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SCIENTIFIC ARTICLE

Lead arthropathy: radiographic, CT and MRI findings

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Abstract
Objective Lead arthropathy is a well-known complication of gunshot injuries with retained intra-articular bullets. Although several previous reports have discussed the radiological findings of this entity, computed tomography (CT) and magnetic resonance imaging (MRI) findings have never been described before in this setting.
Materials and methods In this paper the authors review the imaging findings of 11 patients with lead arthropathy (1 of whom had clinical signs of lead poisoning as well), all of them studied by means of radiographs. In addition, non-enhanced CT scans were obtained in 3 patients and gadolinium-enhanced MRI in 1.
Results Classic findings of intra-articular speckled lead deposits (occasionally with a "lead arthrogram" appearance), joint space narrowing and preserved bone density were found at radiographs in the great majority of cases. Furthermore, extension of intra-articular lead to adjacent tendon sheaths was observed in almost half of the patients, an observation rarely reported in the literature. CT scans and MRI, in their turn, were superior with regard to soft tissue abnormalities, accurately depicting joint effusion and the thickened synovium with lead particles embedded in it.
Conclusion Post-gadolinium MRI had the advantage of showing the enhancement pattern of the inflamed synovium and associated bone marrow edema pattern. Although it is not possible to establish the role of axial imaging in lead arthropathy from the small number of cases studied, this initial experience shows that both methods hold promise in this setting and may be useful, at least in selected cases.

Keywords Lead · Arthropathy · Poisoning · Computed tomography · Magnetic resonance imaging · Radiography · Trauma · Gunshot wound

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Introduction

Victims of gunshot injuries can have the projectile indefinitely retained, and a lead-containing bullet embedded in soft tissues or in bone is usually harmless. However, when lodged in a joint, the projectile can be dissolved by synovial fluid, causing local (lead arthropathy) or systemic (saturnism) effects [1].

The authors discuss the findings of 11 patients with lead arthropathy (one of whom developed signs of saturnism as well), reviewing clinical, pathophysiological, and imaging features with emphasis on the important role of radiology

Table 1 Radiological and clinical parameters analyzed in 11 patients diagnosed as having lead arthropathy

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Gender	Male	Male	Male	Male	Male	Male
Site	Left wrist	Right shoulder	Right hip	Left shoulder	Right wrist	Right knee
Time elapsed between gunshot wound and radiological evaluation	2 months	8 months	2 years	Not available	Not available	3 years
Local clinical symptoms	Pain	None	Pain, restricted motion	Pain	Pain	Pain
Systemic symptoms	None	None	Recurrent colicky abdominal pain and gingival pigmentation	None	None	None
Bone density	Normal	Normal	Normal	Normal	Normal	Normal
Joint space narrowing	Asymmetric	Asymmetric	Asymmetric	Absent	Asymmetric	Asymmetric
Joint effusion at CT or MRI	Not performed	Present	Present	Not performed	Not performed	Present
Synovial thickening at CT or MRI	Not performed	Present	Present	Not performed	Not performed	Present
"Lead arthrogram"	Present	Present	Present	Present	Present	Present
Intra-articular metallic particles	Present	Present	Present	Present	Present	Present
Projectile presence	Present	Absent	Absent	Absent	Absent	Absent
Extension to adjacent tendon sheaths	Absent	Present	Absent	Present	Present	Absent

	Case 7	Case 8	Case 9	Case 10	Case 11
Gender	Male	Male	Male	Male	Male
Site	Right knee	Right ankle	Right foot	Right knee	Left elbow
Time elapsed between gunshot wound and radiological evaluation	Not available	3 years	8 years	8 months	Not available
Local clinical symptoms	Pain, restricted motion	Pain	Pain	Pain	Not available
Systemic symptoms	None	None	None	None	Not available
Bone density	Normal	Normal	Normal	Normal	Normal
Joint space narrowing	Absent	Asymmetric	Evaluation not possible[a]	Absent	Asymmetric
Joint effusion at CT or MRI	Not performed	Not performed	Not performed	Present	Not performed
Synovial thickening at CT or MRI	Not performed	Not performed	Not performed	Present	Not performed
"Lead arthrogram"	Absent	Present	Present	Absent	Absent
Intra-articular metallic particles	Present	Present	Present	Present	Present
Projectile presence	Present	Present	Absent	Absent[b]	Present
Extension to adjacent tendon sheaths	Absent	Present	Present	Absent	Absent

[a] This patient had a mass-like metallic arthrogram over the interphalangeal joint of the right hallux, precluding evaluation of the joint space
[b] This patient reported a transfixing gunshot wound and the bullet itself was not retained, only fragments of it were intra-articular

on diagnosis and follow-up of this condition. Computed tomography (CT) and magnetic resonance imaging (MRI) findings in this entity are described for the first time in the literature.

Materials and methods

A review of the teaching files of four different imaging facilities was performed, searching for the diagnosis of lead arthropathy. Eleven cases of articular gunshot wounds were eligible (3 knees, 2 shoulders, 2 wrists, 1 hip, 1 forefoot [hallux], 1 elbow, and 1 ankle), all of them submitted for conventional radiological evaluation. Additional computed tomography (CT) scans were performed in 3 of these patients, without the use of iodinated contrast media, and gadolinium-enhanced magnetic resonance imaging (MRI) was performed in 1 patient.

