]. Regarding the junctional tourniquets, the application of the Abdominal Aortic and Junctional Tourniquet (AAJT) model was found to produce more pain than the application of the Combat Ready Clamp (CRoC), Junctional Emergency Treatment Tool (JETT) and SAM Junctional tourniquet (SJT)[25] models.

The second most frequent adverse effect was the need for fasciotomy, as it was identified in 148 patients (22.7%) from the only study that assessed it. Infection secondary to tourniquet application was found in 17 patients (8.6%) from a single study[24], a similar figure to venous thromboembolism, with 9 (8.6%), also identified in a single publication[31]. The incidence of compartment syndrome was 19 cases (6.3%), described in two publications[31,34]. Other adverse effects observed, although less frequently, were: 7 cases (3.6%) of ischemic injury in one study[34], 21 (3.2%) of clot formation in one study[24], 26 (2.7%) of nerve paralysis in three studies[31,34,36], 10 (1.3%) of renal failure in two studies[31,24], 13 (1.9%) of paradoxical bleeding in one study[24], 10 (1.5%) of myonecrosis in one study[24] and 1 (0.2%) of rigidity in one study[24]. Finally, respiratory distress, nausea and dizziness were also described, although no data on incidence were provided[25].

Regarding the relationship of these adverse effects with the tourniquet application time, one of the publications analyzed[34] found that the group of patients with ischemia or compartment syndrome had the tourniquet applied for less time than those who did not suffer these complications, and therefore may not have been due to the application of the tourniquet. On the other hand, different studies[24,36] do not show a relationship between the prolonged time of application of the tourniquet and cases of nervous paralysis, pain, renal failure, formation of clots or myonecrosis.

Lastly, in 9 studies (52.9%)[11,24,26-28,31,34-36] researchers considered the relationship between tourniquet use and survival. Some of them[24,26] determined a survival increase in the cases in which the tourniquet was applied before the appearance of shock signs (pre-shock: 90-96% and postshock: 4-18%)[24,26]. Other authors[11] related survival to the severity of the injury, determining that mean survival in subjects with lesions in the extremities when applying the tourniquet was 96% [578/603], and decreases as the severity of the injury increases (severe = 98% [550/563], very severe = 76% [28/37], and critical = 0% [0/3]). Other studies[27,31,34] affirm the existence of an improvement in patient survival through the use of the tourniquet, although they do not provide specific data.

Thanks to the analysis of the methodological quality, two publications with a low level of evidence were identified, so the information they provide was not considered relevant in comparison with the studies that obtained high (9 studies) and medium (6 studies) evidence.

Discussion

The results of this review indicate that tourniquet is effective in stopping exsanguinating bleeding (high evidence), with the CAT, EMT and SWAT-T tourniquet models showing the greatest effectiveness[22,29]. As for the possible complications derived from the use of the tourniquet, no permanent or serious adverse effects have been identified that can be directly related to its regulated application. The most frequently described are pain

