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Implant-related sepsis in lower limb fractures following gunshot injuries in the civilian population: A systematic review

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ABSTRACT

Introduction: The management of long bone lower limb fractures secondary to gunshot wounds (GSWs) in the civilian setting are complex and there is currently no consensus regarding the optimal approach to managing such fractures. This study aims to address the relationship of implant related sepsis in fractures secondary to GSWs.
Methods: A systematic review of the literature was performed on both Pubmed and Scopus databases that look at fractures caused by GSWs in the lower limb. A total of 14 studies met the inclusion criteria set in this study.
Results: Current literature suggests that low and high velocity injuries managed with internal fixation, such as intramedullary nails, may carry a low risk of superficial and deep infection, with no obvious risk of osteomyelitis. However, infection was poorly defined across all studies and no study used a validated scoring system for infection making it difficult to draw any valid conclusion on the rate of infection following internal fixation of lower limb fractures following both high and low velocity GSWs.
Conclusion: There is no clear evidence to confirm or refute that internal fixation is the ideal method of management in these complex injuries and guidance is needed due to the high and increasing proportion of patients presenting with these complex injuries worldwide.

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Introduction

The number of gun and firearm related crimes, injuries and deaths continues to increase worldwide, with a reported rise in firearm offences of 23% in the United Kingdom (UK) [1] and 9% in the United States of America (USA) [2] both between 2015–2016. In total, gun-related violence kills over 1000 people and injures millions of others worldwide everyday [3–5]. Furthermore, with the recent gun related terrorist attacks across Europe [6], there is a need for Orthopaedic and Trauma Surgeons, who have no military training or experience, to understand the management of gunshot wounds (GSWs) in the civilian population.

There is a clear difference between civilian injuries and war zone injuries caused by GSWs. GSWs in war zones are generally the result of high velocity firearms and any trauma or fractures are commonly more complex than those sustained in the civilian population [7]. War zone injuries can also be complicated by other significant injuries, such as blast injuries. Furthermore, the level of contamination and associated destruction of tissues is often worse in war zone injuries [7]. These differences make it difficult to compare the outcomes of fracture following GSWs in war zone injuries, with civilian GSWs. However, due to the paucity of available literature on the treatment of civilian GSWs, treatment protocols are often based on military experience [8].

Our institute in Cape Town, South Africa manages over 240 gunshot injuries to the lower limb per year, more than 70 with associated fractures. These numbers are similar in other trauma centres throughout South Africa [8]. Our protocol, in two large tertiary referral trauma centres in South Africa, for the management of lower limb GSW fractures is to manage the wound with a simple dressing and administer a single dose of prophylactic intravenous antibiotic (first generation cephalosporin). Wounds are not routinely debrided and simple entry and exit wounds are treated with dressings alone. Bullets and fragments are only removed if retained intra-articular or if causing mechanical symptoms. The underlying fracture is treated on its merit and internal fixation is used in a high percentage of cases.

Lower limb GSW fractures represent a significant burden to the South African health care system and this is mirrored in many low and middle-income countries (LMIC) around the world. Currently there is no clear evidence based consensus on the best way to manage these complex injuries and the management varies from country to country. Therefore, it is not known if internal fixation is a safe method of fixation for these complex injuries [9,10].

The aim of this study is to undertake a systematic review to assess the frequency of implant-related sepsis in fractures of the femur and tibia caused by GSWs in the civilian population, in order to determine if internal fixation is a safe management option for these injuries. Additionally, we aim to address if there is a role for debridement of the bullet wound and track sustained following these complex injuries.

Methods

A systematic review of the literature was carried out to identify all relevant studies that evaluated lower limb fractures caused by gunshot injuries. This was carried out in accordance to the PRISMA guidance [11]. The search was carried out on the PubMed and Scopus databases. The search strategy incorporated in each database was as follows: ((gunshot OR shotgun OR gun OR ballistic) AND fracture). The Medical Subject Headings(MeSH) terms were kept broad to maximise sensitivity.

The last search was carried out on the 08th June 2017.The search was restricted to studies in the English language, human studies and those that were produced from 1990 to present.

The inclusion and exclusion criteria of studies are shown in Table 1.

The process of the literature search is shown in Fig. 1. Two authors (SMG and MPW) performed both review of abstracts and data extraction of the included studies. Any disagreements were resolved with discussion with the two authors and senior author (WJH). A total of 14 studies were included in this systematic review. Studies that met the inclusion criteria were summarised onto a spreadsheet so that data could be extracted. The summary consisted of type of injury, study results, methods and limitations. Each study was classified based on the circumstance of injury. This was classified based on setting as civilian, war or mixed setting. Where there was no mention of the circumstance it was assumed to have taken place in a civilian setting. Only injuries occurred in a civilian setting were included in this study.