Each case was retrospectively examined by two musculoskeletal radiologists (JLF and ALR) and the final conclusion was reached by consensual decision. CT scans and radiographs were reviewed with regard to intra-articular projectiles and intra-articular metallic particles, classified as

present or absent. It was also recorded if the latter, when present, outlined the joint capsule, leading to an "arthrogram-like" appearance. Joint space narrowing was also specifically sought and, if present, categorized as symmetric or asymmetric. A given finding would be regarded as present if found in at least one of the examinations.

In addition, bone density was subjectively analyzed and classified as normal, increased or reduced. CT scans and MRI were also reviewed with regard to the presence of articular effusion and synovial thickening (thickness of 1 mm or more). If available, the clinical history of each patient was reviewed with regard to articular complaints and to the presence of systemic involvement that might suggest lead intoxication.

Results

The clinical and imaging findings for each patient are summarized in Table 1.

All the patients were male, and an extremely variable period of time (between 2 months and 8 years) elapsed between the gunshot injury and the moment of the diagnosis of lead arthropathy. In 4 patients the time elapsed since the firearm injury was not available. Pain was the most frequent clinical complaint (present in 9 patients), monoarticular and confined to the affected joint, absent in only 1 patient; this information was not available in 1 patient. Two patients presented with reduced joint mobility in addition to pain.

One patient experienced recurrent episodes of intense colicky abdominal pain, which had already resulted in several hospital admissions and two negative laparotomies. As this patient also had gingival pigmentation, his clinical picture was assumed to be due to lead intoxication. However, serum lead levels were not available in his records and he was lost to follow-up. This patient (as others in this series) was an interne in a correctional facility and, as such, very difficult to follow.

Normal bone density and intra-articular deposits of lead particles were found in all patients, either at radiographs or at CT scans. Among the patients who underwent CT scans, joint effusion, synovial thickening, and synovial deposition of lead particles were found in all (Figs. 1, 2). "Lead arthrogram" was seen in 8 cases (Figs. 1, 2, 3, 4, 5, 6 and 7), and in 5 cases metallic particles were also observed along the course of tendon sheaths adjacent to affected joints (Figs. 1, 4, 5, 6 and 7). Joint space narrowing was found in 7 patients, asymmetric in all of them (Figs. 1, 2, 3, 5, 6, and 9). In 1 patient (Fig. 7), the lead arthrogram assumed the configuration of a very dense, mass-like lesion, obscuring the interphalangeal joint of the right hallux and

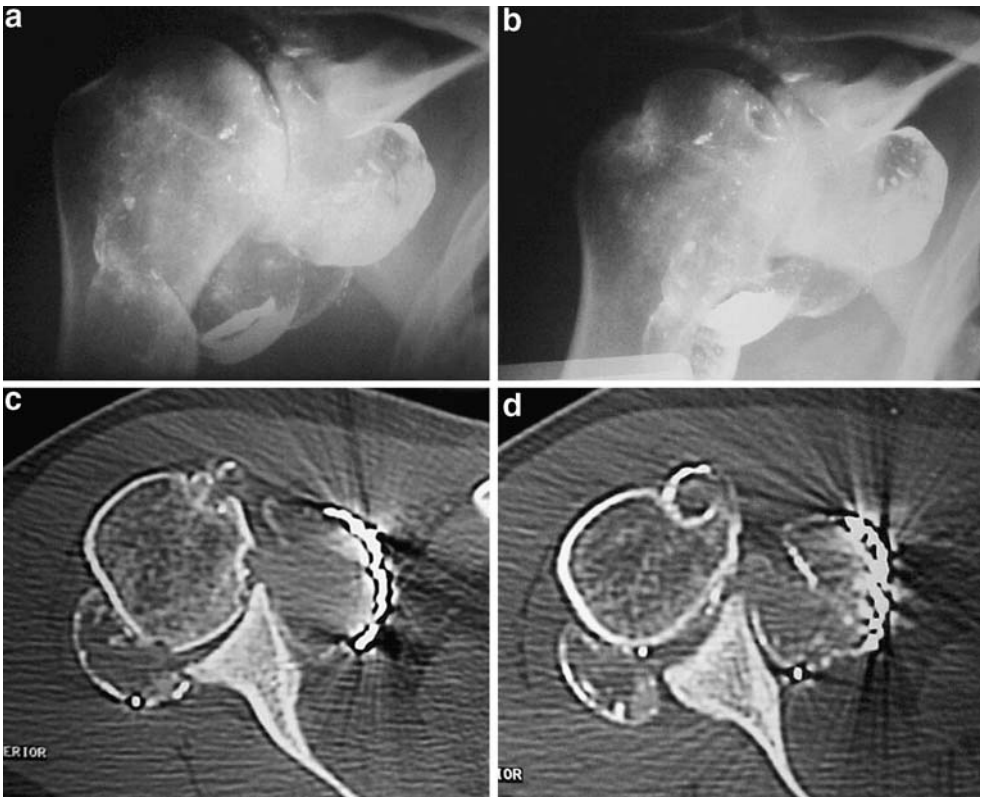


Fig. 1 Lead arthropathy of the right shoulder (case 2). **a**, **b** The radiographs reveal coarse lead particles delineating the joint capsule ("lead arthrogram") and asymmetric joint space narrowing. **c**, **d** CT scans display joint effusion and a thickened synovium, with metallic material embedded in it. Lead is also present inside the bicipital sheath. The offending projectile is no longer identifiable

