Pinhole Scintigraphic Sign of Chondromalacia Patellae in Older Subjects: A Prospective Assessment with Differential Diagnosis

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Chondromalacia patellae (CP) is an important cause of anterior knee pain. Two clinical types are known: one that typically affects young subjects and the one that affects older patients. The primary diagnostic approach is radiography reinforced with arthrography. A ^{99m}Tc-MDP bone scan is invaluable in the study of bone diseases especially when augmented with pinhole scintigraphy (PS). In this study previously unknown, specific sign of CP demonstrated by PS in six middle-aged and elderly patients is described. **Methods:** Noting an increased patellar uptake in a planar spot view, a medial PS scan of the patella was taken to detail the uptake pattern using a 3-mm or 4-mm aperture pinhole collimator. The uptake pattern was analyzed in terms of location, definition, mode, grade and other associated changes, and correlated with radiographic and CT scan alterations. **Results:** The planar views showed patellar uptake to be diffuse and nonlocalizing in five patients and ill-defined and spotty in the remaining patient. In contrast, PS revealed small, spotty uptake well localized in the central retropatellar facet in all but one patient in whom uptake was segmental. A control PS study of 16 patients with their patellas involved by osteoarthritis (n = 6), rheumatic arthritis (n = 5) and Reiter's syndrome (n = 5) also revealed retropatellar uptake with or without anterior patellar uptake in every patient. The CP with localized osteolysis or osteopenia accumulated tracer intensely, whereas those without showed mild to moderate uptake. **Conclusion:** Spotty tracer uptake occurring exclusively in the central retropatellar facet without other knee joint alteration appears pathognomonic of CP in older patients.

Key Words: chondromalacia patellae; patella; bone scan; pinhole scintigraphy

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Chondromalacia patellae (CP), first described by Büdinger (*1*) in 1906, is a condition characterized by a series of degenerative changes initiated in the retropatellar facet cartilage that may often progress to cause focal exposure of bone, subchondral osteophytosis and cystic change. As Wiles et al. (*2*) indicated, the term "chondromalacia" seems to have been introduced by Aleman (*3*). It is an important cause of anterior knee pain in adolescents and young adults, as well as in older patients, often predisposing to osteoarthritis of the knee joint (*2,4,5*).

Clinically, CP may be suspected by symptoms and signs which include patellar crepitus, retropatellar pain, soft-tissue swelling, tenderness, effusion, misalignment and limping. The primary imaging diagnostic approach is plain skeletal radiography, but it plays a relatively minor role, providing indirect information about CP when the pathology is confined to cartilage (*5,6*). However, in established cases, the "excavation" has been described to be a reliable sign (*7*) and the small focal osteolysis or osteopenia in the central aspect of the retropatellar facet bone was confirmed as specific of CP with subchondral bone involvement as shown in the present series. Arthrography supplemented with conventional tomography (*8*) or computed tomography (CT) (*9*) and magnetic resonance imaging (MRI) (*10–12*) has been shown to be sensitive and decisive in the vast majority of cases, but these examinations are often invasive, costly or not readily available.

The bone scan, on the other hand, has also been explored in the clinical study of painful patellofemoral joints in general (*13–15*) and for CP in particular (*16*), demonstrating various levels of sensitivity. Admittedly, the widely practiced, ordinary, planar bone scan with relatively low resolution suffers the drawback of reduced specificity as well as sensitivity. Pinhole scintigraphy (PS) with greatly enhanced anatomical resolution has been reported to be a potent breakthrough (*17–20*). In effect, bone scintigraphy complemented with the pinhole technique is able to portray features which are specific for many bone and joint diseases (*17–23*).