Articles were categorised according to high and low velocity injury based on the type of weapon. Injury caused by handguns were classified as low velocity as bullets fired by handguns travel under 2000 feet per second (the ballistic definition of low velocity

Table 1
Rationale for inclusion and exclusion criteria.

	Criteria	Rationale
Inclusion Criteria	Lower limb fractures	As per research question
	Any age range	To increase the number available
	Case series with >5 cases	As case reports and those studies with small sample size carry a weak evidence base.
	Studies should have a follow up period of >6 weeks	To allow sufficient time for outcomes to occur.
	Outcomes assessed should focus on infection post internal fixation	As per research question
Exclusion Criteria	Battle field management and emergency department management	Study aim is to evaluate the orthopaedic management of civilian injuries
	Follow up not mentioned	Adequate follow up is necessary to evaluate long-term outcomes.
	External fixation or conservative management	As per research question
	Foot	The aim of the study is to evaluate long bone fractures
	Intra-articular	Different management principles to long bone fractures
	Poor data presentation	Where the complication could not be traced to the lower limb or fixation.

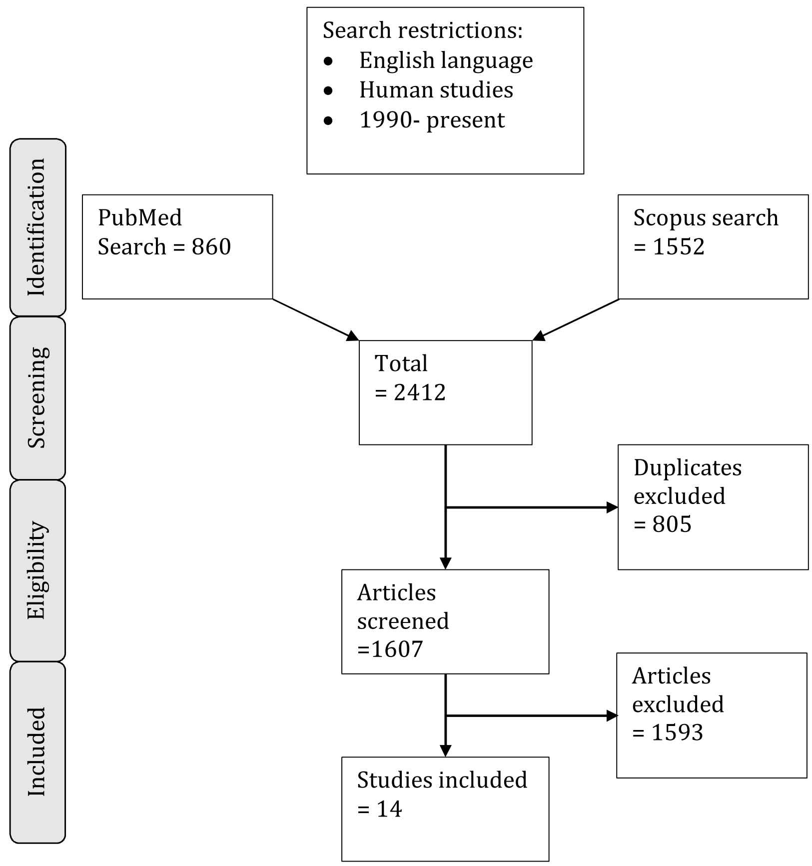

Fig. 1. Flow diagram of study inclusion.

gunshots) [8]. Those caused by shotguns were classified as intermediate velocity; whereas injury caused by military guns or hunting rifles were classified as high velocity.

Results

Low velocity injuries

We identified 8 studies that managed fractures of the lower limb with internal fixation caused by low velocity GSWs in the civilian population (Table 2) [12–20]. There was no study with a cohort of greater than 5 participants with low velocity tibial fractures that underwent internal fixation, as it did not meet the inclusion criteria of this review.

None of these studies reported wound infection using validated scores such as the ASEPSIS [21] or the Centres for Disease Control (CDC) score [22].A common theme among several of the studies was infection rates, such as superficial infection were reported without specifying the types and site of infection [15–17]. In addition, the fate of the bullets in general was poorly reported by all the studies reviewed, as most authors did not state if bullets or bullet fragments were removed during surgery. This was also true for high velocity firearms injuries.

Femur

Superficial wound infection. The CDC define superficial wound infection as an infection that affects skin and subcutaneous tissue and occur with 30 days of an operative procedure. It may result in symptoms of pain, redness, heat, swelling or purulent drainage [22].