Table 4. Studies included in the systematic review

Study	Country and year	Type of design	Metho-dological quality	Scenario type	Sample size	Model of tourniquet used	Tourniquet Effectiveness	Adverse effects (% [n])	Average duration of tourniquet application	Survival with use of tourniquet % [n]
Ode *et al.*[26]	US 2015	Control-case	High	C	56	CAT (E)	92%	No	72 min (16-241)	Pre-shock: 96%; post-shock: 4%; pre-hospital 2015: 89%; hospital: 78%; general: 87%.
Kragh *et al.*[11]	US 2015	Cohorts	High	M	4,297	NS	Yes	No	No	Limb injury: 96% 2015 [578/603] severe: 98% [550/563]; very severe: 76% [28/37]; critical: 0% [0/3]].
Unlu *et al.*[27]	Turkey 2015	Clinical case	High	M	102	CAT (L)	69.6-96%	No	No	Positive relationship between prehospital clinical use 2015 and survival. No data.
Passos *et al.*[28]	Canada 2014	Cohorts	High	C	190	NS	Yes	No	91 ± 72 min.	Without tourniquet: 96.8% [180] 2014 With tourniquet: 100% [186]
Taylor *et al.*[21]	UK 2013	Quasi-experimental	Low	M	16	AAT (J)	94%	Pain (100% [16])	< 1 min.	NS
Savage *et al.*[30]	Canada 2013	Quasi-experimental	Medium	M	22	CAT, SOFTT and SOFTT-W (E)	CAT 97%, SOFTT 72.7%, SOFTT-W 73.8%	Pain (100% [22])	No	NS
Scerbo *et al.*[31]	US 2016	Cohorts	High	C	105	CAT (L)	Yes	Acute renal failure (2.9% [3]), Noncompartmental syndrome (1.9% [2]), nerve palsy (4.8% [5]), and venous hromboembolism (8.6% [9]).	No	Positive relationship between pre-shock use and survival.
Wall *et al.*[32]	US 2012	Quasi-experimental	Medium	M	30 (150 uses)	SWAT-T (L)	94%	Pain (64.6% [97])	1 min.	NS
van Oostendorp *et al.*[6]	Netherlands 2016	Systematic review	High	C	NA	CRoC, JETT, SAM-JT, AAJT and iTClamp. (J)	Yes	No	No	NS
Lyon *et al.*[33]	US 2012	Control-case	Low	C	13 (26 uses)	AAJT (J)	Yes	Pain (100% [26])	No	NS
Schroll *et al.*[34]	US 2015	Cohorts	High	C	197	MIA-T (L)	88.8%	Nerve palsy (6.1% [12]), compartment csyndrome (8.6% [12]), ischemia injury (3.6% [7]), secondary infection (8.6% [17]).	48 min.	Possible positive relationship in civilian population.
Wall *et al.*[22]	US 2013	Quasi-experimental	Medium	M	33 (192 uses)	SWAT-T and CAT (L)	Yes, SWAT-T in 60 seconds, CAT in 96 seconds.	Pain (71.9% [138])	1 min.	NS
Kragh *et al.*[25]	US 2015	Quasi-experimental	Medium	M	10 (120 uses)	CRoC, AAJT, JETT and SJT (J)	CroC 87%, AAJT 27%, JETT 77%, SJT 77%	Pain (100% [120]), shortness of breath, nausea, and dizzinesss	1 min.	NS
Bulger *et al.*[35]	US 2014	Systematic review	High	C	NA	NS	Yes	Unspecified adverse effects	No	Military: 92% (CI95% 88-95%); children: 92% (CI95% 84-96%); civilians: 91% (CI95% 56-99%)
Mawhinney *et al.*[36]	UK 2015	Systematic review	Medium	M	NA	NS	Yes	Nerve paralysis (1.4% [9])*	No	Pre-shock: 90% [429/477]; post-shock 18% [4/22]*
Taylor *et al.*[29]	UK 2011	Quasi-experimental	High	M	24	CAT and EMT (L	Yes (EMT, CAT no)	No	No	NE
Kragh *et al.*[24]	US 2011	Cohorts	Medium	M	559	CAT, EMT and SOFTT (L)	Yes	Fasciotomy (22.7% [148]), clots (3% [21]), myonecrosis (1.5% [10]), nerve palsy (1.4% [9]), acute renal failure (1% [7]), significant pain (0.1% [1]), stiffness (0.1% [1]), and paradoxical leeding (2.0% [13]).	Up to 16 hours	Pre-shock: 90% [429/477]; post-shock 18% [4/22]

