

# Transarticular gunshot injuries: a systematic review of 150 years of management

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## Abstract

### Background

This review aims to collate all published work on the management of transarticular gunshot injuries to better inform decision-making when managing these injuries.

### Methods

A systematic review using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) was undertaken. A literature search of major electronic databases was conducted to identify journal articles relating to the management of transarticular gunshot injuries published from database inception until 31 January 2021.

### Results

Sixty-eight publications reporting on the management of 544 patients were included. Injuries to the lower limbs were reported in 438 cases (81%), while injuries to the upper limb accounted for 106 cases (19%). A total of 145 patients (27%) developed a deep infection. Following the routine use of antibiotics, 6% of patients (14/251) developed an infection. A significantly higher hip joint infection rate was seen in patients who sustained associated hollow viscus injury (11/30, 37%).

### Conclusion

The management of transarticular gunshot injuries is currently based on limited high-quality evidence. Modern antibiotic and surgical management practices have resulted in low overall septic complications; however, different joints have different injury and complication profiles. Future research should be aimed at identifying joint-specific evidence-based care pathways.

**Level of evidence:** Level 4

**Keywords:** gunshot, ballistic, joint, transarticular, intra-articular

## Introduction

The global surge in civilian gun-related violence has focused a need for evidence-based management protocols.<sup>1-3</sup> At present, the management of transarticular gunshot injuries remains controversial, with limited high-quality research to guide evidence-based management. Controversies regarding the need for surgical debridement, the long-term local and systemic effects of retained bullets or bullet fragments, the choice and duration of antibiotic therapy, and the management of intra-articular fractures remain.<sup>4-9</sup>

This systematic review explores the literature reporting on the treatment of transarticular gunshot injuries and aims to interpret the data to provide physicians with evidence to guide the management of these cases.

## Methods

A systematic review using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) was undertaken.

The review was prospectively registered on the PROSPERO database (CRD42021233384).

### Search strategy for the identification of relevant studies

A literature search of databases was conducted and included Medline, Scencedirect, Articlefirst, SA ePublications Journal collection and Web of Science. The search terms included 'gunshot', 'ballistic', 'bullet', 'joint', 'intra-articular' and 'transarticular' with the Boolean terms 'AND' and 'OR'. Searches were conducted from database inception to 31 January 2021 and were limited to human participants and publications in English. A manual search of the reference list of included studies was also undertaken to identify other studies meeting the inclusion criteria.

### Inclusion and exclusion criteria

The PICOTT framework was used to develop the inclusion and exclusion criteria (*Table 1*).

**Table 1:** Eligibility criteria developed according to the PICOTT framework

	Inclusion	Exclusion
Population	<ul style="list-style-type: none"> <li>All patients treated for transarticular gunshot injuries. Included joints: shoulder, elbow, radiocarpal, hip, knee, and ankle</li> <li>All bony and soft tissue injuries</li> <li>Patients presenting at any time point after injury</li> </ul>	<ul style="list-style-type: none"> <li>Gunshot injuries to the small joints of the hand and foot, sacroiliac joints and spine</li> <li>Gunshot injuries not traversing a large joint</li> <li>Joint-penetrating injuries other than from gunshots</li> </ul>
Intervention	<ul style="list-style-type: none"> <li>Gunshot injuries that traversed any of the following joints: shoulder, elbow, radiocarpal, hip, knee, ankle</li> <li>Any medical treatment would be included, including operative and nonoperative treatment</li> </ul>	
Control	Different management strategies identified in the review would serve as controls	
Outcome	Studies reporting on outcomes in terms of infection, fracture union, arthropathy and systemic complications	
Type of question	Therapeutic and prognostic	
Type of study (design)	All observational and interventional study designs were considered for inclusion	<ul style="list-style-type: none"> <li>Technical articles</li> <li>Review articles</li> <li>Non-peer-reviewed</li> <li>Opinion pieces</li> </ul>

### Study selection

Identified records were downloaded into Mendeley Desktop (version 1.19.4) and deduplicated. Titles were screened by a single reviewer (NF). Abstracts and then full texts were independently screened by two researchers (NF, CA) against the eligibility criteria, and any discrepancies were resolved through discussion.