Dougherty et al [13] reported retrospectively results of 68 patients that underwent a mix of retrograde nailing (63%) and anterograde nailing (37%), following low velocity GSWs. Patients were treated with first-generation cephalosporins from presentation to the emergency department and for 48 h post-operatively. The authors observed what they defined as a superficial wound infection in 2 patients (3%), around the bullet track in the retrograde nailing group. The author did not state if these patients had retained bullets fragments. Both were successfully treated with of antibiotics. Dougherty et al [13], confirmed that bullet fragments were removed if accessible however this was at the discretion of the surgeon and the number of patients who had this done was not reported [13], a similar approach to our units.

Cannada et al [14] reported equally encouraging results in a smaller cohort (n = 35) of patients who underwent IM nailing. In this study, bullets were removed from only 3 patients and no patients developed superficial wound infections. All patients were on a first-generation cephalosporin preoperatively and postoperatively for 48 h. Similar promising results have been reported by other researchers in smaller cohorts of patients [20].

Seng et al [12] described their experience of 7 femoral fractures that were managed with open reduction and internal fixation with plates and screws. All patients were treated with co-amoxiclav and gentamicin for 48 h. No patients developed superficial infection [12].

Several study groups did not report superficial wound infection or did not provide enough information to determine if the study cohort developed superficial infection [15–19]. Furthermore, there were no studies that reported the results of superficial wound infection or pin site infection in femur fracture fixed with external fixators.

Table 2
Low velocity gunshot wounds.

Author/ Year	Country	Follow up/ mean (range)	Type of fracture		Classification of fractures	IV Antibiotics used + length (hours)	Management	Inclusion/ exclusion criteria	Plastics and vascular input	Complications	Notes
			Tibia	Femur							
Seng et al/ 2013	France	24.4 (6–24)	–	7	Gustillo Anderson (all were II/ IIIA)	Co-amoxiclav/ co-amoxiclav and gentamicin + 48	Internal fixation – 7/7	Inclusion: Civilian ballistic fractures that does not use external fixation All diaphyseal fractures	1 had nerve surgery for sciatic nerve lesion	Infections = 0	Included fractures of other bones
Dougherty et al/ 2013	USA	33.5 (3–148)	–	68	OTA (all type 32)	1st generation cephalosporin+ 48	Anterograde IM nailing- 25/68 Retrograde IM nailing- 43/68	Inclusion: All diaphyseal fractures(OTA 32) caused by handguns and definitive fixation by antegrade or retrograde nailing Exclusion: Proximal or distal femur fractures (OTA 31/33), extensive soft tissue injury that required flap closure, shotguns, incomplete records, other treatment methods	Vascular injuries = 2/ 25 anterograde and 4/43 retrograde	Superficial infection = 2/68 (both in retrograde), Deep infections = 2/68 (1 in each group),	
Cannada et al/2009	USA	7[a]	–	35	OTA (71/74 type 32)	1st generation cephalosporin[b] + 48	Retrograde IM nailing -35/74 Initial management: 3/74 had external fixation (all with vascular injuries), 35/74 had traction (for an average of 1.3 days range 1-2 days)	Inclusion: All civilian diaphyseal fractures caused by GSWs treated with retrograde nailing	7/74 had vascular repairs	SSI = 0 Deep infection = 0 Septic arthritis = 0	Preoperative injury radiographs could not be located for 2 patients.
Nowotarski et al/1994	USA	12.5 (6–40)	–	39	Winquist-Hansen Grade IV = 21; Grade III = 9; Grade II = 6 3 long spiral fractures	1st generation cephalosporin + 48	Intramedullary nailing – 39 (32 first generation nails, 2 had additional lag screw; 7 had second generation reconstruction nails) 10 subtrochanteric 6 isthmal 15 infraisthmal 6 supracondylar 2 T condylar Russell Taylor 18, Delta femoral 14, reconstruction 3, delta reconstruction 4 Immediate nailing	Inclusion: IM nailing within 18 hours, complete radiographic and clinical follow up available to union, minimum follow up of 6 months, shotgun or high velocity rifle injuries excluded.	1/39 Peroneal nerve palsy 2 /39 vascular repair 1/39 required vascular grafting	Deep infection = 0% Osteomyelitis = 1 (grade IV)	
	USA		–	38							

Table 2 (*Continued*)

