

Carpal bone cysts: MRI, gross pathology, and histology correlation in cadavers

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PURPOSE

Intraosseous cysts of carpal bones are frequently observed on routine imaging examinations of the wrist. There is controversy regarding the underlying pathogenesis of these cysts. In this study, we aimed to investigate the magnetic resonance imaging (MRI) appearance of intracarpal bone cysts in correlation with histologic analysis, using cadaveric wrists.

METHODS

Five freshly frozen cadaveric wrist specimens (from three women and two men; mean age at death, 80 years) were studied. Imaging was performed with T1-weighted fast spin-echo, and proton density-weighted fast spin-echo with and without fat-suppression. The existence of cysts was confirmed by comparing MRI and histology findings. Hematoxylin and eosin stain was performed on tissue slices of 3 mm thickness to analyze the structure of cysts and their communication with the joint cavity.

RESULTS

Ten cysts were observed. In all cases, cysts were eccentrically located either in the subchondral bone or beneath the cortex. On histologic examination, there were regions of fat necrosis without inflammation or increased vascularity, surrounded by fibrous walls. There were no giant cells, cholesterol granules, or a true synovial lining. Mucoïd change was rare. Fibrous component of cysts varied from small fibrous septa to well-formed walls. Some cysts communicated with the joint cavity. Two cysts were adjacent to ligamentous attachments. Those cysts with fibrous tissue demonstrated variable hypointensity on T2.

CONCLUSION

In contrast to previous reports that described a mucoïd composition of intracarpal bone cysts with occasional foamy macrophages, our observations support the concept that these lesions reflect a spectrum of fat necrosis and fibrous changes, without inflammation or hypervascularity. These cysts are typically surrounded by fibrous walls without a true synovial lining.

Intraosseous cysts of the carpal bones are commonly identified as an incidental finding on routine imaging examinations of the wrist, particularly in older patients. Although the clinical significance of these cysts is variable, the majority are asymptomatic. In contrast, “intraosseous ganglion cysts”, as described by previous investigators, are painful, with histopathologic features that are identical to those of soft-tissue ganglion cysts; and they are surrounded by a sclerotic rim without a synovial lining or overlying cartilage pathology (1–3). In several case reports, these intraosseous ganglion cysts have been described to have a soft-tissue component. Some of these cysts have been characterized as mucoïd in nature, filled with mucoïd material and located in close proximity to the carpal insertion of the joint capsule and intrinsic or extrinsic ligaments. Other authors have considered true ganglion cysts of the carpus to be rare and pathologically distinct from degenerative cysts (2).

This has led to inconsistencies in the nomenclature, with various terms being used to describe them such as intraosseous ganglion, intraosseous ganglion cysts, intraosseous bone cysts, juxta-articular bone cysts, subchondral bone cysts, and subchondral synovial cysts (1, 4–6). There are multiple hypotheses regarding the underlying pathogenesis of these cysts. Potential causes include intramedullary metaplasia of mesenchymal cells into synovium-like cells, ischemic bone necrosis with resultant resorption of the necrotic material, or cortical penetration of a previously existing soft-tissue ganglion cyst.

In this study, the magnetic resonance (MR) imaging (MRI) appearance of carpal bone cysts is correlated with histologic analysis using cadaveric wrist specimens derived from persons who were elderly at the time of death, to further characterize the imaging as well as histologic features of these controversial, yet frequently encountered, lesions.

Methods

Five wrist specimens from five human cadavers were used (three women, two men; age at death, 64–87 years; mean, 80 years). Three of the wrists were from the same cadavers whose elbows were used in a previous study (7). The freezing and thawing of cadavers, MRI, photography and histologic analysis for the specimens were similar to previous cadaveric studies (7–9). The specimens had been amputated at the level of distal metaphysis of both the radius and ulna and were immediately deep-frozen at -40°C (Bio-Freezer, Forma Scientific, Marietta, Ohio, USA). The specimens were allowed to thaw for at least 24 hours at room temperature. Approximately 3–7 mL of a gadopentetate dimeglumine (Magnevist; Bayer Schering Pharma, Berlin, Germany) solution (1:200 dilution in normal saline) was injected into the radiocarpal and mid-

