Retained bullet fragments after nonfatal gunshot wounds: epidemiology and outcomes

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BACKGROUND: With no consensus on the optimal management strategy for asymptomatic retained bullet fragments (RBF), the emerging data on RBF lead toxicity have become an increasingly important issue. There are, however, a paucity of data on the magnitude of this problem. The aim of this study was to address this by characterizing the incidence and distribution of RBF.

METHODS: A trauma registry was used to identify all patients sustaining a gunshot wound (GSW) from July 1, 2015, to June 31, 2016. After excluding deaths during the index admission, clinical demographics, injury characteristics, presence and location of RBF, management, and outcomes, were analyzed.

RESULTS: Overall, 344 patients were admitted for a GSW; of which 298 (86.6%) of these were nonfatal. Of these, 225 (75.5%) had an RBF. During the index admission, 23 (10.2%) had complete RBF removal, 35 (15.6%) had partial, and 167 (74.2%) had no removal. Overall, 202 (89.8%) patients with nonfatal GSW were discharged with an RBF. The primary indication for RBF removal was immediate intraoperative accessibility (n = 39, 67.2%). The most common location for an RBF was in the soft tissue (n = 132, 58.7%). Of the patients discharged with an RBF, mean age was 29.5 years (range, 6.1–62.1 years), 187 (92.6%) were me, with a mean Injury Severity Score of 8.6 (range, 1–75). One hundred sixteen (57.4%) received follow-up, and of these, 13 (11.2%) returned with an RBF-related complication [infection (n = 4), pain (n = 7), fracture nonunion (n = 1), and bone erosion (n = 1)], with a mean time to complication of 130.2 days (range, 11–528 days). Four (3.4%) required RBF removal with a mean time to removal of 146.0 days (range, 10–534 days).

CONCLUSION: Retained bullet fragments are very common after a nonfatal GSW. During the index admission, only a minority are removed. Only a fraction of these are removed during follow-up for complications. As lead toxicity data accumulates, further follow-up studies are warranted. (*J Trauma Acute Care Surg.* 2021;90: 973–979. Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic and epidemiological, level III.

KEY WORDS: Gunshot; retained bullet; complication; bullet removal; lead toxicity.

Nonfatal firearm injuries remain a common problem. According to the Centers for Disease Control and Prevention, in 2017 there were 113,407 nonfatal firearm injuries reported in the United States.[1] These nonfatal firearm injuries may result in a retained bullet fragment (RBF). It is often standard practice to leave an RBF in place unless it is easily accessible or symptomatic; however, the optimal management for RBFs remains unclear. To date, several studies have demonstrated that RBFs can be associated with elevated blood lead levels and that periodic evaluation may be required in patients with a history of an RBF.[2–9] A recent meta-analysis examined the association between RBFs and elevated blood lead levels (BLL), finding that BLL were statistically significantly higher in individuals with an RBF compared with those without.[10] Understanding the magnitude of this problem will require not only understanding the role of retained bullets in causing lead poisoning but also the prevalence, incidence, and distribution of RBFs after a nonfatal gunshot wound (GSW). To the best of our knowledge, there have been no comprehensive epidemiological studies that look at the latter question, a gap that this study aims to address.

METHODS

After obtaining institutional review board approval from the University of Southern California, the LAC+USC Trauma Registry was used to identify all patients presenting between July 1, 2015, and June 31, 2016, with a GSW. All patients who present with a GSW to the head, neck, torso, or extremities proximal to the elbow or knee are captured in this registry. Extremity injuries with neurological or vascular compromise regardless of location are also included. Patients who presented with only superficial injuries or isolated injury to fingers or toes are excluded from the trauma registry. Patients who died from their injuries during the index hospital admission were also excluded.