Author/ Year	Country	Follow up/ mean (range)	Type of fracture		Classification of fractures	IV Antibiotics used + length (hours)	Management	Inclusion/ exclusion criteria	Plastics and vascular input	Complications	Notes
			Tibia	Femur							
Tornetta et al/1994		24 (14–36)			Basic: 12 spiral, 26 communited Winquist-Hansen Grade II = 5; Grade III = 8; Grade IV = 25 Gustillo Anderson: I = 36 II = 1 IIIa = 1	1st generation cephalosporin[c] +48	Anterograde interlocking nailing Fracture extended to within 8 cm of the distal femoral ephiphyseal scar All treated with locked reamed nail Reason not stated	Inclusion: Extraarticular distal femoral fractures with anterograde interlocked IM nailing	0/38 required repair	Deep infections = 0, Cellulitis at insertion site = 1,	31/33 pts low velocity but cannot trace complication to the type of injury. 8/38 had additional fractures
Levy et al/ 1993	USA	17.4 (6–36)	–	32	Winquist-Hansen Type I = 4; Type II = 6; Type III = 8; Type IV = 14.	Type N/M +48-72	Reamed IM nailing 32/32 (1 had cerclage wiring) A Grosse-Kempf nail/ russel-Taylor nail used 27 statically locked 4 distally locked 1 proximally locked	Inclusion: All femoral shaft fractures caused by low velocity GSW treated with immediate reamed IM nailing	3/32 needed repair	Infections = 0	17/32 had multiple GSWs
Wright et al/1993	USA	12 (6–39)	–	18	Winquist-Hansen- 15 with grade III/IV	1st generation cephalosporin preoperative and 48 hours postoperative	Closed nailing -15/18 ORIF- 3/18 Russell Taylor implants with static interlocking Immediate Immediate <16 hours from admission	Inclusion/ exclusion criteria not stated	1 /18 required vascular repair 1/18 injury to the sciatic nerve that resolved without treatment	Deep infection = 0 Osteomyelitis = 0,	5/18 had multiple GSWs
Wiss et al/ 1991	USA	16 (12–29)	–	56	Winquist-Hansen Grade III/ IV = 52 Grade II = 4	1st generation cephalosporin for 72 hours (time interval not specified)	Gross-Kempf nail -56/56 (Closed IM nailing in 50, modified open nail in 6) (Method- static interlocking nailing in 52, dynamic interlocking with proximal screws in 3, dynamic interlocking with distal crews in 1) static interlocking nail was converted to dynamic nailing in 7 All femoral shaft fractures Delayed nailing = 14	Inclusion/ exclusion criteria not stated	5 vascular repairs 5 peripheral nerve (injury management not explained)	Deep infection = 0 Osteomyelitis = 0	
Hollmann et al/ 1990	USA	20 (4–10)	–	19	Winquist-Hansen Grade II = 5, Grade III = 5, Grade IV = 6 3 long spiral fractures.	1st generation cephalosporin+ 48[c]	Delayed by an average of 9 days. Closed IM nailing in 17/19 Open nailing 2/ 19 (with Gross-	Inclusion: Femoral fractures caused by low velocity bullets (<2000 feet/s)	0/19 required vascular repair	Superficial infection = 1 Deep infection = 0 Osteomyelitis = 0	

Table 2 (*Continued*)

Author/ Year	Country	Follow up/ mean (range)	Type of fracture		Classification of fractures	IV Antibiotics used + length (hours)	Management	Inclusion/ exclusion criteria	Plastics and vascular input	Complications	Notes
			Tibia	Femur							
							Kempf nail and cerclage wiring)	Excluded High velocity or shotgun Fractures associated with major vascular injuries treated with external fixation			

GSWs- gunshot wounds; SSI- surgical site infection.
[a] There were 74 in initial sample but only 35 that were followed up for 7 months.
[b] or an equivalent antibiotic for Gram-positive bacteria in patients with a hypersensitivity.
[c] 3 patients had anaerobic cover for 72 h.

Deep infection. Deep infection as defined by the CDC is an infection one that involves the fascial or muscle layers and usually occurs between 30–90 days post-surgery. It presents with pain, fever, or tenderness and may result in an abscess, purulent drainage or spontaneous wound dehiscence [22].

Among the 68 cases Dougherty et al [13] retrospectively studied there was a 3%(n = 2) rate of deep wound infection. Both patients had sustained large soft tissue injuries and had received first-generation cephalosporin for 48 h post-operatively. They were successfully treated with antibiotics and one patient required debridement with irrigation and antibiotics but no removal of metal work was required in either patient. Patients were followed up for an average of 33.5 months (range 3–148) [13].

Further researchers, Wiss et al [19] (n = 56), Nowotarski et al [15] (n = 39),Tornetta et al [16] (n = 38) and Wright et al [18] (n = 18) reported retrospective studies that managed patients with IM nailing and demonstrated 0% rate of deep infection. All these patients were treated with a cephalosporin for at least 48 h postoperatively.

Septic arthritis. Two authors evaluated septic arthritis in patients managed with intra-medullary nailing of the femur [13,14]. Dougherty et al [13] defined septic arthritis as a positive culture on an aspirate or if a patient had to returned to theatre for irrigation and debridement of the joint. This was the primary outcome of this study, which compared retrograde nailing, and antegrade nailing of the femur. There were no cases of septic arthritis of the knee or hip in either group over the average follow up of 33.5 months [13].