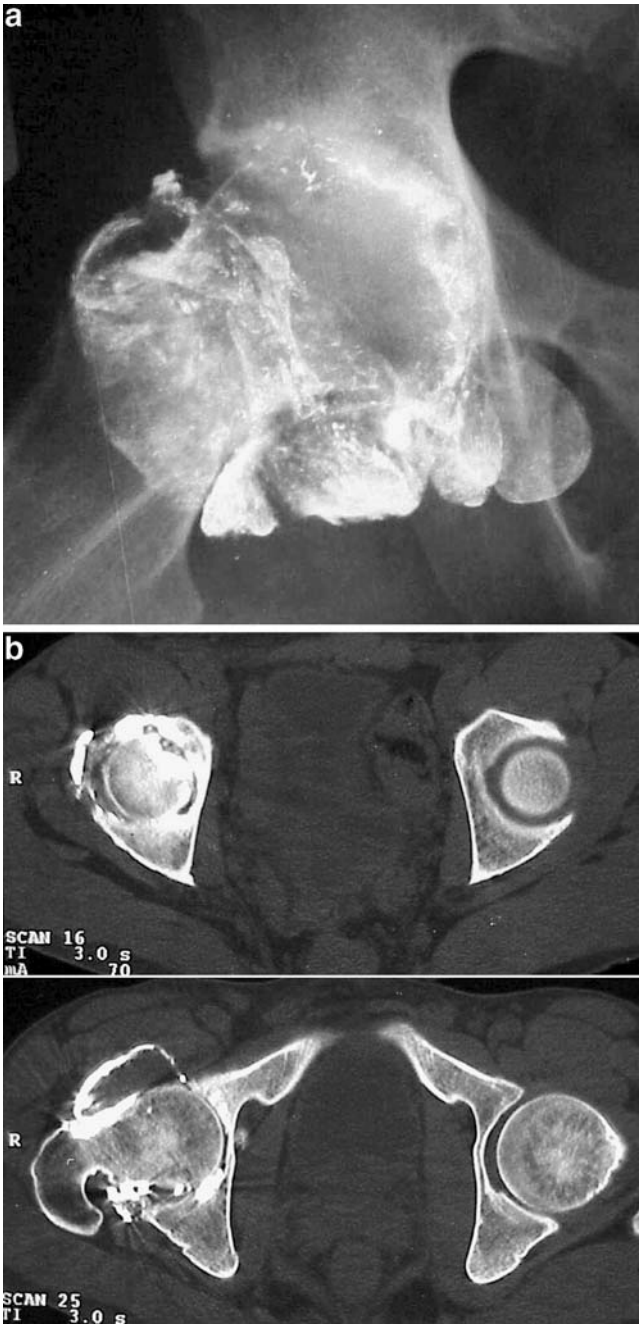


Fig. 2 Lead arthropathy of the right hip (case 3). **a** Plain anteroposterior radiograph showing that the joint space is asymmetrically reduced and the joint capsule is entirely outlined by metallic particles, configuring a lead arthrogram. **b** CT scans, besides confirming the radiographic findings, reveal joint effusion and a thick stripe of lead embedded in the synovium of the right hip. The bullet is no longer visible

precluding evaluation of the joint space. The offending projectile was still present in 4 patients (Figs. 3, 6, 8, and 9), was entirely reabsorbed and not identified in another 6 (Figs. 1, 2, 4, 5, and 7), and exited through a transfixing wound in 1. In the latter, the only patient studied

Fig. 3 Lead arthropathy of the left wrist (case 1). There is asymmetric joint space narrowing and a neat lead arthrogram is noticeable along the radiocarpal, ulnocarpal, and radioulnar joints. The bullet is still present, as the accident was recent (2 months before)

with MRI, the metallic particles were evident as confluent foci of low-signal on T2-weighted images (T2-WI) and, in particular, in gradient-echo images (blooming effect), being almost imperceptible on T1-weighted images (T1-WI; Fig. 10). In the other hand, synovitis was more conspicuous in post-contrast T1-WI with fat suppression (although also

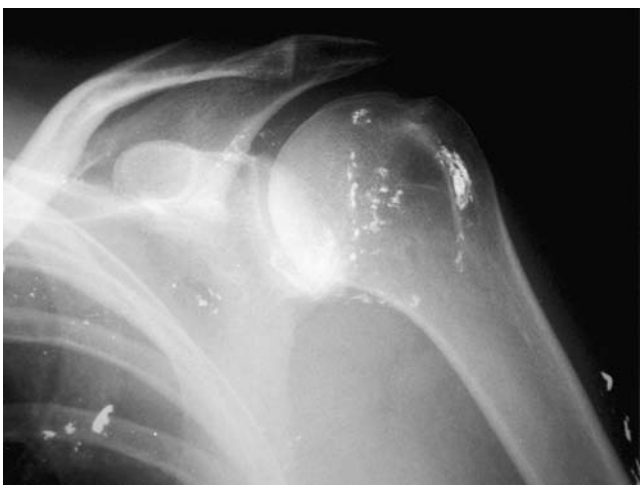


Fig. 4 In this case of lead arthropathy of the left shoulder (case 4) the joint space is not significantly narrowed, although a faint lead arthrogram is present. Metallic particles are also present along the bicipital sheath