C: civil; M: militar; NA: non-aplicable; NS: not specified; L: Limb tourniquet; J: Junctional tourniquet, CAT: Combat Application Tourniquet; AAT: Abdominal Aortic Tourniquet; SOFTT: Special Operations Forces Tactical Tourniquet; SOFTT-W: y Special Operations Forces Tactical Tourniquet-Wide; SWAT-T: Stretch; Wrap and Tuck Tourniquet; CRoC: Combat Ready Clamp; JETT: Junctional Emergency Tool; SAM-JT: SAM Junctional Tourniquet; EMT: Emergency & Military pneumatic tourniquet; MIA-T: Multi-institutional retrospective analysis of prehospital tourniquet; CI: confidence interval
*Data extracted from the study by Kragh et al. 2011.

and fasciotomy[11,21,22,30-34,37], although different authors[28,31,34] determined that the complications were not attributable to the use of the tourniquet, but rather to the severity of the lesions.

Historically, the use of tourniquets in emergency medical care has always been linked to military conflicts[21]. In recent years, there have been changes in military practice motivated by recent conflicts in Afghanistan, Syria and Iraq. There has been an increase in the use of tourniquets and topical haemostatic agents with good results in the management of trauma on the battlefield[34], although it is not clear if the results in the military field can be extrapolated in a beneficial way to the civilian environment[27,34,36].

Today we face an increase in traumatic events of every kind: stabbing and firearms, explosions or other terrorist attacks[5,27]. After the attack during the Boston Marathon in 2013, there were many amputations of lower limbs because the devices detonated were strategically placed close to the ground for further damage. Different health authorities raised the need to implement the use of the emergency tourniquet to stop bleeding after severe limb trauma[11,27]. In today's military conflicts, there has also been a change in injury patterns because the explosive devices used produce pelvic fractures, traumatic lower limb amputations and torso injuries that require control of union hemorrhages[4].

Recently, the declaration of the IV Hartford Consensus[5,35] promotes the application of tourniquets and the use of topical hemostatic dressings by all prehospital staff, including emergency medical services, and first responders to stop bleeding early. TCCC (Tactical Combat Casualty Care)[37] was first to recommend the use of tourniquet to control bleeding from limb trauma. Its guidelines also promote the use of tourniquets by teams that provide the first assistance response, health personnel or passers-by who may be closer to the victim, especially in the case of hostile incidents[31].

As far as the effectiveness of the use of the tourniquet in the extremities it is necessary to consider the great variety of commercial devices available. The studies analyzed show that the CAT and EMT models are the tourniquets that seem to have the best designs[29]. CAT is a fast applying device that occludes distal blood flow better than SOFTT and SOFTT-W[27,30] models. On the other hand, Taylor et al. in 2011 (high methodological quality) conclude that CAT is not effective in stopping bleeding if applied at mid-thigh level compared to EMT pneumatic tourniquet[29]. However, despite the advantage of EMT over CAT, in the military setting the use of EMT is not recommended because it is not designed for self-application[29]. On the other hand, Wall et al. in 2013 (medium methodological quality) compared the CAT system with the SWAT-T model, observing that the effectiveness of SWAT-T is identical and also has the advantage of requiring less pressure to achieve occlusion compared to the first[22].

In view of the results, we could say that the SWAT-T model is designed to be used in tactical or first aid scenarios by soldiers, military doctors or the police, among others, given its easy application and degree of effectiveness[22,32]. Therefore, if direct pressure is ineffective in controlling hemorrhages in the extremities, the use of commercial tourniquets such as SWAT-T is recommended.

The four tourniquets approved by the Food & Drug Administration (CRoC, AAJT, JETT, SJT)[38] have been shown to be effective in occlusion of bleeding, with varying degrees of manipulation by users[32]. CRoC and SJT models are the most effective and safe, as no serious adverse effects have been described[25]. The AAJT model is also effective in eliminating axillary and femoral blood flow, although several studies[21,25,33] reported moderate to severe application discomfort that resolved immediately after removal of the device. A systematic review[5] analysing the different treatment options for the control of junctional and trunk haemorrhage in the prehospital or experimental setting concluded that the level of evidence from the included studies was low and therefore the information it provided was of little use on the use of junctional tourniquets. Several of the interventions discussed require a high level of ability on the part of healthcare personnel to control non-compressible bleeding. We must bear in mind that there is a wide variety of devices designed for union bleeding and that many of them are new to the market, so there are still few studies evaluating them. For the time being, controlling bleeding in the junctional and non-compressible trunk areas remains a challenge, so we cannot make a recommendation on their use due to the small number of quality studies evaluating them.