Cannada et al [14] reported a 0% rate of septic arthritis of the knee or hip, in the cohort of patients (n = 35) that underwent retrograde nailing of the femur. Patients were followed up for 7 months. However, the diagnosis of septic arthritis was not defined by authors [14].

Osteomyelitis. Osteomyelitis was reported in four studies [15,18–20] although the definition of osteomyelitis was not provided by any author. Nowotarski et al [15] reported one case of osteomyelitis (3%) among the 39 patients who underwent IM nailing in a retrospective study. The patient that developed osteomyelitis had a Winquist-Hansen grade IV femoral fracture. This patient was initially started on oral antibiotics, and underwent exchange nailing, which led to fracture union. This patient was classified as a deep infection by the authors, however the description given suggests it was in fact osteomyelitis or late implant infection, using the CDC definition for deep infection.

Additional research groups report 0% rates of osteomyelitis in study cohort sizes between 18–56, with a minimum average follow-up of 12 months (total range 4–39 months) [18–20].

High velocity injuries

There was only one study [23] that evaluated management of civilian gunshot injuries to the lower limb as the result of high

Table 3
High velocity Gunshot wounds.

Author/ Year	Country	Follow up/ mean (range)	Number of procedures		Classification of fractures	IV Antibioticsused + length (hours)	Management	Inclusion/ exclusion criteria	Plastics and vascular input	Complications
			Tibia	Femur						
Ali/ 2008	Pakistan	(18–30)	–	68	Gustillo Anderson IIIa = 68/68 Winquist-Hansen II = 12/68 III = 22/68 IV = 34/68	First generation cephalosporin and aminoglycosides given IV + 72	Closed interlocking nails = 64 /68 Open interlocking nails = 4/68 Dynamic nail = 10 static nail = 58 (10 of these were converted to dynamic from 24–30 weeks post-surgery to achieve union) Initially all patients were put in traction	Inclusion: Femoral shaft fracture due to high velocity GSW Excluded: Intertrochanteric, supracondylar femoral fractures Gustillo Anderson type IIIB and IIIC	Peripheral nerve injuries in 6/68	Infections = 7/68 (3 superficial 4 deep all caused by bullet track), Osteomyelitis = 0

GSWs- gunshot wounds.

Table 4
Ambiguous studies.

Author/ Year	Country	Follow up/ mean (range)	Number of procedures		Classification of fractures	IV Antibiotics used + duration (hours)	Management	Inclusion/ exclusion criteria	Plastics and vascular input	Complications	Notes
			Tibia	Femur							
Ferraro et al /1995	USA	N/M[a]	90	–	Winquist-Hansen 0/I/ II = 52/90 III = 24/90 IV/V = 14	N/M[b]	Unreamed locked IM nail = 15/90 Long leg casting = 58/90 External fixation = 17/90	Inclusion: Gunshot tibial fractures Excluded: Fractures within 4 cm of knee or ankle	Vascular injuries = 5/90 Nerve injuries = 2/90 2 /16 external fixation needed muscle flap and split thickness skin graft	Deep infection = 0	Mechanism if civilian or war injuries not clear
Perry et al /1995	USA	14	29	29	N/M	N/M	Femur ORIF = 8/29 Tibial ORIF = 4/29 Open debridement = 32/ 67 Arthroscopic debridement = 4/67 Patella fractures=9 .	Inclusion: GSWs to knee between femoral metaphysis and tibial metaphysis	4 needed vascular repair 2 peripheral nerve injuries (1 resolved)	Superficial infection = 1/8 (Femoral ORIF) Deep infection = 0	Mechanism if civilian or war not mentioned
Nicholas et al /1995	UK	21.6 (9–39)	–	14	Winquist-Hansen All grades III/ IV	N/M initiated on admission + 120	All closed statically locked IM nailing with Grosse Kempf nails	Inclusion: Femoral shaft fractures of any velocity	Vascular injuries = 3 (femoral arterial injuries that needed reverse vein graft)	Superficial infections = 2/14 Deep infections = 0/14	Mixed velocity
Bergman et al/ 1993	USA	24 (9.5–72)	–	65	Winquist-Hansen Grade III/ IV = 64/65 Grade II = 1/ 65	Cephazolin + 48[c]	Statically locked reamed IM nailing = 62/ 65 Statically locked reconstruction nail = 3/ 65 Initial management = traction All Grosse Kempf nail	Inclusion: Femoral fractures caused by GSWs treated with intramedullary nail	Vascular repair = 1/65 Arteriograms = 48/65	Acute infection = 0 Chronic infection = 0 Persistent drainage of serous fluid from bullet entry wound = 2 (stopped after antibiotics)	Velocity: 2 low 4 medium 4 high Rest speed not determined

GSWs- gunshot wounds.
[a] Does not mention time of follow up but states that all fractures were followed till healing.
[b] Antibiotics given but not specified.
[c] 20 patients had aminoglycoside antibiotics continued till 48 h post-surgery. Overall 4 days (1–15 range).

velocity injuries (Table 3). No studies reported results in tibia fractures. Again, none of the studies used a validated method to describe wound infection. Deep wound infection and septic arthritis were not reported as complications by the authors.