Individual patient charts and imaging studies were used to extract clinical demographics, injury data (Injury Severity Score [ISS], Glasgow Coma Scale [GCS]), location of GSW, associated injuries, presence and location of RBF, RBF management, and outcomes. Patients were grouped by type of RBF removal (complete, partial, or none) and compared in regard to demographics, clinical data, and outcomes. Patients who underwent partial removal and those who did not undergo removal were classified as having an RBF at discharge. The outcomes included hospital length of stay, follow-up received, and complications. Descriptive statistics were calculated with continuous variables expressed as mean ± standard deviation; median (range) and categorical variables presented as n (%). Continuous variables were compared using the Student's *t* test or Mann-Whitney U Test; categorical variables were compared using the χ^2 test or Fischer's exact test. All statistical analyses were performed using SPSS Version 23.0.

RESULTS

During the 1-year study period, 344 patients presented to the LAC+USC Medical Center with a GSW. Of these, 298 (86.6%) were nonfatal. At the time of presentation, 225 (75.5%) of the nonfatal GSW had retained bullet fragments. During the index hospital admission, 23 (10.2%) underwent complete removal of RBF, 35 (15.6%) patients underwent partial removal of RBF, and 167 (74.2%) did not undergo any RBF removal (Fig. 1). At discharge, 96 (32.2%) had no RBF (underwent complete RBF removal or did not have an RBF initially) and 202 (67.8%) had an

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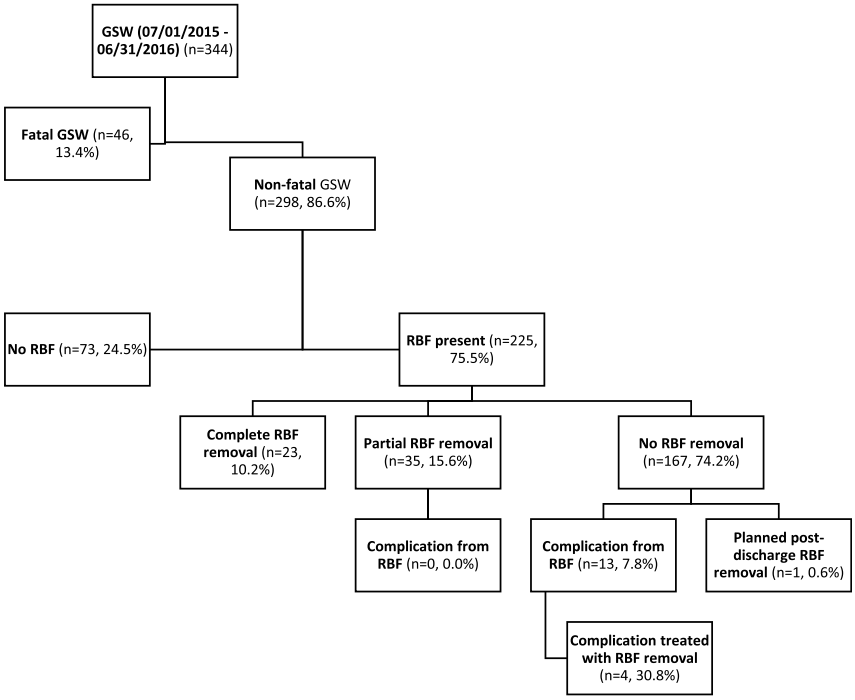

Figure 1. Flow of patients through study.

TABLE 1. Comparison of Demographics of Patients With No RBF at Discharge and RBF at Discharge

