Relationship between the degeneration of the cruciate ligaments and calcium pyrophosphate dihydrate (CPPD) crystal deposition of the knee: Anatomic, radiographic and MR imaging study with histologic correlation in cadavers

Poster No.: C-625
Congress: ECR 2009
Type: Scientific Exhibit
Topic: Musculoskeletal
Authors: B. Dirim¹, M. Abreu², M. Wangwinyuvirat², D. Trudell², P. Haghighi², D. Resnick²; ¹Izmir/TR, ²San Diego, CA/US
Keywords: CPPD, cruciate ligament, osseous metaplasia, chondroid metaplasia, degeneration
DOI: 10.1594/ecr2009/C-625

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.
Purpose

Calcium pyrophosphate dihydrate (CPPD) crystal deposition disease is the most common cause of crystalline arthropathy. The radiographic findings of CPPD crystal deposition disease are characterized by calcification in and around joints and arthropathy. The integrity of the anterior cruciate ligament (ACL) is very important before joint replacement in determining the type of prosthesis to use. Microscopic evidence of ACL degeneration has not been well documented in patients with CPPD crystal deposition disease.

The first aim of this study was to investigate the association of CPPD crystal deposition and cruciate ligament degeneration, using magnetic resonance (MR) imaging; high-resolution radiography; anatomical inspection and histologic correlation in cadaveric knees. The second aim of this study was to describe the distribution of CPPD crystal deposition, using high-resolution radiography; anatomical inspection of cadaveric knees.

Methods and Materials

Ten fresh frozen anatomic specimens of human knees from 10 persons (five men and five women; six left knees and four right knees; age range, 74-90 years-old at the time of death; mean age, 81.5-years-old at the time of death) were obtained. The knee specimens were obtained and used according to institutional guidelines, and informed consent for research was obtained from relatives of the deceased. Frontal and lateral radiographs were performed in each specimen and evaluated to ensure that the knee joint was not affected by surgical alterations. The cadaveric specimens were immediately frozen at -40°C (Bio-Freezer; Forma Scientific, Marietta, Ohio). They were later allowed to thaw for 24 hours at room temperature prior to MR imaging. Fresh cadaveric knees were studied with 1.5 Tesla MR magnet (Signa; GE Signa LX Horizon, software version 8.3, GE Medical Systems, Milwaukee, Wisconsin) using a 6.5 inch (16.5 cm) standard knee coil (Dia Coil; Medical Advances, Milwaukee, Wisconsin). Imaging was performed in the coronal, transverse, and sagittal planes. The MR imaging protocol consisted of T1-weighted spin-echo (SE) sequences (repetition time msec/echo time msec, 550/20-21). To acquire high-spatial-resolution images, a section thickness of 1.5 mm, intersection gap of 0.5 mm, field of view of 12x12 cm, and data acquisition matrix of 512 x 256 pixels were used. Spin-echo T1-weighted MR images with and without fat suppression in all three planes were acquired.

The knee specimens were frozen again at -40°C and then were sectioned using a band saw (model B12, Butcher) into 2-mm-thick slices in the sagittal (n=6), axial (n=2), and coronal (n=2) planes. After debris was rinsed from the surface of the specimens, the sections were thawed and then each slice was imaged with high-spatial-resolution radiography (Faxitron; Hewlett Packard, McMinnville, Ore) and photographed under floodlighting with a digital camera (Nikon Coolpix 990). To determine the anatomic sites of calcification, the findings on faxitron radiographs of
each specimen were compared with the findings derived from visual inspection of the anatomic slices by two musculoskeletal radiologists. With faxitron radiography, calcifications in the knee specimens were defined as high-density focal areas greater than 0.3 mm that were linear or round in morphology. In sectional radiographs, the locations of the calcifications were recorded as follows, femoral condyles; tibial plateau; menisci; joint capsule; popliteus, quadriceps, and patellar tendons; cartilage; gastrocnemius muscle; collateral and cruciate ligaments. To determine the MRI signal characterization of the cruciate ligaments that contained CPPD cyrstals, MRI signal of the cruciate ligaments in each specimen were compared with the findings derived from faxitron radiography and visual inspection of the anatomic slices.

Of the 10 cadaveric knees, 8 contained cyrstal depositon in the cruciate ligaments on visual inspection and radiographs. Histologic samples of 12 cruciate ligaments were collected in those 8 knee specimens for routine histologic analysis. Histologic samples of 4 cruciate ligaments were collected in 2 knee specimens that did not contain CPPD cyrstals on visual inspection for routine histologic analysis as control group. The samples were suspended in a 10% formalin solution, embedded in parafin; sectioned further into 5-µm-thick slices. Histologic slices were stained with hemotoxylin-eosin (H-E) and analyzed at light microscopy (magnification, x2 to x40), in consensus, by a musculoskeletal radiologist and an orthopedic pathologist. Also the histologic preparations were examined under a polarized light using first-order red compensator. Weakly positive birefringent pointed the CPPD cyrstals.