Femur

Superficial wound infection. Ali et al [23] studied 68 patients who sustained high velocity GSW, that underwent interlocking nailing. Ninety-four per cent of patients were managed with closed interlocking nailing while 6% patients required open nailing as the guide wire could not be passed across the fracture. There was a 4% (n = 3) rate of superficial infection, all occurring in the bullet track and were treated with antibiotics and daily dressings. All patients were given first generation cephalosporin and aminoglycosides intravenously for 72 h. Authors did not state at what time interval the antibiotics were administered [23].

Osteomyelitis. Ali et al [23] reported a 6% (n = 4) rate of osteomyelitis in their cohort of 68 patients, but failed to give a clear definition of osteomyelitis. Two patients resolved with the administration of antituberculosis drugs. The other two patients with chronic discharge and signs of delayed union underwent excision of the infection track with curettage of fracture site, bone grafting and dynamisation at an average of 34 weeks post operatively. The source of infection was the bullet track in all cases and the fate of the bullet was not described. The follow-up period for this cohort was between 18–30 months [23].

Ambiguous studies

Four studies reviewed did not clarify if the patients' fractures were caused by low or high velocity firearms [24–27]. Another two studies [24,25] did not present the type of weapon that caused the injury (Table 4). Nicholas et al [26] and Bergman et al [27] did not map the complications to the firearm velocity. None of these studies commented on the rate of septic arthritis, osteomyelitis or late implant sepsis.

Ferraro et al [24] managed 90 tibial fractures by casting (64%), external fixation (18%) and unreamed intramedullary locking nail (16%). There were 5 cases with vascular injuries and all patients were given intravenous antibiotics where the type, length and interval was not stated. Eight patients (with 6 in the casting group) underwent extensive irrigation and debridement and were admitted for 72 h of intravenous cephalosporin. The rest were discharged on oral antibiotics. Among those that underwent nailing, there was a 0% rate of deep infection [24].

Perry et al [25] studied 29 tibial, and 29 femoral fractures following gunshot injuries. Eight femoral fractures underwent ORIF and 4 tibial fractures were managed with ORIF or fine wire external fixation (distribution not described by authors). All other fractures were conservatively managed. Thirty six patients required irrigation and debridement. Since there were 9 patella fractures included in the original sample, the bone distribution of irrigation and debridement could not be accurately determined. In addition, the number of procedures did not add up to the sample size and the use of antibiotics was not detailed by the authors. The rate of superficial infection among the femurs was 13%(n = 1) which was internally fixed and this patient underwent multiple debridement with IV antibiotics. The rate of superficial infection among the tibial fractures was 0%. The rate of deep infection in the tibial and femoral fractures were 0% [25].

Nicholas et al [26] studied a cohort of 14 femoral fractures that were managed with closed intramedullary nails and consisted of mixed velocity injuries. All patients were started on unspecified intravenous antibiotics upon admission and were continued for 120 h. There were 3 cases with arterial injuries, two required grafts and the other underwent a below the knee amputation. There were 2 superficial infections (14%) that resolved with antibiotics, and no deep infections [26].

Bergman et al [27] studied a cohort of mixed velocity GSWs of 65 femoral fractures however, the distribution of velocity of the fractures was determined in only 10 patients. Two patients had a low velocity injury, 4 patients each sustained intermediate and high velocity injuries. Patients were treated with statically locked intramedullary nailing 95% (n = 62) and statically locked reconstruction nail 5%(n = 3). One patient required vascular repair. All patients were given intravenous cephazolin on admission and 31% had an aminoglycoside. The antibiotics were continued for 48 h postoperatively and patients were on antibiotics for an average of 96 h. There were no cases of infection (acute or chronic as stated by the authors). However, authors did report a persistent serous discharge from 2 bullet wounds that halted after further antibiotic administration. This was not classified as an infection as it did not meet any of the CDC criteria for wound infection [27].

Discussion

Only four groups [13,19,23,27] reported studies with large sample sizes (N > 55) that evaluated the management of fractures of the lower limb caused by GSWs. The general trend of management was intramedullary nailing of low energy GSWs and external fixation for high-energy injuries.

All researchers treated patients with a course of antibiotics for between 48–72 hours, except Nicholas et al [26] who treated patients with antibiotics from admission and was continued for 120 h. There was no clear consensus on the optimal duration or type of antibiotic across the studies making it difficult to draw a clear conclusion on the best duration of antibiotic use. There are no studies that do not use antibiotics, or use a single dose, to compare these results against. However, low rate of deep infection amongst low velocity injuries are shown with the use of postoperative IV antibiotics, as seen amongst the femoral fractures that required IM nailing. The synergistic use of gram negative cover has no effect on reducing infection rates. This has been confirmed in a systematic review by Papasoulis et al [28].