### Quality assessment

Included articles were assigned a level of evidence according to Sackett's rules of evidence that rank studies according to the probability of bias.<sup>10</sup>

### Data extraction and synthesis

Data extracted from the included studies were captured in Microsoft Excel for Mac (version 16.45). Information relating to the joint involved, injury characteristics, treatment instituted, and complications/outcomes were collected. Additionally, the following information was listed for all articles: research theme, year of

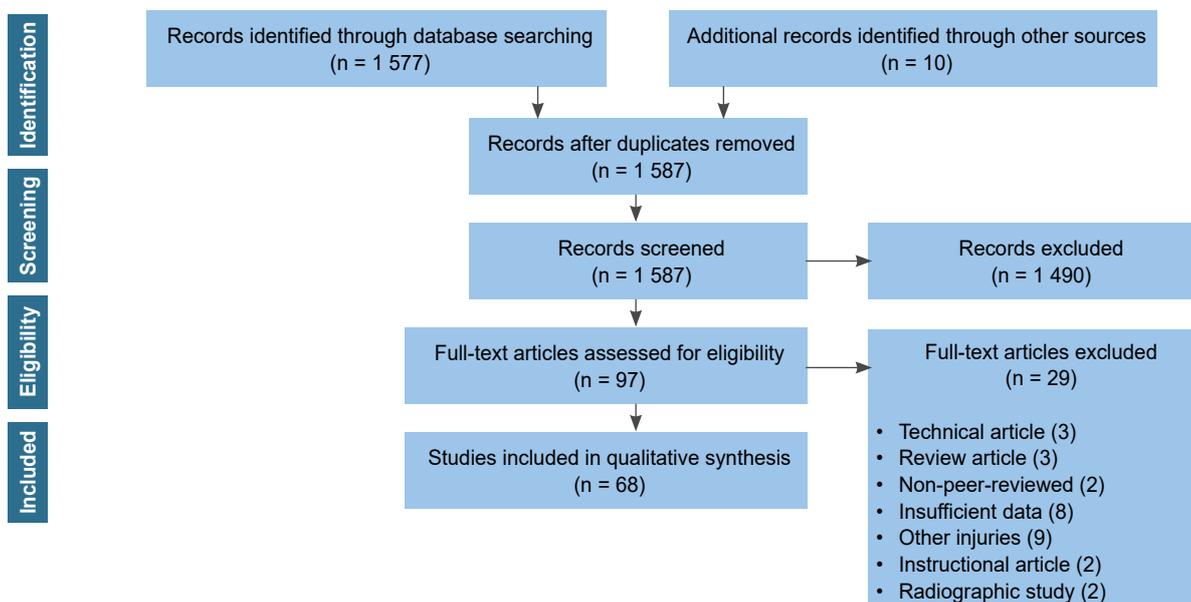
publication and geographic origin. A qualitative synthesis of studies with sufficient homogeneity was performed, while a narrative descriptive synthesis was used for the remaining data.

## Results

The search strategies identified 1 587 references after deduplication. Full-text review of 97 studies resulted in 68 publications being retained for final review (Figure 1).

### Study characteristics

The included studies spanned 153 years and were published between 1867 and 2020, with a marked increase in publications over the last two decades (Figure 2).<sup>11-79</sup> Ten studies were published before 1944 (pre-antibiotic era), with the remaining 58 being published in the antibiotic era. The United States of America (n = 29) and the United Kingdom (n = 11) contributed the bulk of the publications (n = 40, 60%) (Figure 3).<sup>11-23,26,28-30,33,34,36,38-40,44,46,48,49,52,64,65,66</sup> The majority of publications consisted of case