Pinhole scientigraphy was prospectively applied to the diagnosis of CP in middle-aged and elderly patients. Parallel to this study, a control study of a few common arthritides of the knee regularly involving the patella was carried out for differential diagnostic purposes. The recently introduced bone scan agent, ^{99m}Tc-oxidronate (HDP), enabled

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TABLE 1
Summary of Clinical Data, Diagnosis and X-Ray/Pinhole Scan/CT Scan Changes in Chondromalacia Patellae and Control Disease Groups

Patient no.	Age/Sex	Chief complaint	Diagnosis and (graded x-ray change)*	PS changes: Location in patella	PS changes: Uptake mode/grade	†EPSC// CTC‡
1	61/M	Knee pain	CP (+/−)	Central facet	Focal (++)	−//DOC/mf
2	53/F	Knee pain	CP (+/−)	Central facet	Focal (+)	−//T/mf
3	52/F	Knee pain	CP (+/+)	Central facet	Segmt (+)	−//TC/lf
4	42/F	Knee pain	CP (+/++)	Central facet	Focal (+++)	−//RTC/lf
5	67/M	Knee pain	CP (+/++)	Upper central	Focal (+++)	−//DC/mf+c
6	70/F	Knee pain	CP^oa (−/+++)	Upper central	Focal (+++)	+//TC/mf+c
7	61/F	Knee pain	OA (++)	Lower facet	Focal (+++)	+
8	49/M	Weakness	OA (+)	Lower facet	Focal (++)	−
9	67/F	Knee pain	OA (+++)	Whole facet	Diffuse (+++)	+
10	57/F	Knee pain	OA (+)	Whole facet	Segmt (++)	+
11	49/F	Knee pain	OA (+)	Whole facet	Diffuse (++)	+
12	59/F	Knee pain	OA (++)	Whole facet	Diffuse (++)	+
13	48/F	Joint pain	RA (++)	Whole facet	Diffuse (++)	+
14	56/F	Joint pain	RA (++)	Whole facet	Diffuse (++)	+
15	42/M	Joint pain	RA (+++)	Whole facet	Diffuse (++)	+
16	40/F	Joint pain	RA (++)	Lower facet	Focal (+)	+
17	47/F	Joint pain	RA (+)	Whole facet	Diffuse (+)	+
18	20/M	Joint pain	RS (++)	Whole facet	Diffuse (++)	+
19	18/M	Joint pain	RS (++)	Whole facet	Diffuse (++)	+
20	20/M	Joint pain	RS (++)	Whole facet	Diffuse (++)	+
21	30/F	Joint pain	RS (+)	Whole facet	Diffuse (++)	+
22	27/M	Joint pain	RS (+++)	Base	Focal (+)	++

*Graded x-ray changes included: focal sclerosis with "excavation" and costeolysis or osteopenia in the patellar facet in chondromalacia patellae; patellar spur and roughening in osteoarthritis; osteoporosis, subchondral roughening, and/or periarticular soft-tissue swelling in rheumatoid arthritis; osteoporosis, soft-tissue swelling, and/or subchondral roughening in Reiter's syndrome. Where possible, individual x-ray changes were arbitrarily graded into mild (+), moderate (++) and marked (+++).

†EPSC = extrapatellar bone scan changes with increased tracer uptake in the patellofemoral, femorotibial and tibiofibular compartments.

‡CTC = computed tomographic changes including thinning (T), roughening (R) and denudation (D) of cartilage and subchondral osteophyte (O) and cyst formation (C). The involved site was the medial facet (mf), lateral facet (lf) or central ridge (C).

CP = chondromalacia patellae; CP^oa = chondromalacia patellae with concurrent osteoarthritis; OA = osteoarthritis; RA = rheumatic arthritis; and RS = Reiter's syndrome.

satisfactory completion of PS within 20 min without increasing the radiation dose.

MATERIALS AND METHODS

Six patients with CP (two males and four females; age 42–70 yr, mean age 57.5 yr) were studied. Chondromalacia patellae was the only significant pathology in all six patients except for one patient with concurrent osteoarthritis in the knee (Patient 6). For differential diagnosis, 16 patellas affected with common arthritic diseases of the knee (osteoarthritis (n = 6); rheumatoid arthritis (n = 5); and Reiter's syndrome (n = 5)) were examined (Table 1).

All patients were seen at the author's institution for the past 3 yr. The diagnoses of CP were based on radiography, high-resolution CT scans with a measure-set technique, MRI, and/or arthroscopy; for the control groups, diagnoses were made based on symptoms and signs, serological tests, radiography, CT, arthroscopy and/or histology.