A survey based study [29] that looked into antibiotic preference among surgeons in the Orthopaedic Trauma Association(OTA) showed that 86% surgeons administered antibiotics for those with fractures caused by low velocity GSWs. This decision was not guided by institutional protocol. However, this survey did not specify if the fractures were treated non-operatively or operatively [29].

The evidence for the use of open reduction and internal fixation with plates are lacking, as only one report of this has been described [12].

In high-energy GSWs, the superficial and deep infection rates were low (4%) in femoral fractures treated with intramedullary nails [23]. This was regardless if patients were treated in synergy with first generation cephalosporin and aminoglycoside. Evidence for this comes from only one study each antibiotic regime.

In high income countries where femurs undergo intramedullary nailing for trauma, the rate of superficial and deep infection is approximately 21% [30], with all patients receiving intravenous antibiotics pre and postoperatively. In the low income setting the reported rate of infection was 7% [31] among femurs that were treated with intramedullary nails and 99% of patients received preoperative antibiotics.

Miric et al [32] managed 17 femoral fractures with pelvifemoral external fixators and reported a 6%(n = 1) rate of deep pin track infection and a 12%(n = 2) rate of chronic osteomyelitis. All patients received perioperative antibiotics with a cephalosporin and gentamicin. To our knowledge, there is no comparative study comparing the use of external fixators for femur fractures following GSWs.

None of the studies produce information regarding late implant sepsis in the lower limb. Low energy carries no risk of osteomyelitis or chronic infection, with the evidence base predominantly supporting femurs treated with intramedullary nailing [18–20]. In high energy injuries, there remains a low level of osteomyelitis [23] with nailed femurs.

Overall, infection was poorly defined across all studies and no study used a validated scoring system for infection. Additionally, late implant sepsis was not looked into by any study. As a result, it is difficult to draw any valid conclusion on the rate of infection following internal fixation of lower limb fractures following GSW.

Limitations of the literature

There are a number of limitations in the study design, length of follow-up and outcome measures used to assess infection in the majority of studies reviewed. Additionally, it is possible that some studies may have misclassified complications in instances where a definition of the outcome was not stated. This is evident in one study [15] where osteomyelitis was misclassified as a deep infection. Most studies were carried out in developed nations such as USA and the UK, except the one study that looked in to high velocity injuries that was carried out in Pakistan. With reference to individual studies, individual risk factors for infection were not explored by authors. Additionally, the fate of the bullets was not adequately described in most studies.

Conclusions

With the number of gun and firearm related crimes, injuries and deaths continuing to increase worldwide [3–5] there is a genuine need to undertake a prospective study investigating the rate of implant sepsis in lower limb fractures following GSWs. Currently there is no clear evidence to confirm or refute that internal fixation is the correct method of management in these complex injuries and guidance is needed due to the high and increasing proportion of patients presenting with these complex injuries worldwide.

Conflicts of interest

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Ethical approval

Not applicable; as this is a systematic review.