**Figure 1.** Flow diagram showing the identification and selection of studies

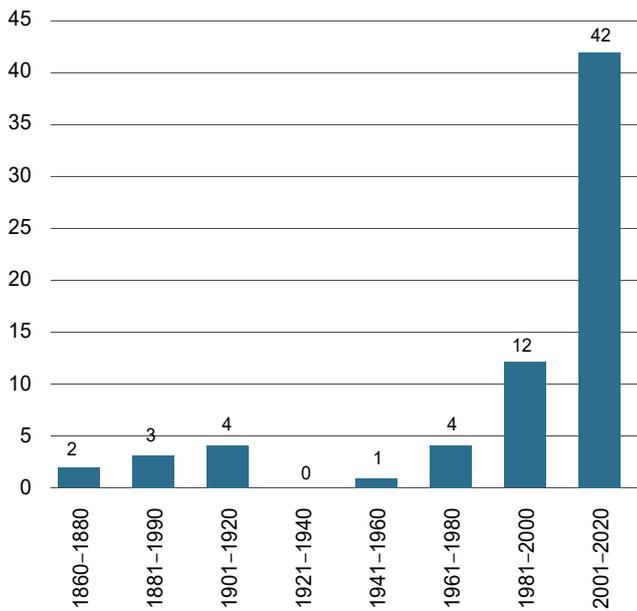


Figure 2. The number of publications per vicennial interval

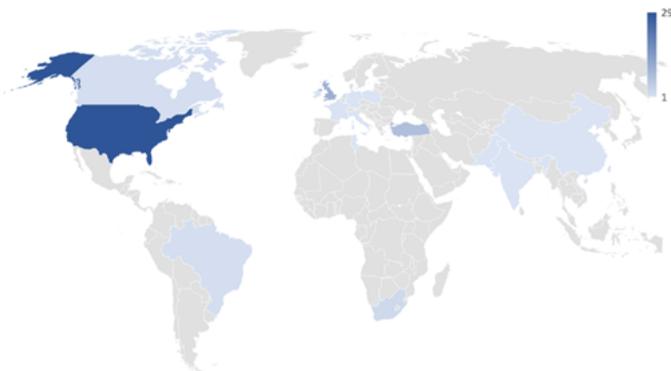


Figure 3. Geographic distribution of country of origin of publications

studies (n = 45, 66%), while 22 (32%) were retrospective case series.<sup>11-60,62-79</sup> Only one randomised control trial was included.<sup>61</sup> According to Sackett's rules of evidence, the included studies consisted of one level 2, 22 level 3 and 45 level 4 studies.<sup>10</sup>

The research themes for the included articles broadly fell into three categories:

1. The management and outcome of acute injuries (n = 22)
2. The presentation and management of late complications (n = 23)
3. Bullet extraction techniques (n = 23)

### Cumulative results of included cases

Sample sizes of the included papers ranged from 1 to 86 cases and included 544 transarticular gunshot injuries. Injuries to the lower limbs were reported in 438 cases (81%), while injuries to the upper limb accounted for 106 cases (19%) (Figure 4). Two hundred and seventy-nine patients (51%) sustained an intra-articular fracture, and 490 patients (90%) underwent surgical debridement as part of their management. A total of 145 patients (27%) developed a deep infection because of their injury. The mean follow-up for the entire cohort was four months, ranging from 0 to 142 months.

Retained intra-articular bullets or bullet fragments were reported in 198 patients (36%). Lead arthropathy due to retained bullet fragments was diagnosed in 24 patients (12%) and was seen after gunshots to 16 hips, three knees, two ankles, two wrists and one shoulder.<sup>21,22,28,30,50,54,58-60,63,65,69,71,73,76,77,79</sup> These patients presented at a median of 42 months (range 3-624) following the