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Figure 1. a–c. Female cadaver; age at death, 87 years. Fat-saturated proton density-weighted image of the wrist (a) shows the hyperintense cysts. Panel (b) shows a photograph of the cut surface. The cysts are eccentrically located next to the scapholunate interosseous ligament, which is thickened and shows degenerative changes. Histology (c) shows continuity of the degenerated ligament (L) with the cyst (H-E staining, $\times 10$).

carpal compartments of the wrist under fluoroscopy guidance. MRI was performed on a 1.5 Tesla MRI scanner (Signa, LX Horizon, software version 8.3, GE Healthcare, Waukesha, Wisconsin, USA) using dedicated wrist coil (Invivo, Gainesville, Florida, USA).

Images were obtained in axial, coronal, and sagittal standard imaging planes using the following pulse sequences: T1-weighted fast spin-echo (TR/TE, 500/10; field of view, 60 \times 60 mm; section thickness, 2.5 mm; gap, 0.5 mm; number of excitations, NEX 2; imaging matrix, 256 \times 256) and proton density (PD)-weighted fast spin-echo with and without fat-suppression (TR/TE 3, 100/40; field of view, 60 \times 60 mm; section thickness, 2.5 mm; gap, 0.5 mm; NEX 3; matrix, 256 \times 256).

For gross and histologic analysis, all five cadaveric specimens refrozen at -40°C for at least 48 hours after MRI were sliced into 3 mm thickness. One sample was cut into axial sections, two samples were cut into sagittal sections, and two samples were cut into coronal sections to correspond to MRI planes using a band saw with a fine-toothed metal blade (Exact, Apparatebau GmbH, Norderstedt, Germany). After macroscopic inspection, each anatomic slice was recorded photographically using a digital camera (Nikon Coolpix, 5.1 megapixels). The existence of the carpal cysts and their contiguity with the ligaments and articular cavities were analyzed.

For histology sections, 4 μm -thick slices were obtained using a sliding microtome. The preparations were fixed in 10% neutral buffered formalin for at

least 72 hours and then decalcified. The specimens were embedded in paraffin wax. The individual cross-sections were mounted on the slides, stained with hematoxylin and eosin, and examined with a light microscope by a musculoskeletal pathologist and two musculoskeletal radiologists, in consensus.

Results

Ten cysts were observed in a total of five specimens; in the lunate (n=2), hamate (n=1), scaphoid (n=3), triquetrum (n=1), radius (n=1), and ulna (n=2). In all specimens, the cysts were eccentrically located, being either subcortical (n=3) or beneath the subchondral bone plate (n=7). The cartilage overlying the articular surface of the cysts showed signs of degeneration in MR images, including chondral fissuring, chondral thinning, and a focal increase in signal intensity in all seven cysts located beneath the subchondral bone plate. The cortical bone overlying the three subcortical cysts was intact, and no communication between these cysts and the joint compartments was observed histologically. On MRI, all cysts were observed to be 1 cm or less in size, presenting as either well-demarcated areas of high signal intensity (n=8) or on fat-saturated PD-weighted images, as areas of slight hypointensity (n=2). On MR arthrography, no contrast was evident that would suggest communication of the cyst lumen with the joint.

Histologic analysis revealed fat necrosis without inflammation or hypervascularity (n=4). All cysts had fi-

brous walls without a synovial lining, giant cells, or cholesterol granules (Figs. 1–3). True mucoid change was rare (n=1). The fibrous component of cysts varied from thin fibrous septa to a thick lining. Two of ten cysts were located at sites of ligamentous attachment (Fig. 1).