Demographics	All Nonfatal GSW (N = 298)	No RBF at Discharge (n = 96)	RBF at Discharge (n = 202)	*p*
Age (years)	29.6 ± 11.2; 26.2 (6.1–73.4)	29.8 ± 12.5; 25.9 (10.3–73.4)	29.5 ± 10.6; 26.3 (6.1–62.1)	0.664
Male	277 (93.0)	90 (93.8)	187 (92.6)	0.711
ISS	7.5 ± 8.5; 5.0 (1.0–75.0)	5.9 ± 5.7; 3 (1.0–25.0)	8.6 ± 9.4; 7 (1–75)	<0.001
GCS - Eye	4; 4 (1–4)	4; 4 (1–4)	4; 4 (1–4)	0.192
GCS - Verbal	5; 5 (1–5)	5; 5 (1–5)	5; 5 (1–5)	0.144
GCS - Motor	6; 6 (1–6)	6; 6 (1–6)	6; 6 (1–6)	0.122
GCS Total	14; 15 (1–15)	15; 15 (1–15)	14; 15 (3–15)	0.134
Total Number of GSW	2.3 ± 1.7; 2 (1–14)	2.0 ± .97; 2 (1–6)	2.45 ± 1.9; (1–14)	0.997
Location of GSW				
Head	40 (13.4)	9 (9.4)	31 (15.3)	0.158
Neck	12 (4.0)	1 (1.0)	11 (5.4)	0.071
Upper Extremity	90 (30.2)	24 (25.0)	66 (32.7)	0.178
Thorax	70 (23.5)	18 (18.8)	52 (25.7)	0.183
Abdomen	75 (25.2)	25 (26.0)	50 (24.8)	0.811
Pelvis	32 (10.7)	8 (8.3)	26 (12.9)	0.250
Lower Extremity	112 (37.6)	37 (38.5)	75 (37.1)	0.814
Disposition after ED				
Discharged	46 (15.4)	26 (27.1)	20 (9.9)	0.0001
Floor	114 (38.3)	33 (34.4)	81 (40.1)	0.349
ICU	41 (13.8)	6 (6.3)	35 (17.3)	0.0101
OR	96 (32.2)	31 (32.3)	65 (32.2)	0.9863
Interventional Radiology	1 (0.3)	0 (0)	1 (0.5)	0.4884
Hospital LOS (days)	10.5 ± 53.8; 4 (0–915)	5.5 ± 9.9; 1.5 (0–60.0)	12.9 ± 64.9; 4 (0–915)	0.114
Follow-up received	156 (52.3)	40 (41.7)	116 (57.4)	0.011
Length of Follow-Up (days)	97.0 ± 151.0; 34 (3–902)	87.0 ± 147.7; 26 (4–706)	100.6 ± 152.6; 37 (3–902)	0.114

Categorical variables presented as n (%), continuous variables presented as Mean ± Standard Deviation; Median (range).

TABLE 2. Associated Injuries of Those With RBF

	Patients Who Underwent Complete or Partial RBF Removal (n = 58)	Patients Who did Not Undergo RBF Removal (n = 167)	*p*
Location of GSW			
Head	15 (25.9)	20 (12.0)	0.012
Neck	3 (5.2)	9 (5.4)	0.950
Thorax	12 (20.7)	42 (25.1)	0.493
Abdomen	19 (32.8)	41 (24.6)	0.223
Pelvis	8 (13.8)	19 (11.4)	0.626
Lower extremity	22 (37.9)	59 (35.3)	0.722
Upper extremity	21 (36.2)	52 (31.1)	0.477
Head			
Soft tissue only	5 (8.6)	3 (1.8)	0.016
Intracranial hemorrhage	2 (3.4)	7 (4.2)	0.803
Skull fracture	3 (5.2)	3 (1.8)	0.169
Facial fracture	8 (13.8)	11 (6.6)	0.089
Facial vessel	1 (1.7)	2 (1.2)	0.763
Other	2 (3.4)	1 (0.6)	0.103
Neck			
Soft tissue only	1 (1.7)	5 (3.0)	0.605
Other	1 (1.7)	1 (0.6)	0.431
Thorax			
Soft tissue only	7 (12.1)	15 (9.0)	0.435
Rib fracture	2 (3.4)	16 (9.6)	0.138
Sternal/xyphoid fracture	0 (0.0)	2 (1.2)	0.403
Pulmonary contusion or laceration	2 (3.4)	10 (6.0)	0.736
Hemothorax or pneumothorax	3 (5.2)	12 (7.2)	0.429
Cardiac injury	0 (0.0)	3 (1.8)	0.407
Vessels	0 (0.0)	2 (1.2)	0.495
Abdomen			
Soft tissue only	3 (5.2)	14 (8.4)	0.264
Diaphragm	2 (3.4)	2 (1.2)	0.264
Stomach	4 (6.9)	1 (0.6)	0.005
Small intestine	12 (20.7)	10 (6.0)	0.001
Colon/rectum	9 (15.5)	15 (9.0)	0.165
Pancreas	0 (0.0)	1 (0.6)	0.555
Liver	4 (6.9)	10 (6.0)	0.805
Spleen	1 (1.7)	1 (0.6)	0.431
Kidney	0 (0.0)	4 (2.4)	0.234
Bladder	3 (5.2)	2 (1.2)	0.077
Gallbladder	0 (0.0)	1 (0.6)	0.555
Abdominal vessels	4 (6.9)	4 (2.4)	0.111
Other	2 (3.4)	1 (0.6)	0.105
Pelvis			
Testicular injury	0 (0.0)	4 (2.4)	0.234
Spermatic Cord	0 (0.0)	1 (0.6)	0.555
Bone	5 (8.6)	12 (7.2)	0.722
Lower extremity			
Soft tissue only	4 (6.9)	23 (13.8)	0.165
Vessels	0 (0.0)	9 (5.4)	0.071
Bone	13 (22.4)	24 (14.4)	0.155
Upper extremity			
Soft tissue only	4 (6.9)	14 (8.4)	0.719
Vessels	1 (1.7)	2 (1.2)	0.763
Nerve	1 (1.7)	4 (2.4)	0.765
Bone	7 (12.1)	31 (18.6)	0.255
Spinal injury			
Bone	1 (1.7)	14 (8.4)	0.064
Cord	0 (0.0)	1 (0.6)	0.555
Ligament	0 (0.0)	1 (0.6)	0.555