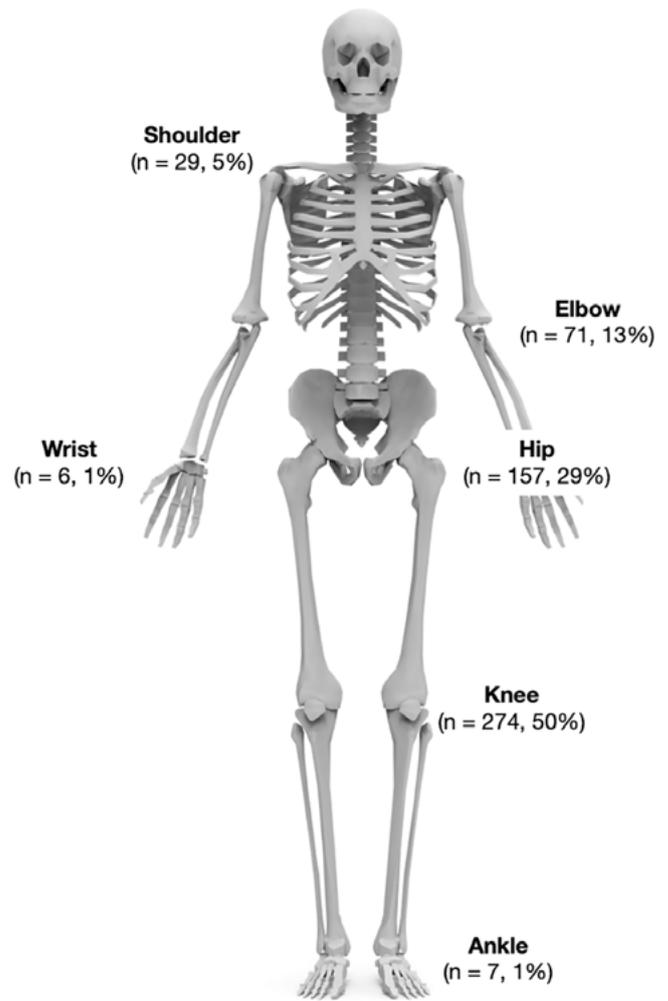


Figure 4. Anatomical site distribution of included cases

injury. All patients underwent surgical joint exploration and bullet removal, including total joint arthroplasty in 15 patients (14 total hip arthroplasty, one total shoulder arthroplasty) and joint arthrodesis for two patients (one radiocarpal joint and one ankle). All papers reported good functional outcomes following arthroplasty for lead arthropathy.

Eleven patients (6%) presented with systemic lead toxicity at a median of 82 months (range 8-624) following the initial injury.<sup>21,54,58,60,65,69,71,73,77</sup> All patients who developed systemic lead toxicity were also diagnosed with lead arthropathy due to retained intra-articular bullets or bullet fragments. Involved joints included seven hips, two ankles, one knee and one wrist. Seven patients were commenced on chelation therapy at presentation and, following bullet removal, the systemic complications resolved in all cases. The intra-articular bullet was not removed in one patient, and this patient returned two years later with repeat acute systemic lead toxicity.<sup>69</sup>

Reviewing the management outcomes of acute presenting cases, a clear difference in septic complications is seen between the pre-antibiotic and antibiotic eras. Before the routine use of antibiotics, 52% of patients (39/75) developed an infection compared to 6% (14/251) following the widespread use of antibiotics. However, many of the initial papers reported on patients already infected at the time of presentation. All reported sepsis-related deaths (n = 9) and amputations (n = 25) also occurred before the routine use of antibiotics (Table II). During this period, management generally consisted of repeat open debridements, joint excision or amputation and daily antiseptic solution irrigation.

Table II: Complications following transarticular gunshot injuries

	Cases (n)	Retained bullet (n, %)	Plumbism (n, %)	Lead arthropathy (n, %)	Sepsis (n, %)	Amputation (n, %)	Death (n, %)
<b>Hip</b>	<b>157</b>	<b>82, 52%</b>	<b>7, 4%</b>	<b>16, 10%</b>	<b>17, 11%</b>	<b>0, 0%</b>	<b>0, 0%</b>
Pre-antibiotic era	0	0, 0%	0, 0%	0, 0%	0, 0%	0, 0%	0, 0%
Antibiotic era	157	82, 52%	7, 4%	16, 10%	17, 11%	0, 0%	0, 0%
<b>Knee</b>	<b>274</b>	<b>91, 33%</b>	<b>1, 0.4%</b>	<b>3, 1%</b>	<b>45, 16%</b>	<b>23, 4%</b>	<b>7, 3%</b>
Pre-antibiotic era	156	47, 30%	0, 0%	0, 0%	43, 28%	23, 15%	7, 4%
Antibiotic era	118	44, 37%	1, 1%	3, 3%	2, 2%	0, 0%	0, 0%
<b>Ankle</b>	<b>7</b>	<b>2, 29%</b>	<b>2, 29%</b>	<b>2, 29%</b>	<b>0, 0%</b>	<b>0, 0%</b>	<b>0, 0%</b>
Pre-antibiotic era	0	0, 0%	0, 0%	0, 0%	0, 0%	0, 0%	0, 0%
Antibiotic era	7	2, 29%	2, 29%	2, 29%	0, 0%	0, 0%	0, 0%
<b>Shoulder</b>	<b>29</b>	<b>13, 45%</b>	<b>0, 0%</b>	<b>1, 3%</b>	<b>4, 14%</b>	<b>0, 0%</b>	<b>1, 3%</b>
Pre-antibiotic era	7	7, 100%	0, 0%	0, 0%	1, 14%	0, 0%	1, 14%
Antibiotic era	22	6, 27%	0, 0%	1, 5%	3, 14%	0, 0%	0, 0%
<b>Elbow</b>	<b>71</b>	<b>8, 11%</b>	<b>0, 0%</b>	<b>0, 0%</b>	<b>34, 48%</b>	<b>2, 0.4%</b>	<b>1, 1%</b>
Pre-antibiotic era	59	8, 14%	0, 0%	0, 0%	32, 54%	2, 3%	1, 2%
Antibiotic era	12	0, 0%	0, 0%	0, 0%	2, 17%	0, 0%	0, 0%
<b>Wrist</b>	<b>6</b>	<b>2, 33%</b>	<b>1, 17%</b>	<b>2, 33%</b>	<b>0, 0%</b>	<b>0, 0%</b>	<b>0, 0%</b>
Pre-antibiotic era	1	0, 0%	0, 0%	0, 0%	0, 0%	0, 0%	0, 0%
Antibiotic era	5	2, 40%	1, 20%	2, 40%	0, 0%	0, 0%	0, 0%
<b>Total</b>	<b>544</b>	<b>198, 36%</b>	<b>11, 2%</b>	<b>24, 4%</b>	<b>100, 18%</b>	<b>25, 5%</b>	<b>9, 2%</b>
Pre-antibiotic era	223	62, 28%	0, 0%	0, 0%	76, 34%	25, 11%	9, 4%
Antibiotic era	321	136, 42%	11, 3%	24, 7%	24, 7%	0, 0%	0, 0%