Discussion

There is controversy regarding the underlying pathogenesis of carpal bone cysts. Previously reported theories for cyst formation generally conform to either the intrusion or the contusion model. In the intrusion model (10–12), a defect occurs in the articular cartilage and joint fluid passes through the breached cartilage, resulting in hydraulic destruction of the subchondral bone (4, 5). The contusion model finds repetitive microtrauma as the principal etiology leading to a localized area of subchondral necrosis and secondary cyst formation (11–13). In line with the contusion model, McLaren et al. (14) previously hypothesized that chronic stress on the bone may produce bone resorption and resultant focal necrosis, leading to the formation of a cyst. Our observation of several cysts containing areas of fat necrosis supports this hypothesis.

In previous reports the term “intaosseous ganglion cyst” has been reserved for lesions with histopathology that was identical to soft-tissue ganglion cysts. In these reports, the wall of the cyst consists of fibrous, collagenous fibers similar to fattened histiocytes, and partly mucoid-degeneration without epithelial cells and synovial lining

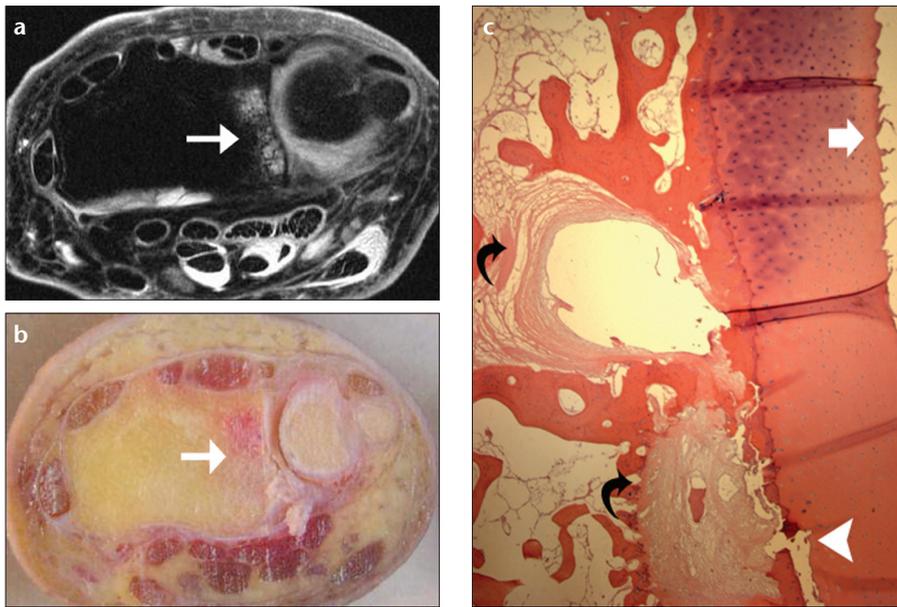


Figure 2. a–c. Male cadaver; age at death, 85 years. Fat-saturated proton density-weighted axial image of the wrist (a) showing cysts located beneath the cartilage of distal radioulnar joint (arrow), with a photograph of the cut surface (b). Histology (c) shows degeneration of cartilage with irregularities on the surface (arrow) and a separation in the tidemark (arrowhead). While fibrous changes (curved arrows) are seen in the cysts, no vascularity, inflammation or synovial lining is noted (H-E staining, $\times 10$).