Bone scans were obtained 3 hr and 1.5 hr after intravenous injection of 20 mCi (0.74 GBq) of ^{99m}Tc-methylene diphosphonate (MDP) and ^{99m}Tc-HDP(Osteoscan-HDP, Mallinckrodt, St. Louis, MO) during the past six mo. A medial pinhole view was taken by placing the pinhole center at a distance of about 10 cm medially to the midsagittal line of the patella that was painful and "hot" in the spot view. Patients were positioned supine on the scan couch in a lateral recumbent position with their knees flexed and crossed as comfortably as possible. The pinhole aperture was either 3 mm or 4 mm, depending upon the number of counts emitted, with the latter size being used more often. A total of 400K–450K counts were accumulated over a period of 15–20 min. Siemens Scintiview II (Model ZLC 7500S) and Orbiter (Model 6601) gamma cameras were used. Generally, the projection was true medial, but in some control group subjects an oblique projection resulted due to the patient's inability to fully cooperate. Parallel to PS, a lateral radiograph of the patella and CT scans with bone- and measure-set techniques (*24*) were taken in each patient to study bone and cartilage alterations in the retropatellar facet, which included roughening, thinning, or denudation of cartilage and osteophyte and/or cyst(s).

The patterns of increased patellar uptake shown on pinhole views were assessed by three nuclear physicians according to intrapatellar location and the mode or appearance and the intensity of tracer uptake. The uptake site was categorized into upper, central and lower zones in the retropatellar facet; the base or inferior edge of the patella; and the whole facet. The uptake mode was focal, segmental

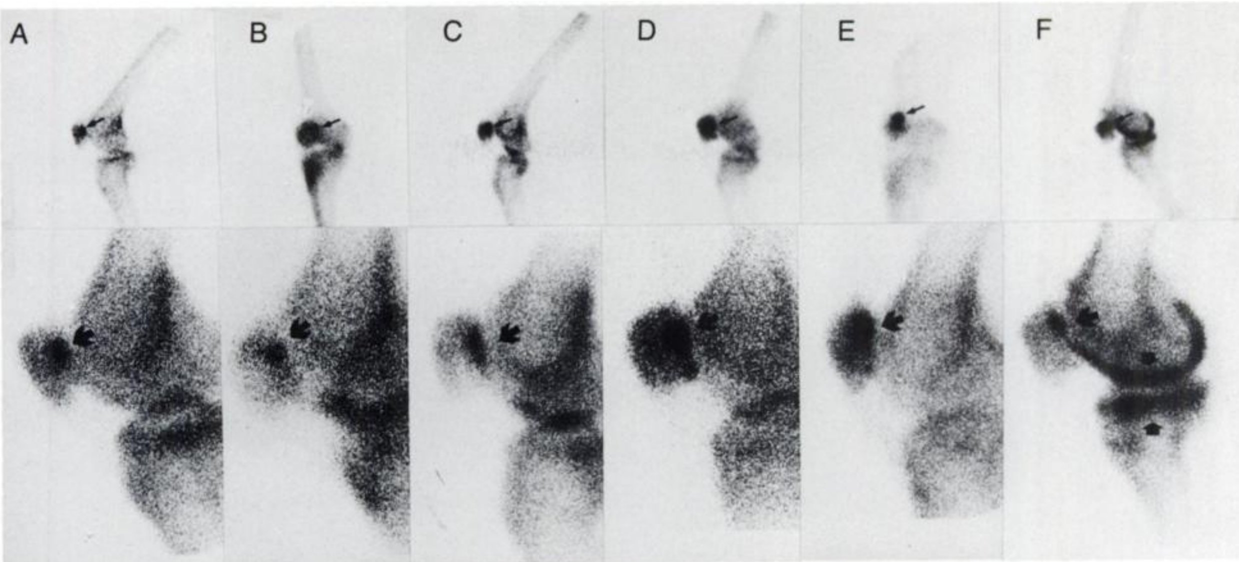

FIGURE 1. [Top row, arrows] Medial and anterior planar spot views of the knee in six patients with CP show show nonspecific, diffuse, patellar uptake or "hot patella" signs (B–F) and ill-defined, spotty uptake (A). [Bottom row, arrows] Medial pinhole scans of the same patellas show spotty uptake well localized in the central retropatellar facet in all but Patient 3 (C), in whom uptake is segmental but again well confined to the facet proper (arrow). Spotty uptake is attended by less intense, reactive uptake in the patellar body in Patients 4 (D) and 5 (E). (F) Curvilinear and linear tracer uptake in medial femoral condyle and medial tibial condyle, respectively, denoting concurrent osteoarthritis (arrows). The knee joint is narrowed (opposing arrows).