Table III: Management of acute presenting cases during the antibiotic era

	Cases (n)	Management						Outcome		
		Antibiotics given (n, %)	Open arthrotomy (n, %)	Surgical dislocation (n, %)	Arthroscopy (n, %)	Fracture fixation (n, %)	Joint arthrodesis (n, %)	Arthroplasty (n, %)	Sepsis (n, %)	Non-union/malunion/AVN (n, %)
<b>Hip</b>	<b>108</b>	<b>64, 59%</b>	<b>50, 46%</b>	<b>17, 16%</b>	<b>16, 15%</b>	<b>33, 31%</b>	<b>0, 0%</b>	<b>2, 2%</b>	<b>9, 8%</b>	<b>17, 16%</b>
No fracture	22	10, 45%*	4, 18%	10, 45%	8, 36%	0, 0%	0, 0%	-	3, 14%	-
Fracture	81	54, 67%*	46, 57%	7, 8%	3, 4%	33, 41%	0, 0%	1, 1%	6, 7%	17, 21%
Acetabulum	52	46, 88%*	25, 48%	4, 8%	2, 4%	14, 27%	0, 0%	0, 0%	6, 12%	10, 19%
Femoral head	9	3, 33%*	4, 44%	2, 18%	1, 9%	3, 33%	0, 0%	0, 0%	0, 0%	0, 0%
Neck of femur	20	5, 25%*	17, 65%	1, 5%	0, 0%	16, 80%	0, 0%	1, 5%	0, 0%	7, 35%
Not reported	5	*	0, 0%	-	5, 100%	-	-	-	0, 0%	-
<b>Knee</b>	<b>115</b>	<b>106, 92%</b>	<b>35, 30%</b>	<b>-</b>	<b>59, 51%</b>	<b>3, 3%</b>	<b>0, 0%</b>	<b>0, 0%</b>	<b>2, 2%</b>	<b>0, 0%</b>
No fracture	54	52, 96%*	16, 30%	-	17, 31%	-	-	-	2, 4%	-
Fracture	54	54, 100%	18, 33%	-	36, 67%	3, 6%	0, 0%	0, 0%	0, 0%	0, 0%
Not reported	7	*	1, 14%	-	6, 86%	-	-	-	0, 0%	-
<b>Shoulder</b>	<b>20</b>	<b>20, 100%</b>	<b>12, 60%</b>	<b>-</b>	<b>4, 20%</b>	<b>0, 0%</b>	<b>3, 15%</b>	<b>4, 20%</b>	<b>3, 15%</b>	<b>-</b>
No fracture	7	7, 100%	1, 14%	-	2, 29%	-	-	-	0, 0%	-
Fracture	12	12, 100%	11, 92%	-	1, 8%	0, 0%	3, 25%	4, 30%	3, 25%	-
Not reported	1	1, 100%	0, 0%	-	1, 100%	-	-	-	0, 0%	-
<b>Elbow</b>	<b>5</b>	<b>5, 100%</b>	<b>5, 100%</b>	<b>-</b>	<b>0, 0%</b>	<b>0, 0%</b>	<b>0, 0%</b>	<b>0, 0%</b>	<b>0, 0%</b>	<b>-</b>
No fracture	1	1, 100%	1, 100%	-	0, 0%	-	-	-	0, 0%	-
Fracture	4	4, 100%	4, 100%	-	0, 0%	0, 0%	0, 0%	0, 0%	0, 0%	-
<b>Wrist</b>	<b>3</b>	<b>3, 100%</b>	<b>2, 67%</b>	<b>-</b>	<b>0, 0%</b>	<b>0, 0%</b>	<b>0, 0%</b>	<b>0, 0%</b>	<b>0, 0%</b>	<b>-</b>
Fracture	3	3, 100%	2, 67%	-	0, 0%	0, 0%	0, 0%	0, 0%	0, 0%	-
<b>Total</b>	<b>251</b>	<b>198, 79%*</b>	<b>104, 41%</b>	<b>17, 7%</b>	<b>79, 31%</b>	<b>36, 14%</b>	<b>3, 1%</b>	<b>5, 2%</b>	<b>14, 6%</b>	<b>17, 7%</b>
No fracture	84	70, 84%*	22, 26%	10, 12%	27, 32%	-	-	-	5, 6%	0, 0%
Fracture	154	127, 82%*	81, 53%	7, 5%	40, 26%	36, 23%	3, 2%	5, 3%	9, 6%	17, 11%
Not reported	13	1, 8%*	1, 8%	0, 0%	12, 92%	-	-	-	0, 0%	0, 0%