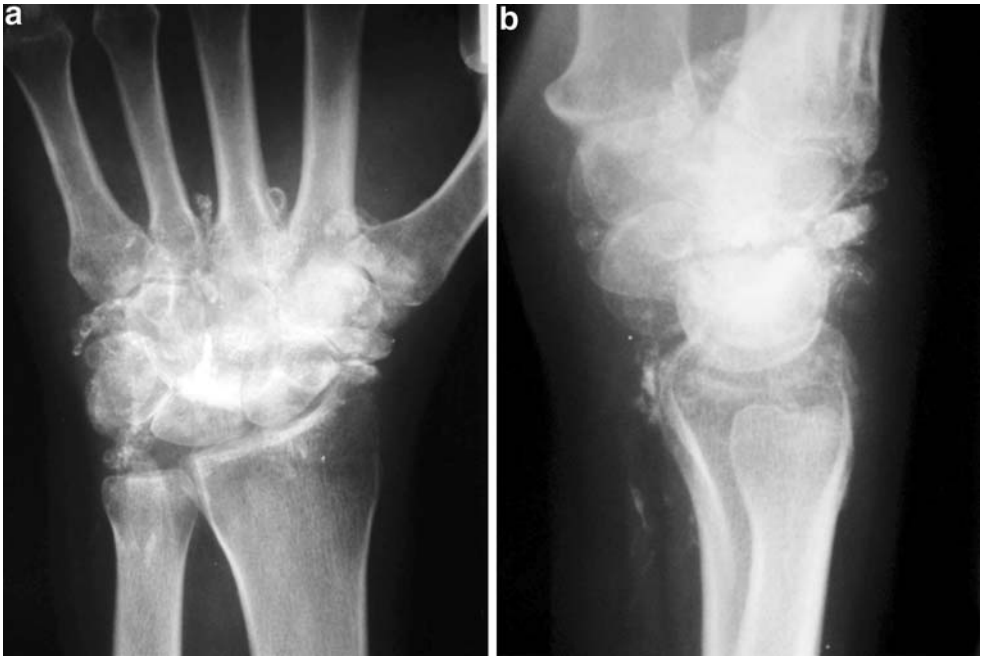


Fig. 5 **a** Anteroposterior and **b** lateral radiographs of the right wrist (case 5) showing a lead arthrogram involving the carpal bones, with extension to the sheaths of the flexor tendons. There is disorganization of the carpal architecture, with asymmetric reduction of the joint spaces

identifiable on T2-WI), appearing as a thickened and enhancing synovium. The femoral condyle transfixed by the projectile exhibited a bone marrow edema pattern, characterized by low-signal on T1-WI and high-signal intensity on T2-WI, which was particularly evident in the latter when fat suppression was used.

A biopsy specimen was obtained in 1 patient (case 3, right hip) and sent for histopathological examination. Blackish particles were found inside the hyperplastic synovium, along with synoviocyte hypertrophy and calcification of the hyaline cartilage (Fig. 11).

Discussion

Lead is a common constituent of bullets and the pathological changes in joints containing bullet fragments are ascribed to the presence of this metal. Generally speaking, retained

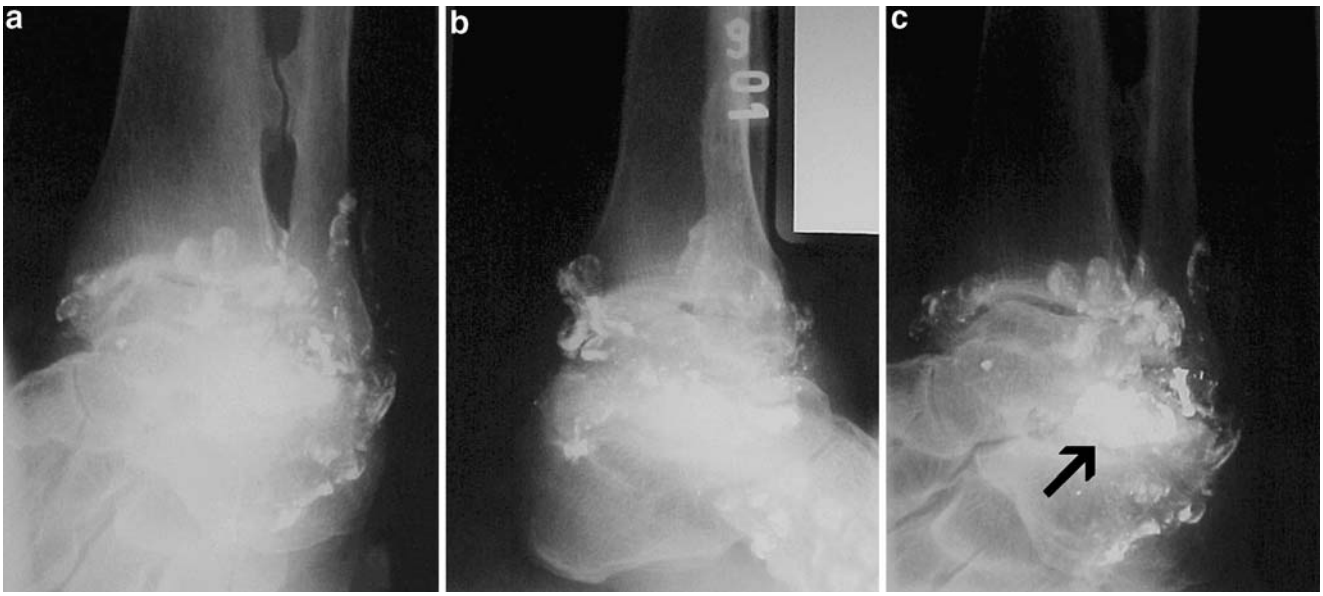


Fig. 6 Oblique radiographs of the right ankle (case 8) reveal a deformed bullet projected over the subtalar joint, more evident in **c** (*black arrow*), asymmetric reduction of the joint spaces and a lead arthrogram with extension to the sheaths of the peroneal tendons