Categorical variables presented as n (%).

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RBF (those who underwent partial RBF removal or did not undergo any RBF removal). Of the patients who had an RBF at discharge, 116 (57.4%) received follow-up care at our institution (Table 1).

Further characterizing the population of nonfatal GSWs, the mean age was 29.6 years (range, 6.1–73.4 years), 277 (93.0%) were men, and the majority were Hispanic (n = 221, 74.2%). Median ISS was 5.0 (range, 1–75) and median total number of GSW, was 2 (range, 1–14). The median hospital length of stay was 4 days (range, 0–915 days) (Table 1).

Compared with patients with no RBF at discharge, patients with an RBF at discharge were more likely to have a higher ISS ($p < 0.001$), and a higher total number of GSWs (2.5 ± 1.9 vs. 2.0 ± 1.0, $p = 0.038$). There was also a statistically significant difference in disposition after ED. Patients with no RBF at discharge were more likely to be discharged home directly from the ED than those with an RBF at discharge (27.1% vs. 9.9%, $p = 0.0001$), and less likely to go to the ICU (6.3% vs. 17.3%, $p = 0.01$). There was, however, no difference in the proportion of patients that went directly to the OR from the ED (32.3% vs. 32.2%, $p = 0.9863$). There was no statistically significant difference in age, gender, ethnicity, GCS, location of GSW, or hospital length of stay between these two groups (Table 1).

Compared with patients with an RBF who did not undergo any bullet removal, patients with an RBF at presentation who underwent complete or partial bullet removal were more likely to have a GSW to the head (25.9% vs. 12.0%, $p = 0.012$). They were also more likely to have associated injuries to the stomach (6.9% vs. 0.6%, $p = 0.005$) and to the small intestine (20.7% vs. 6.0%, $p = 0.001$) (Table 2). Patients who underwent complete or partial RBF removal required operative intervention more frequently than those who did not undergo RBF removal; however, the difference did not reach statistical significance (50.0% vs. 42.5%, $p = 0.323$).

For patients undergoing either complete or partial removal of an RBF, the primary indication given for bullet removal was immediate intraoperative accessibility (n = 39, 67.2%), followed by the bullet being located superficially (n = 10, 17.2%). Comparing those who underwent complete removal to those who underwent partial removal, there was no statistically significant difference in the indication for bullet removal (Table 3).

TABLE 3. Reason for Bullet Removal

Reason for RBF Removal	All Patients who Underwent RBF Removal (n = 58)	Complete RBF Removal (n = 23)	Partial RBF Removal (n = 35)	*p*-value
Proximal to Vessel	1 (1.7)	1 (4.3)	0 (0.0)	0.213
Intraoperative	39 (67.2)	17 (73.9)	22 (62.9)	0.380
Superficial Location	10 (17.2)	4 (17.4)	6 (17.1)	0.749
Within Joint	4 (6.9)	1 (4.3)	3 (8.6)	0.057
Other*	4 (6.9)		4 (11.4)	

Categorical variables presented as n (%).