\* not reported in all publications

### Management of acute injuries during the antibiotic era

Following the dawn of the antibiotic era, virtually every patient reported in the literature (99%, 198/199) who presented with an acute transarticular gunshot injury received systemic antibiotics as part of their management; the only patient who did not receive antibiotics left the hospital against medical advice before receiving medication (Table III).<sup>32</sup> First-generation cephalosporins were the antibiotic of choice in most publications (84%, 166/198). One paper combined gentamycin with a first-generation cephalosporin for seven patients who sustained gunshot injuries to the shoulder.<sup>29</sup> One report used a third-generation cephalosporin following gunshot injuries to the hip.<sup>26</sup> Although the authors did not expand on the motivation for using a third-generation rather than a first-generation cephalosporin, it is worthy to note that most of the patients in this report also sustained associated hollow viscus injuries.<sup>26</sup>

Most cases (80%, 202/251) underwent surgical arthrotomy, debridement and joint lavage. An open debridement was performed in 123 patients (61%). In 19 cases of gunshot injuries to the hip, a surgical hip dislocation was performed to facilitate bullet removal. An arthroscopic debridement was performed in 79 patients (39%).

Two papers investigated the need for operative intervention of transarticular gunshot injuries. A 2018 study by Maqungo et al. and a 2019 study by Shultz et al. compared antibiotics alone versus antibiotics in addition to operative treatment of transarticular gunshot injuries.<sup>32,61</sup> Both studies showed no difference in infective complications, but when considering a baseline infection rate of 6% for acute presenting patients, these studies were possibly underpowered, and additional research is needed before the widespread adoption of this management strategy.

Intra-articular fractures were reported in 154 patients (65%).

These injuries were treated nonoperatively in 110 cases, by fracture fixation in 36 cases, arthroplasty in five cases (four shoulders, one hip)<sup>27,29</sup> and shoulder arthrodesis in three patients.<sup>29</sup> Poor outcomes requiring implant removal were experienced in all four shoulder arthroplasty cases (three periprosthetic joint infections and one painful implant loosening).<sup>29</sup>

Thirty-three papers reported 157 transarticular gunshot wounds to the hip, including 30 patients who sustained transabdominal or transpelvic bullet trajectory with associated hollow viscus injury.<sup>24,26,48,49,62,74</sup> Bowel injury treatment consisted of primary repair in 20 cases and bowel diversion in ten patients. A significantly higher hip joint infection rate was seen in patients who sustained hollow viscus injury (11/30, 37%) than those who did not (6/127, 5%). The included papers did not provide enough information to discern any difference in infective complications following small bowel or large bowel injuries.

### Late complications during the antibiotic era

Seventy patients presented with late complications (Table IV) following transarticular gunshot injuries at a median of 15.7 months after the injury (range 3–624); 26 patients had retained intra-articular bullets, 24 of whom developed lead arthropathy, of which 11 had signs of systemic lead toxicity. All (n = 70, 100%) were managed surgically.