Fig. 7 Plain radiographs of the right hallux (case 9). There is a mass-like lead arthrogram over the interphalangeal joint, precluding evaluation of the joint space. Note extension of the metallic particles to the sheath of the extensor hallucis tendon. This patient had suffered a shotgun injury 8 years earlier, and the metal pellets are no longer discernible (courtesy of Dr. Pushkin Pires Leal, Brasília, Brazil)

bullets are usually managed conservatively because the hazard linked to surgical procedures is greater than the risk associated with their presence in the majority of body tissues [2]. In fact, in soft tissue and bones the projectiles are encased by fibrotic scar tissue with poor vascularization, preventing lead dissolution [3]. However, this is not true when bullet fragments are lodged in joint spaces or bursae, in contact with synovial fluid. Due to its physicochemical properties, the acidic joint fluid can dissolve lead projectiles. Furthermore, mechanical forces within the joint fragment the bullet, increasing the area exposed to the acidic fluid and reinforcing the capacity for solubilization [1, 3–5]. Lead fragments interact with synovial fluid leading to foreign body reactions, mechanical damage to the articular cartilage and local joint abnormalities related to reactive proliferative synovitis [6]. These alterations lead to destructive inflammatory arthritis, cartilage lysis and secondary degenerative joint disease, resulting in great damage to the synovial capsule and the joint cartilage surface [6]. The hyperemic response facilitates the diffusion of solubilized lead and its absorption into the bloodstream, so that systemic toxicity due to lead may be also observed (see below) [1].

The severity of the radiographic findings varies among patients and depends on several factors, including the duration of exposure, the degree of fragmentation of the projectile and the amount of lead exposed to synovial fluid [3]. Lead particles spread inside the articular space by joint movement and tend to become larger, coarser, and confluent over time [3, 7]. As

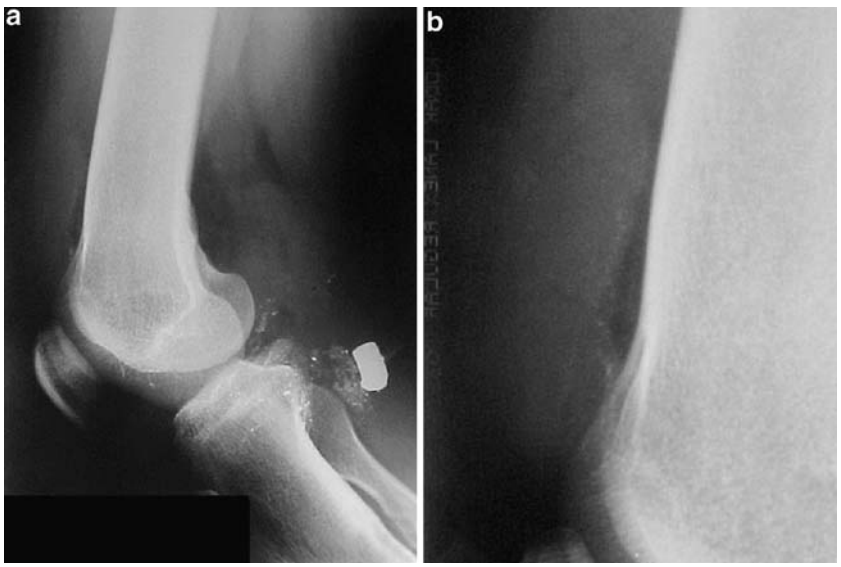


Fig. 8 Plain radiographs of the right knee (case 7) disclosing speckled fragments of lead inside the joint, although a lead arthrogram is not present. The joint space is preserved. Notice the bullet lodged in the popliteal fossa in **a**

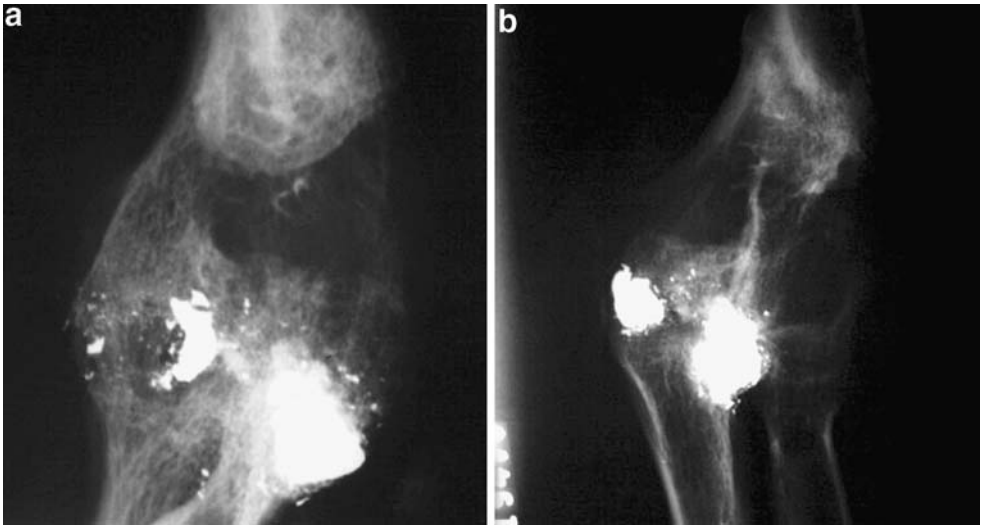


Fig. 9 Plain radiographs of the right elbow (case 11) shows a fragmented bullet and particles of lead inside the joint. The joint space is asymmetrically reduced. The lead fragments do not assume the configuration of an arthrogram