There is an association between the correct application of the tourniquet, the effectiveness and the survival of the patient[11]. Of all the factors related to effectiveness, the correct application stands out, avoiding venous tourniquets (venous stasis without arterial compression, which leads to inflammation of the limb), which can cause a compartment syndrome[36]. Therefore, adequate training ensures correct and rapid application of the device, reducing exposure time and improving the survival of the injured[26,31,36]. Different studies have shown that patients without a tourniquet needed more blood transfusions compared to those with a tourniquet applied early, finding that such application increases survival[11,26,36]. However, a study of 190 patients from two large trauma centers found no statistically significant differences in the mortality rate between patients who received a pre-hospital tourniquet and those who did not. It should be noted that this study was limited by the small number of patients who received pre-hospital tourniquets[28].

In the civilian population, in which pre-hospital tourniquets were used, most of the cases were applied safely and effectively[26,34]. Patients who lose the pre-hospital tourniquet or it is applied late have a higher incidence of shock (85.7% vs 60%) and blood transfusions (71.4% vs 40%)[26]. However, in the study by Schroll et al. (high methodological quality)[34] no significant differences were observed between the mortality of patients who were in a state of shock and those who were not at the time of applying the tourniquet (2.7% vs 1.5%;

p > 0.05). This study was limited by the low overall mortality rate, in addition to having a small number of patients in a state of shock at the time of application. Thus, the evidence suggests that the use of a tourniquet before the onset of shock improves survival[11,26,31,36]. The use of tourniquets in military and civil prehospital settings is recommended for the control of significant limb bleeding if direct pressure is ineffective[28,34,35].

No permanent or serious adverse effects have been identified with regard to the possible complications arising from the use of the tourniquet. Pain was identified as the most common adverse effect. In the study by Kragh et al. (mean methodological quality)[24], the authors describe that along with pain there were 8 cases of nerve paralysis derived from its application that were remitting in a period of between 3 minutes and 3 days. Different authors[31,34] determined that the complications observed were not attributable to the use of the tourniquet, but rather to the severity of the injuries produced by the trauma in patients. Passos et al. (high methodological quality)[28] agree with this assertion, since they found that the use of a tourniquet did not cause a higher percentage of compartment syndrome or limb amputations, but that these effects were related to the severity of the trauma. In addition, not applying the tourniquet may increase the severity of the injury or compromise the patient's life.

As limitations of the present study, we have observed the lack of existing bibliography on this subject that provides good methodological quality, in addition to the existence of a wide variety of tourniquets that can be used for limb and joint hemorrhage. In relation to the quality of the evidence generated and the possibility of risk of bias of the selected articles, the non-randomized designs stand out as follow-up studies, with consecutive sampling systems in some occasions, but indeterminate in others, and the absence, in some cases, of a masking system that prevents to interpret if the application of the tourniquet is effective in comparison to the classic techniques of compression. Following the Cochrane recommendations[19], articles with "high" and "unclear" risk of bias were first combined and then compared with those with "low" risk.

We can conclude that in the pre-hospital environment, the use of the limb tourniquet is effective, with the SWAT-T model being the best rated. Complications from these devices are rare and most are attributable to the critical state of the patients and not to their placement. Delay in their application is a determining factor that negatively affects their effectiveness. Therefore, at an out-of-hospital level the tourniquet should be used in patients with major trauma if direct pressure is not sufficient to control a life-threatening exanguinant hemorrhage.

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