*Other includes: proximal to organ,[1] spontaneously coughed up in ventilator,[1] neuropathy,[1] found in lumen of small bowel.[1]

For those who underwent complete bullet removal, the most common location of the RBF was the abdomen (39.1%); and for those who underwent partial bullet removal, the most common location of the RBF was the lower extremity (34.3%). There was no statistically significant difference in the type of tissue the RBF was removed from when comparing those who underwent complete removal and those who underwent partial removal. For both groups, the most common location of the RBF removed was the soft tissue (73.9% vs. 65.7%, $p = 0.509$).

Looking at all patients with an RBF, the most common location for an RBF was within the soft tissue (n = 132, 58.7%), followed by proximal to a fracture site (n = 59, 26.2%). Other locations included a joint (n = 12, 5.3%), intraosseous (n = 7, 3.1%), and proximal to a vessel (n = 5, 2.2%). There was no statistically significant difference in the final resting spot of the RBF between patients who underwent RBF removal and those who did not undergo RBF removal (Table 4).

Of the 202 patients who were discharged from the index admission with an RBF, 116 (57.4%) received follow-up care at our institution, either through a scheduled follow-up visit or ED visit. The mean time of follow-up was 100.6 days (range, 3–902 days). Of the patients who were seen again at our institution, 13 (11.2%) had a documented complication from the RBF. Seven patients presented via the emergency department, five via the outpatient clinic, and one via an E-consult. The most common location of the RBF was the upper extremity (n = 5, 38.5%) and lower extremity (n = 5, 38.5%). Two of the patients had an RBF located in the thorax and one in the pelvis. Of the 13 patients who presented with complications from an RBF, the most common complication was pain (n = 7), followed by four with an infection, one with fracture nonunion, and one with bone erosion, with a mean time to complication of 130.2 days (range, 11–528 days).

Of the 13 patients who experienced a complication from RBF, four (30.8%) patients underwent subsequent removal of the RBF; the indication for two of the patients was infection and for two it was pain. The mean time to removal was 146 days (range, 10–534 days). An additional patient underwent bullet removal postdischarge as a planned outpatient procedure. Table 5 depicts details of the patients who underwent delayed RBF removal.

DISCUSSION

The optimal management strategy for retained bullet fragments after firearm injuries remains unclear. This issue has recently gained attention due to several studies suggesting RBFs are associated with elevated blood lead levels.[2,10,11] There, however, are a lack of comprehensive epidemiological data on RBFs, which are essential to determine the scope of the problem.

We found that RBFs are very common after a GSW. During the index admission, only a minority of these RBFs are removed, with the majority of patients sustaining a nonfatal gunshot wound being discharged home with an RBF. In our study population, almost 90% of persons who had a retained bullet at presentation were discharged with retained fragments.

It has been suggested that the location in which a retained bullet fragment resides impacts removal, because RBFs in certain locations have an increased rate of complications. A retrospective study found that fractures with retained bullet fragments greater than or equal to 20% of cortical width near the fracture site had an increased rate of delayed union or nonunion.[12] However, findings from a different retrospective study suggested that fracture debridement with bullet removal is only necessary in cases with intraarticular involvement.[13] Multiple studies have found an association between RBFs and bony fractures with increased BLL.[5,14,15] McQuirter et al.[14] found that RBFs near a bone and joints were associated with a higher BLL. De Araújo et al.,[3] however, found no relation between BLL and RBF location. These are all relatively small studies and as an aggregate remain inconclusive. In this study, the location of the retained bullet did not appear to influence clinical practice.

Within the group of patients who had RBF removal, there were both partial and complete removal. Relatively few RBFs are actually completely removed. The majority of patients who underwent removal of the retained bullet had partial removal. Comparing this group of patients with those who underwent complete removal, we found no statistically significant difference in the final resting place of the RBF. The clinical impact and potential value of partial bullet removal remains unclear.