seen in many of our patients, the bullet itself may not be identified at imaging if it was entirely reabsorbed, but the history of previous gunshot injury associated with the presence of intra-articular metallic fragments leaves no room for a margin of error. In an appropriate clinical setting, these fragments can be considered pathognomonic, and although they may occasionally resemble chondrocalcinosis at first sight, careful analysis will reveal that their density is higher than that observed in calcifications [3, 8]. Eventually, the entire joint cavity may become completely outlined by lead, resulting in a characteristic lead arthrogram or "plumbogram" [7, 9], observed in the majority of our cases. An interesting finding seen in 5 patients in this series is the presence of metallic fragments along tendon sheaths in the vicinity of affected joints, which has rarely been reported previously [1, 3]. Associated radiological findings include joint effusion, joint space narrowing and, at a later stage, bone fragmentation, subchondral sclerosis, and erosions. Bone density is typically normal, as observed in all patients in this work. Timely removal of lead particles and surgical toilette of the affected joint would prevent lead arthropathy and systemic toxicity, which may take from weeks to decades to show up. In advanced cases, however, synovectomy or even arthroplasty may be indicated as a last resort [2, 6, 7, 9].

Although radiographic findings of lead arthropathy are reasonably well established from the several previous reports, the roles of CT and MRI in this setting are not clear as, to our knowledge, these methods have never been used before to evaluate this entity. In our series, plain radiographs were sufficient to diagnose intra-articular projectiles and intra-articular metallic fragments, as well as the lead arthrogram. Nevertheless, they were fairly insensitive with regard to joint effusion, synovitis, and other soft tissue abnormalities. Non-enhanced CT scans, in their turn, were at least as good as plain radiographs in demonstrating the intra-articular metallic material, and had the advantage of displaying intra-articular fluid and the thickened synovium with lead particles embedded in it. The conspicuity of CT scans for synovitis probably would be even better if intravenous contrast was used, as for other causes of synovial inflammation. In the only patient examined by means of MRI in this series, the contrast-enhanced examination showed in great detail the joint effusion and the inflamed synovium, being also capable of revealing metallic particles inside the joint, especially in the gradient-echo sequence. In addition, a pattern of bone marrow edema was also evident in this case, which would not be apparent on X-rays or CT scans. However, despite the good results found with CT and MRI in our cases, the number of patients studied is too small to answer some questions that could be raised. For example, it may be anticipated that large or heavily dense metallic deposits/projectiles might severely degrade images obtained by CT scans (beam hardening artifacts) and MRI (magnetic susceptibility artifacts), obscuring the neighboring structures and limiting their diagnostic accuracy, especially in small joints. Even though this is theoretically correct, it remains to be proven that it would be a major issue in a larger series. Another question is whether or not the higher conspicuity for soft tissue abnormalities of these methods would have an impact in the way these patients are managed, as the finding of an intra-articular bullet (or its fragments) is currently an indication for surgical intervention per se, either prophylactic or therapeutic. Further data are necessary before these methods can be routinely indicated in this setting, but it seems that they could be valuable in selected cases (for example, in preoperative planning or to study joints of complex anatomy).