Fifty-five patients underwent arthroplasty for complications following transarticular gunshot injuries. These patients presented at a median of 15.7 months (range 3–624) following the initial injury. Total joint arthroplasty of the hip was the most common procedure (n = 46). Eight cases (17%) were complicated by periprosthetic joint infection, including both patients who sustained associated hollow viscus injuries; five patients underwent revision arthroplasty, while

Table IV: Management of late complications during the antibiotic era

	Cases (n)	Presentation				Management and outcome		
		Median time since injury in month (range)	Retained bullet (n, %)	Lead arthropathy (n, %)	Plumbism (n, %)	Surgery (n, %)	Sepsis (n, %)	Good outcome (n, %)
<b>Hip</b>	<b>49</b>	<b>15.7 (3–624)</b>	<b>17, 35%</b>	<b>16, 33%</b>	<b>7, 14%</b>	<b>49, 100%</b>	<b>8, 16%</b>	<b>32, 65%</b>
Open debridement	2	154 (8–300)	2, 100%	2, 100%	2, 100%	2, 100%	0, 0%	0, 100%
Arthroscopic debridement	1	4	1, 100%	0, 0%	0, 0%	1, 100%	0, 0%	1, 100%
Arthroplasty	46	15.7 (3–624)	14, 30%	14, 30%	5, 11%	46, 100%	8, 17%	31, 67%
<b>Knee</b>	<b>3</b>	<b>22 (14–396)</b>	<b>3, 100%</b>	<b>3, 100%</b>	<b>1, 33%</b>	<b>3, 100%</b>	<b>0, 0%</b>	<b>3, 100%</b>
Open debridement	1	396	1, 100%	1, 100%	0, 0%	1, 100%	0, 0%	1, 100%
Arthroscopic debridement	2	(14–22)	2, 100%	2, 100%	1, 50%	2, 100%	0, 0%	2, 100%
<b>Ankle</b>	<b>7</b>	<b>27 (27–588)</b>	<b>2, 29%</b>	<b>2, 29%</b>	<b>2, 29%</b>	<b>7, 100%</b>	<b>0, 0%</b>	<b>7, 100%</b>
Open debridement	1	480	1, 100%	1, 100%	1, 100%	1, 100%	0, 0%	1, 100%
Arthrodesis	6	27 (27–588)	1, 17%	1, 17%	1, 17%	6, 100%	0, 0%	6, 100%
<b>Shoulder</b>	<b>2</b>	<b>35.5 (11–60)</b>	<b>2, 100%</b>	<b>1, 50%</b>	<b>0, 0%</b>	<b>2, 100%</b>	<b>0, 0%</b>	<b>2, 100%</b>
Arthroplasty	2	35.5 (11–60)	2, 100%	1, 50%	0, 0%	2, 100%	0, 0%	2, 100%
<b>Elbow</b>	<b>7</b>	<b>24 (17–39)</b>	<b>0, 0%</b>	<b>0, 0%</b>	<b>0, 0%</b>	<b>7, 100%</b>	<b>2, 29%</b>	<b>2, 29%</b>
Arthroplasty	7	24 (17–39)	0, 0%	0, 0%	0, 0%	7, 100%	2, 29%	2, 29%
<b>Wrist</b>	<b>2</b>	<b>152 (16–288)</b>	<b>2, 100%</b>	<b>2, 100%</b>	<b>1, 50%</b>	<b>2, 100%</b>	<b>0, 0%</b>	<b>2, 100%</b>
Open debridement	1	16	1, 100%	1, 100%	0, 0%	1, 100%	0, 0%	1, 100%
Arthrodesis	1	288	1, 100%	1, 100%	1, 100%	1, 100%	0, 0%	1, 100%
<b>Total</b>	<b>70</b>	<b>15.7 (3–624)</b>	<b>26, 37%</b>	<b>24, 34%</b>	<b>11, 28%</b>	<b>70, 100%</b>	<b>10, 14%</b>	<b>48, 69%</b>
Open debridement	5	300 (8–480)	5, 100%	5, 100%	3, 60%	5, 100%	0, 0%	3, 60%
Arthroscopic debridement	3	14 (4–22)	3, 100%	2, 67%	1, 33%	3, 100%	0, 0%	3, 100%
Arthrodesis	7	27 (16–588)	2, 29%	2, 29%	2, 29%	7, 100%	0, 0%	7, 100%
Arthroplasty	55	15.7 (3–624)	16, 29%	15, 27%	5, 9%	55, 100%	10, 18%	35, 64%



**Figure 5.** Intra-articular bullet extracted using a 3.2 mm threaded guide pin

one patient was treated by resection arthroplasty.<sup>30,50,54,63,65,67,71,77,79</sup> Seven total elbow replacements were performed of which five patients (71%) required implant removal for either septic ( $n = 4$ ) or aseptic loosening ( $n = 1$ ).<sup>41</sup> Good outcomes were reported in both patients who underwent shoulder arthroplasty.<sup>31,59</sup>