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References

[1] Office for National Statistics. Crime in England and Wales: year ending March 2017. Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/crimeandjustice/bulletins/crimeinenglandandwales/yearendingmar2017.
[2] Gun violence archive, 2017. Available from: http://www.gunviolencearchive.org/past-tolls.
[3] United Nations general assembly. Report of the panel of governmental experts on small arms. General and complete disarmament: small arms. Available from:. 1997. https://www.un.org/Depts/ddar/Firstcom/SGreport52/a52298.html.
[4] United Nations office on drug and crime. Global study on homicide. Homicide statistics 2013; homicide counts and rates time series 2000–2012. UNODC Homicide Stat. Available from: https://www.unodc.org/gsh/en/data.html.
[5] Geneva Decleration Secretariat. Global burden of armed violence. Available from:. 2015. http://www.genevadeclaration.org/measurability/global-burden-of-armed-violence/global-burden-of-armed-violence-2015.html.
[6] Hirsch M, Carli P, Nizard R, Riou B, Baroudjian B, Baubet T, et al. The medical response to multisite terrorist attacks in Paris. Lancet 2015;386:2535–8.
[7] Giannou C, Baldan M. War Surgery: working with limited resources in armed conflict and other situations of violence. Int Committee Red Cross 2010.
[8] Swanepoel S, Chivers D, Leong W, Laubscher M, McCollum G, Maqungo S. Intramedullary nailing of subtrochanteric femur fractures caused by low velocity gunshots. SA Orthop J 2017;16:46–50.
[9] Nanchahal J, Nayagam S, Khan U, Moran C, Barrett S, Sanderson F, et al. Standards for the management of open fractures of the lower limb. R Soc Med Press 2009.
[10] Hauser CJ, Adams CA, Eachempati SR. Surgical Infection Society guideline: prophylactic antibiotic use in open fractures: an evidence-based guideline. Surg Infect (Larchmt) 2006;7:379–405.
[11] The Prisma Group from Moher D, Liberati A, Tetzlaff JAD. Preferred reporting items for systematic reviews and meta analyses: the Prisma Statement. PLoS Med 2009;6:1–15.
[12] Seng VS, Masquelet AC. Management of civilian ballistic fractures. Orthop Traumatol Surg Res 2013;99:953–8.
[13] Dougherty PJ, Gherebeh P, Zekaj M, Sethi S, Oliphant B, Vaidya R. Retrograde versus antegrade intramedullary nailing of gunshot diaphyseal femur fractures trauma. Clin Orthop Relat Res 2013;471:3974–80.
[14] Cannada LK, Jones TR, Guerrero-Bejarano M, Viehe T, Levy M, Farrell ED, et al. Retrograde intramedullary nailing of femoral diaphyseal fractures caused by low-velocity gunshots. Orthopedics 2009;32:162.
[15] Nowotarski P, Brumback RJ. Immediate interlocking nailing of fractures of the femur caused by low- to mid-velocity gunshots. J Orthop Trauma 1994;8:134–41.
[16] Tornetta P, Tiburzi D. Anterograde interlocked nailing of distal femoral fractures after gunshot wounds. J Orthop Trauma 1994;8:220–7.
[17] Levy AS, Wetzler MJ, Guttman G, Covall DJ, Fink B, Whitelaw GP, et al. Treating gunshot femoral shaft fractures with immediate reamed intramedullary nailing. Orthop Rev 1993;22:805–9.
[18] Wright DG, Levin JS, Esterhai JL, Heppenstall RB. Immediate internal-fixation of low-velocity gunshot-related femoral fractures. J Trauma-Injury Infect Crit Care 1993;35:678–82.
[19] Wiss DA, Brien W, Becker V. Interlocking nailing for the treatment of femoral fractures fue to gunshot wounds. J Bone Joint Surg Am 1991;73:598–606.
[20] Hollmann MW, Horowitz M. Femoral fractures secondary to low velocity missiles: treatment with delayed intramedullary fixation. J Orthop Trauma 1990;4:64–9.
[21] Byrne DJ, Malek MM, Davey PG, Cuschieri A. Postoperative wound scoring. Biomed Pharmacother 1989;43:669–73.
[22] National Healthcare Safety Network Centers for Disease Control and Prevention. Surgical Site Infection (SSI) event.
[23] Ali MA, Hussain SA, Khan MS. Evaluation of results of interlocking nails in femur fractures due to high velocity gunshot injuries. J Ayub Med Coll Abbottabad 2008;20:16–9.
[24] Ferraro SP, Zinar DM. Management of gunshot fractures of the tibia. Orthop Clin North Am 1995;26:181–9.
[25] Perry DJ, Sanders DP, Nyirenda CD, Lezine-Hanna JT. Gunshot wounds to the knee. Orthop Clin North Am 1995;26:155–63.
[26] Nicholas RM, McCoy GF. Immediate intramedullary nailing of femoral shaft fractures due to gunshots. Injury 1995;26:257–9.
[27] Bergman M, Tornetta P, Kerina M, Sandhu H, Simon G, Deysine G, et al. Femur fractures caused by gunshots: treatment by immediate reamed intramedullary nailing. J Trauma 1993;34:783–5.
[28] Papasoulis E, Patzakis MJ, Zalavras CG. Antibiotics in the treatment of low-velocity gunshot-induced fractures: a systematic literature review. Clin Orthop Relat Res 2013;471:3937–44.
[29] Marecek GS, Earhart JS, Gardner MJ, Davis J, Merk BR. Surgeon preferences regarding antibiotic prophylaxis for ballistic fractures. Arch Orthop Trauma Surg 2016;136:751–4.
[30] Malik MHA, Harwood P, Diggle P, Khan SA. Factors affecting rates of infection and nonunion in intramedullary nailing. J Bone Joint Surg Br 2004;86:556–60.
[31] Young S, Banza LN, Hallan G, Beniyasi F, Manda KG, Munthali BS, et al. Complications after intramedullary nailing of femoral fractures in a low-income country. Acta Orthop 2013;84:460–7.
[32] Miric DM, Bumbasirevic MZ, Senohradski KK, Djordjevic ZP. Pelvifemoral external fixation for the treatment of open fractures of the proximal femur caused by firearms. Acta Orthop Belg 2002;68:37–41.