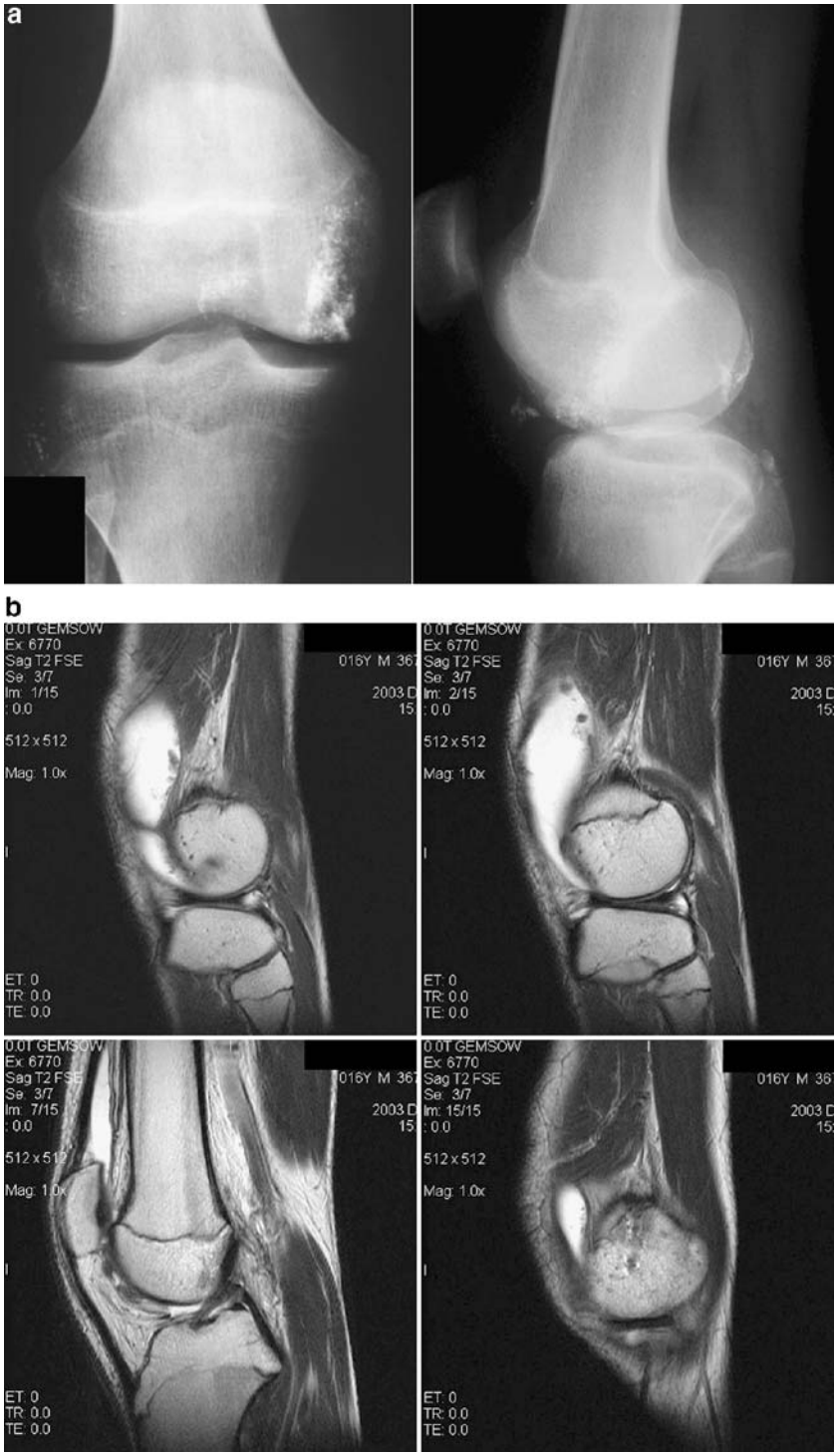


Fig. 10 **a** Radiographs of the right knee (case 10) showing speckled lead deposits inside the joint cavity and within the medial condyle, 8 months after a transfixing gunshot wound. There is no reduction of the joint space and no lead arthrogram is identified. **b** At MRI, lead particles are seen as low-signal foci on T2-weighted images and, particularly, in **c** gradient-echo images, being virtually imperceptible on **d** non-enhanced T1-weighted images. However, **e** post-contrast T1-weighted images with fat suppression are best for displaying the thickened and diffusely enhancing synovium. Also present are joint effusion and bone marrow edema patterns in the transfixed condyle, exhibiting enhancement after infusion of gadolinium

The histopathological picture of lead arthropathy has been described in previous reports and complies with the findings of our only case studied by biopsy. Gross pathological findings include capsular bulging and thickened synovium with lead particles attached to it [3]. Histological findings include synovial hypertrophy, diffuse chronic inflammation, deposition of hemosiderin, and calcification [4, 8]. The synovium and the synovial fluid have a characteristic grayish to blackish hue [10].

Systemic lead intoxication, known as saturnism or plumbism, is a rare complication of intra-articular lead bullets, and usually occurs years or decades after the gunshot wound [5]. It has an insidious course, with intermittent and nonspecific clinical manifestations. Therefore, this diagnosis is often

Fig. 10 (continued)