While most survivors of gunshot wounds have retained bullet fragments that are not removed, the immediate complication burden was found to be low. The most common complication experienced by patients in this study who had an RBF was pain followed by infection. A retrospective study on RBFs in the pediatric population also found the most common complications to be pain and infection.[16] It is important to note that we were only able to capture the patients who returned to our center for a complication, so the actual incidence of complications may be higher. Furthermore, this study was not designed to capture the effect of RBFs on lead toxicity, one of the major

TABLE 4. Location of Retained Bullet Fragment

Tissue Interaction of RBF	All Patients with RBF (N = 225)	Complete or Partial RBF Removal (n = 58)	No RBF Removal (n = 167)	*p*
Soft Tissue	132 (58.7)	40 (69.0)	92 (55.1)	0.064
Proximal to Vessel	5 (2.2)	1 (1.7)	4 (2.4)	0.616
Fracture Site	59 (26.2)	13 (22.4)	46 (27.5)	0.444
Intraosseous	7 (3.1)	1 (1.7)	6 (3.6)	0.423
Joint	12 (5.3)	1 (1.7)	11 (6.6)	0.137

Categorical variables presented as n (%).

TABLE 5. Complications Requiring RBF Removal

Age	Sex	ISS	Total, GSW	Location GSW	Assoc. Injuries	LocationRBF	Tissue Interaction	Details	How they Presented	Reason for RBF Removal	Time to Removal (d)
18	M	21	1	L cheek	R temporal lobe extra-axial hemorrhage, R orbital floor fx	Head	Intraosseous	Within bone posterior to R pterygopalatine fossa	Outpatient	Planned as outpatient procedure postdischarge	10
42	M	1	1	L calf	None	LE	Soft Tissue	Superficial soft tissue of the proximal L calf	ED	Infection (cellulitis)	24
40	M	4	1	L post. shoulder	Bone (comminuted humeral shaft fx)	UE	Soft Tissue	Soft tissue surrounding humeral fracture	Outpatient	Infection (abscess)	141
30	M	14	1	L post. shoulder	Bone (comminuted fx of L scapular body, anterior T3 vertebral body, and R second rib)	UE	Soft Tissue	Soft tissue between post. L fifth rib and scapular body	ED	Pain	534
19	M	14	8	R chest wall, epigastrium, LLQ,[2] forearm,[2] R upper back, L lower flank	Bone (rib fx), pulmonary contusion, colon injury, renal laceration	Pelvis	Soft Tissue	Soft tissue of L hip	ED	Pain	21

R, right; L, left; post., posterior; LLQ, left lower quadrant; UE, upper extremity; LE, lower extremity; Fx, fracture; ED, emergency department.

complications thought to be associated with an RBF, as blood lead levels are not currently drawn as a part of routine follow-up care. As a result, we cannot comment on the prevalence of lead toxicity as a complication in this population.

Finally, since the study was performed at a single institution, and the management of retained bullets is not standardized across hospitals, generalizations between our study population and those seen at other trauma centers may not be valid. However, the overall magnitude of the problem, and the prevalence of those patients who survive their GSW and have retained metallic fragments, is likely consistent across the country.[1]

Even with the limitations, this study clearly showed that RBFs are very common after a nonfatal GSW and that the optimal clinical management strategy is not clear. Retained bullet fragments are very common after a nonfatal GSW with almost 70% of the patients who were admitted for a nonfatal GSW discharged with fragments in place. While a fraction of these are removed during follow-up for complications, the majority are not. With data regarding RBFs causing lead toxicity accumulating from a variety of research projects at other institutions, concern over the long-term effects of RBF is mounting, and further follow-up studies are warranted to determine the optimal management of an RBF.

AUTHORSHIP

All authors participated in writing and critically reviewing the final manuscript. In addition, the authors contributed to the following: N.N. participated in the concept; literature search; study design; data collection, analysis and interpretation. K.I. participated in the concept, study design, data interpretation.

DISCLOSURE

The authors declare no funding or conflicts of interest.

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