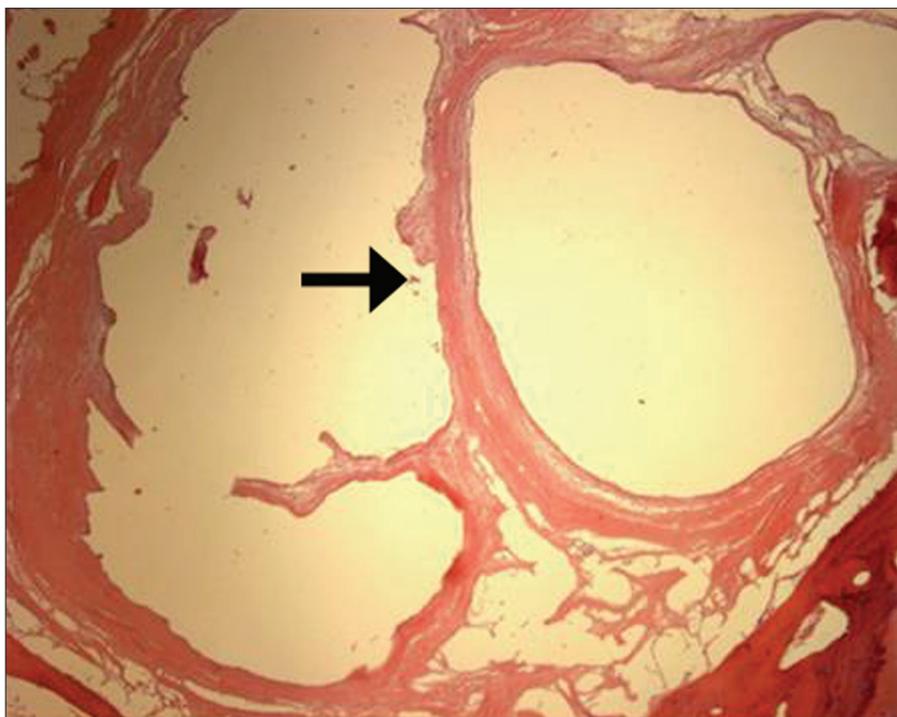


Figure 3. Male cadaver; age at death 64 years. Histology of the scaphoid shows fibrous component of the cyst and a thick septal lining (arrow) (H-E staining, $\times 10$).

(1, 4). Intraosseous ganglion cysts were reported to occur predominantly in young and middle-aged adults (3, 15).

Alternatively, Schrank et al. (1) defined a cyst as degenerative when it displayed a fibromyxoid wall, lined

with a nonspecific fat epithelium and a synovial covering, with crevices and erosions connecting them to the joint space. According to Schrank et al. (1), distinguishing features of intraosseous ganglion cysts were the location

of these cysts at the site of intrinsic or extrinsic ligamentous attachments and the lack of direct communication with the joint. On the contrary, degenerative cysts were commonly located in the subchondral region with direct connection to the joint.

Diagnosis of intraosseous ganglion cyst is important as some symptomatic cysts require surgical treatment with curettage. However, distinguishing imaging and histologic features between an intraosseous ganglion cyst and a cyst arising through a degenerative process have not been fully established. Several of the cysts observed in our series had the typical features of degenerative cysts in that they were located in the subchondral bone with overlying cartilage degeneration and direct communication with joint cavity. However, three cysts in our sample were subcortically located and separated from the articular surface. None of our cysts displayed a true synovial lining, a feature that was previously thought to be diagnostic of degenerative cysts. Two cysts in our study were adjacent to attachment sites of intercarpal ligaments, a feature thought to be more characteristic of intraosseous ganglion cysts.

Our study has several limitations. First, the number of specimens studied was limited; however, the absence of a synovial covering was documented in all of the specimens. Second, the specimens were frozen and thawed, which may have influenced the signal intensities of the lesions in the MR images. The processing of the specimen may also have resulted in loss of internal cyst contents. Third, MR images and anatomic slices were analyzed concurrently, and this may have caused bias in assessing the detectability of cysts, which were of low intensity or not well seen owing to their fibrous content.

In conclusion, MRI, gross pathology and histology correlation in our study suggests that intracarpal bone cysts that are found in degenerative wrists are common and often subcortical or subchondral, reflecting a spectrum of fatty necrosis and fibrocystic change. Inflammation and vascularity are absent. These cysts are typically surrounded by fibrous walls without a true synovial lining and are frequently in

close proximity to degenerated tissue such as cartilage or ligaments. Degenerative intracarpal cysts are far more common than the previously reported intraosseous ganglion cysts. However, the two share multiple overlapping imaging and histologic features. The diagnosis of a true intraosseous ganglion cyst should be reserved for younger patients who are clinically symptomatic, with lesions that are metabolically active, or clearly connecting with a soft-tissue ganglion cyst.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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