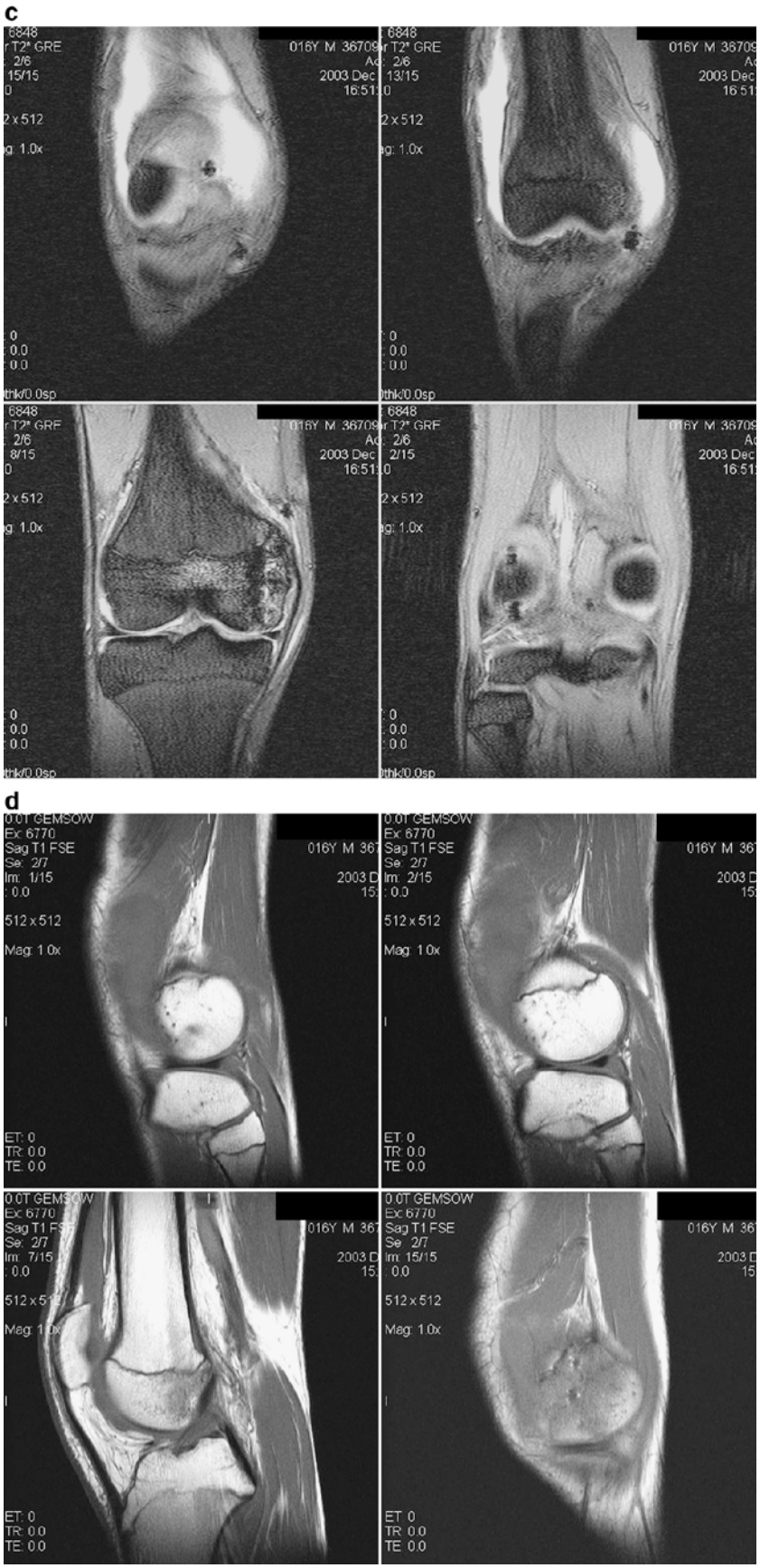
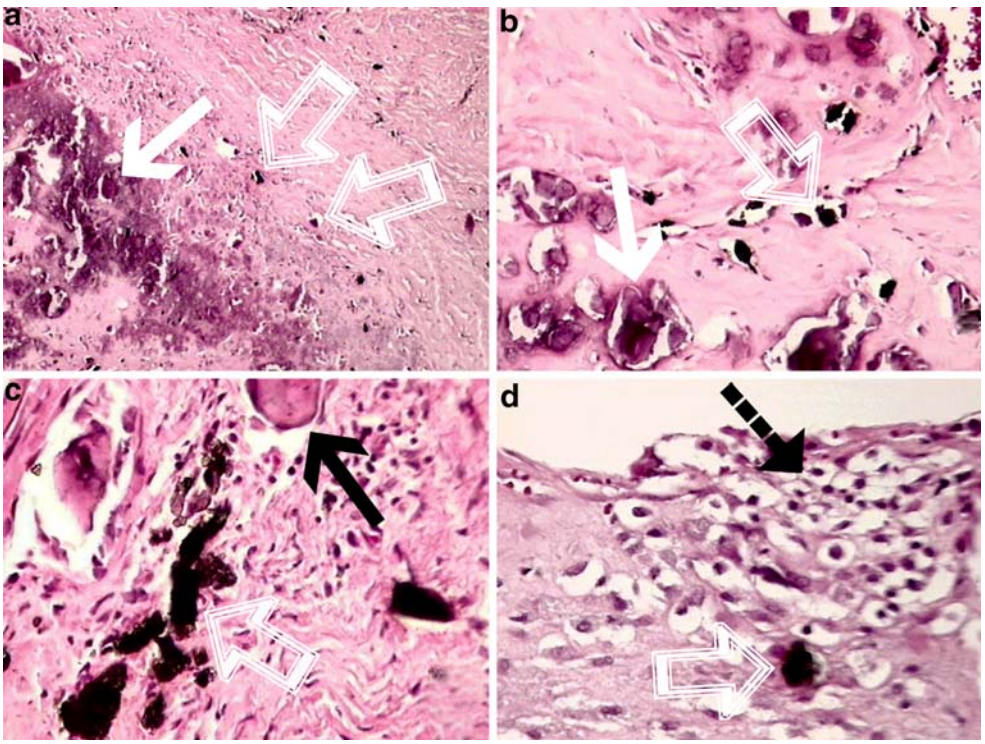


Fig. 10 (continued)

Fig. 11 Biopsy specimen of the right hip (case 3), hematoxylin-eosin stain. **a** Panoramic view with synovium demonstrated as a hyalinized fibrous dense connective tissue with irregular blackish particles inside (*open white arrows*). There is extensively calcified cartilage on the left (*solid white arrow*; ×100). **b** Hyaline cartilage shows extensive areas of calcification (*solid white arrow*) and deposits of irregular blackish particles (*open white arrow*; ×200). **c** Abundant deposition of blackish irregular particles (*open white arrow*) inside fibrous synovium, with some osseous microsequestra (*solid black arrow*; ×400). **d** Hyperplastic synovium with synoviocyte hypertrophy (*dashed black arrow*) and incorporation of blackish particles into the surface (*open white arrow*; ×400)



delayed in these patients, as the projectiles are frequently overlooked as being the cause of their symptoms [5, 6]. The most frequent gastrointestinal manifestations are gingival pigmentation and colicky abdominal pain, often associated with nausea, vomiting, and constipation, simulating a picture of acute abdomen and occasionally leading to negative laparotomies. A typical example of this kind of evolution was observed in case 3.

Conclusion

Bullets in joints are not physiologically inert and should be removed whenever encountered. Radiological findings of an intra-articular firearm bullet associated with capsulosynovial metallic deposition, joint space narrowing, and normal bone density are typical of lead arthropathy and are sufficient for this diagnosis. CT scans and MRI are superior with regard to the diagnosis of synovial abnormalities and may be useful in selected cases. Radiologists should be aware of the risks involved with intra-articular bullets in order to provide early diagnosis and enable prompt therapeutic intervention.

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