Results

Radiographic imaging and visual inspection of the slices demonstrated diffuse calcification of numerous structures in 8 of 10 (80%) specimens (Figure 1).
Fig.: Faxitron radiograph of the sagital knee slice shows the calcifications of the cartilage of the lateral tibial plateau; lateral meniscus; and cartilage of the proximal tibiofibular joint.

Calcification of the cruciate ligaments was determined in 7 of these 8 (87.5%) specimens. Calcifications were observed in 12 of the 16 (75%) cruciate ligaments in 8 CPPD crystals included knees. Five (41.6%) were ACL and 7 (38.4%) were posterior cruciate ligament (PCL) (Figure 2).
Fig.: Figure 2. Faxitron radiograph of the sagittal knee slice; and sagittal 2-mm-thickness anatomic slice show the calcification (arrow) in the posterior cruciate ligament.

Additionally, calcifications were observed in the cartilage of the medial femoral condyles, lateral and medial meniscus in all 8 knee specimens. Quadriceps tendon, patellar tendon, joint capsule, and patellar cartilage contained calcification in 7 of 8 (87.5%) diffuse calcified knee specimens (Table 1). CPPD crystal deposition related calcifications were observed in 2 of 16 (12.5%) CPPD crystals included and calcified cruciate ligaments as low signal on spin-echo T1-weighted images (Figure 3).
Figure 3. Faxitron radiograph of the sagittal knee slice shows the calcification (black arrow) in the posterior cruciate ligament. Calcification in the posterior cruciate ligament is observed as low signal area (white arrow) on sagital spin-echo T1-weighted MR image.

CPPD crystal deposition related calcifications did not lead to signal alterations on MR images in 14 of 16 (87.5%) CPPD crystals included and calcified cruciate ligaments.

Degenerative changes in the cruciate ligaments associated with CPPD crystal deposition were observed in 9 of 12 (75%) CPPD crystals included cruciate ligaments. Degeneration pattern of the cruciate ligaments were determined as follows: loose fibrous tissue (Figure 4) in seven of 9 (78%); chondroid metaplasia (Figure 5) in one of 9 (11%); and osseous metaplasia (Figure 6) in one of 9 (11%).

Figure 4. Faxitron radiograph of the axial knee slice; and axial 2-mm-thickness anatomic slice show the calcification (white arrow) in the anterior cruciate ligament. Photomicrograph of histologic section shows the loose fibrous tissue (black arrows) and calcium pyrophosphate dihydrate crystal (cppd) in the degenerated anterior cruciate ligament (Hematoxylin-eosin stain; X40 magnification).
**Figure 5.** Faxitron radiograph of the sagittal knee slice shows the calcification (white arrow) in the posterior cruciate ligament. Photomicrograph of histologic section shows chondroid metaplasia (black arrow); and calcium pyrophosphate dihydrate crystal (cppd) in the degenerated posterior cruciate ligament (Hematoxylin-eosin stain; X10 magnification).

**Figure 6.** Sagital 2-mm-thickness anatomic slice shows the calcification (white arrow) in the posterior cruciate ligament. Photomicrograph of histologic section shows osseous metaplasia (black arrow); and calcium pyrophosphate dihydrate crystal (cppd) in the degenerated posterior cruciate ligament (Hematoxylin-eosin stain; X4 magnification).

There was no evidence of degeneration in three of 12 (25%) CPPD crystals included cruciate ligaments (Table 2).
Images linked within the text of this section:

Fig.
Conclusion

CPPD crystal deposition in the cruciate ligaments was first described in a cadaveric case by Steinbach et al in 1996. After this first description, cruciate ligament involvement with CPPD crystals was reported in 4 of 10 (40%) cadaveric knees in only one cadaveric study in 2004. Those studies did not include information about degeneration in the cruciate ligaments associated with CPPD crystal deposition.

Chondroid metaplasia as a degeneration pattern followed by CPPD crystal deposition was reported in one of 19 anterior cruciate ligaments that were harvested from patients who underwent total knee arthroplasty by Cushner et al. To our knowledge, no other reports describing degeneration of the cruciate ligaments associated with CPPD crystal deposition.

In our study, calcifications were observed in 12.5% CPPD crystals included cruciate ligaments as low signal on SE T1 MR images. CPPD crystal deposition did not lead to signal alterations in 87.5% calcified cruciate ligaments on MR images. High-resolution radiography was more sensitive than MR imaging for the detection of calcifications in cadavers with CPPD crystal deposition.

Suan reported that in the detection of chondrocalcinosis, spoiled gradient 4 T MRI was superior to the X-ray techniques for assessment of articular cartilage and menisci. But Suan's study did not include information about the cruciate ligaments. One limitation of our study is using only SE T1 sequences. We think that using stronger magnets and MR sequences that have very short T2 relaxations times may allow better detection of CPPD crystal deposition and degeneration in cruciate ligaments.

In our study degenerative changes in the cruciate ligaments associated with CPPD crystal deposition were observed in 75% of CPPD crystal included cruciate ligaments. Such chronic degenerative changes may possibly lead to ACL failure. Failure in recognition of degenerative or nonfunctional ACL may result in early failure of prosthetic designs in joint replacement patients.