Bek et al. reported a 100% fusion rate following Ilizarov circular external fixation ankle arthrodesis in five patients who presented at a median of 27 months following gunshot injuries to the ankle joint.<sup>53</sup>

### Bullet extraction techniques

Twenty-three publications reporting on the management of 44 patients focused on extraction techniques for retrieving retained bullets from 27 hips, 13 knees and four shoulder joints. Most publications ( $n = 20$ , 33 patients) described arthroscopic bullet removal, including 15 hips, 13 knees and four shoulder joints; one failed arthroscopic removal from a knee converted to an open arthrotomy.<sup>52</sup> Two publications (11 patients) reported a 100% success rate, without complications, with the use of surgical hip dislocation for removal of bullets lodged in the femoral head and acetabulum.<sup>23,57</sup> Krishnan et al. described a posterior approach and extracapsular cortical window to remove a bullet lodged in the posterior wall of the acetabulum.<sup>48</sup>

Most authors reported the successful use of a pituitary rongeur to grasp loose bullets within the joint cavity during arthroscopic removal.<sup>24,34,35,38,39,42,47</sup> Budeyri and Cankus resorted to using an arthroscopic shaver with high-pressure suction to 'grasp' the bullet and rongeur claw after the rongeur claw broke off in the joint.<sup>66</sup> Several authors noted instances of iatrogenic cartilage damage when embedded bullets were levered from their bony recesses. To circumvent this, Singleton et al. and Lee et al. described using a 3.2 mm threaded guide pin inserted into the bullet under power to capture the embedded bullet and extract it from the bone (Figure 5).<sup>49,52</sup>

## Discussion

The management of transarticular gunshot injuries is currently based on limited high-quality evidence. This systematic review aimed to explore the literature reporting on treating these injuries to interpret the data and provide physicians with evidence to guide their management.

Together with a surge in global civilian gun-related violence, a drive for evidence-based medical care has stimulated a reciprocal increase in gunshot injury research over the last 20 years. A recent bibliometric analysis and the current review have confirmed that most publications on orthopaedic ballistic injuries originated from developed countries, including the United States of America and the United Kingdom, despite most gun-related violence reported in developing countries.<sup>80</sup> El Salvador, Jamaica, Eswatini, Honduras

and Venezuela, for example, have the highest firearm-related homicide rates.<sup>81</sup> Yet, no publications on gunshot-related injuries have originated from any of these five countries. Researchers and non-governmental organisations in countries that see high numbers of firearm-related trauma should be encouraged to report their experience of managing these injuries to assist the development of global gun violence care pathways.

It is interesting to note that complication profiles were not consistent across different joints. The most prominent example was septic complications following transarticular gunshot injuries to the hip with associated hollow viscus injury, which was significantly higher than for any other joint (11/30, 37%). Different infection rates were also observed for the other joints: 15% for shoulder, 8% for hip, 2% for knee and 0% for wrist and elbow injuries. From arthroplasty and arthroscopy research, it is evident that different joints experience different infective complications, which might also be true for transarticular gunshot injuries.<sup>82-87</sup> It might therefore be plausible to develop individualised care pathways for gunshot injuries based on each joint and associated injuries. This will, however, require more extensive cohort studies focusing on specific joint injuries.

The quality of the included publications limits recommendations that could be extracted from this review, most reports being either retrospective case series or case reports. No publications reported patient-reported outcomes following the management of gunshot-related transarticular injuries. The heterogeneity and quality of the included studies precluded performing a meta-analysis.

## Conclusion

The contemporary management of transarticular gunshot injuries is based on limited high-quality evidence predominantly from developed countries. Modern antibiotic and surgical management practices have resulted in low overall septic complications; however, different joints have different injury and complication profiles. Future research should be aimed at identifying joint-specific evidence-based care pathways.

## Key points

1. All intra-articular bullets or bullet fragments should be removed to mitigate long-term complications.
2. Gunshot injuries to the hip joint with associated hollow viscus injury have a high infection incidence and should be treated aggressively.
3. Although systemic lead toxicity is a severe complication, lead arthropathy is more common following retained intra-articular bullets and bullet fragments.
4. At present, there is insufficient evidence to propose nonoperative treatment of acute presenting transarticular gunshot injuries.

### Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.

### Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

### Author contributions

NF: assembled the team of reviewers, coordinated the review process, conducted the primary review and compiled the manuscript  
 CA: screened eligible manuscripts, assisted with data extraction, reviewed, and approved the final submission  
 E.J: assisted with data extraction, reviewed and approved the final submission

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