or diffuse. The avidity of tracer uptake was arbitrarily graded into mild, moderate and marked, and associated changes in the patellofemoral and femorotibial articular compartments were evaluated.

The plain radiographic abnormalities in CP included osteosclerosis and an "excavation" sign (7) and small, focal osteolysis or osteopenia confined to the central zone of the retropatellar facet. The observed abnormalities in the control group were porosis, periarticular soft-tissue swelling, joint space changes, subchondral aberrations and spurs or osteophytes. To correlate with PS alterations, the radiographic facet changes of CP were classified as absent, osteopenic or osteolytic. Bone sclerosis was either absent or present. Finally, CT scan alterations of the patellas were roughening, thinning and denudation of retropatellar facet cartilage, and focal subchondral osteophyte and/or cystic change, and their intrapatellar location in the medial facet, the lateral facet or the central ridge.

RESULTS

Pertinent patient data, chief clinical complaints, diagnosis, graded radiographic alterations, categorized PS findings and graded patellar tracer uptake, the presence or absence of extrapatellar scan alterations and categorical CT changes are summarized in Table 1.

The preliminary, planar spot views showed patellar uptake to be diffuse without the localizing sign in five patients (Figs. 1B–1F, top row). The uptake was spotty but poorly defined in one patient (Fig. 1A, top). In contrast, PS in all six patients portrayed moderate to marked increased tracer uptake which was well localized in the central (n = 4) and upper central or supraridge (n = 2) zones of the retropatellar facet (Figs. 1A–1F, bottom row). Tracer uptake was focal and spotty in mode in all six patients (Fig. 1A, B, D–F, bottom row) except one, in whom the uptake was segmental (Fig. 1C, bottom). In two patients with focal, radiographic osteolysis and osteopenia, tracer uptake was extremely intense and was attended by relatively less intense uptake in the remaining patella (Figs. 1D, 1E, bottom). In the other four patients, the uptake was mild to marked. The avidity of tracer uptake in CP appeared to roughly correlate with radiographic changes. Thus, tracer uptake tended to be marked and extreme in patients with osteolysis or osteopenia (Figs. 1D–F, bottom; see Figs. 6A, 7A), while mild to moderate in those without bone change (Figs. 1A–1C, bottom). Sclerosis with the "excavation" sign was noted in the facet in all but one patient

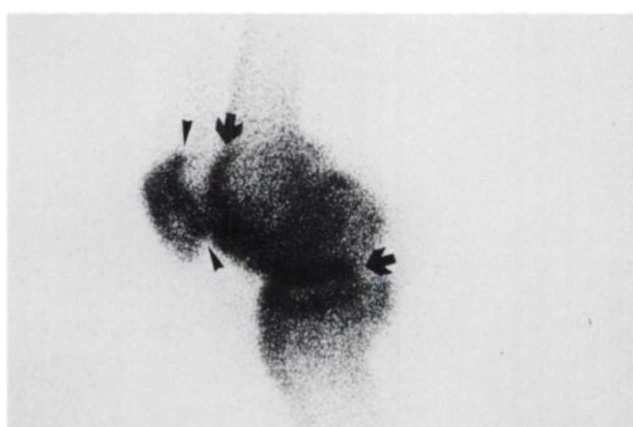

FIGURE 2. Medial pinhole scintigraph of the osteoarthritic right knee and patella of Patient 11 shows diffuse tracer uptake in the whole retropatellar facet (arrowheads) and curvilinear and linear bands of intense tracer uptake in the main osteoarthritic alterations of patellofemoral (vertical arrow) and femorotibial (horizontal arrow) compartments, respectively.

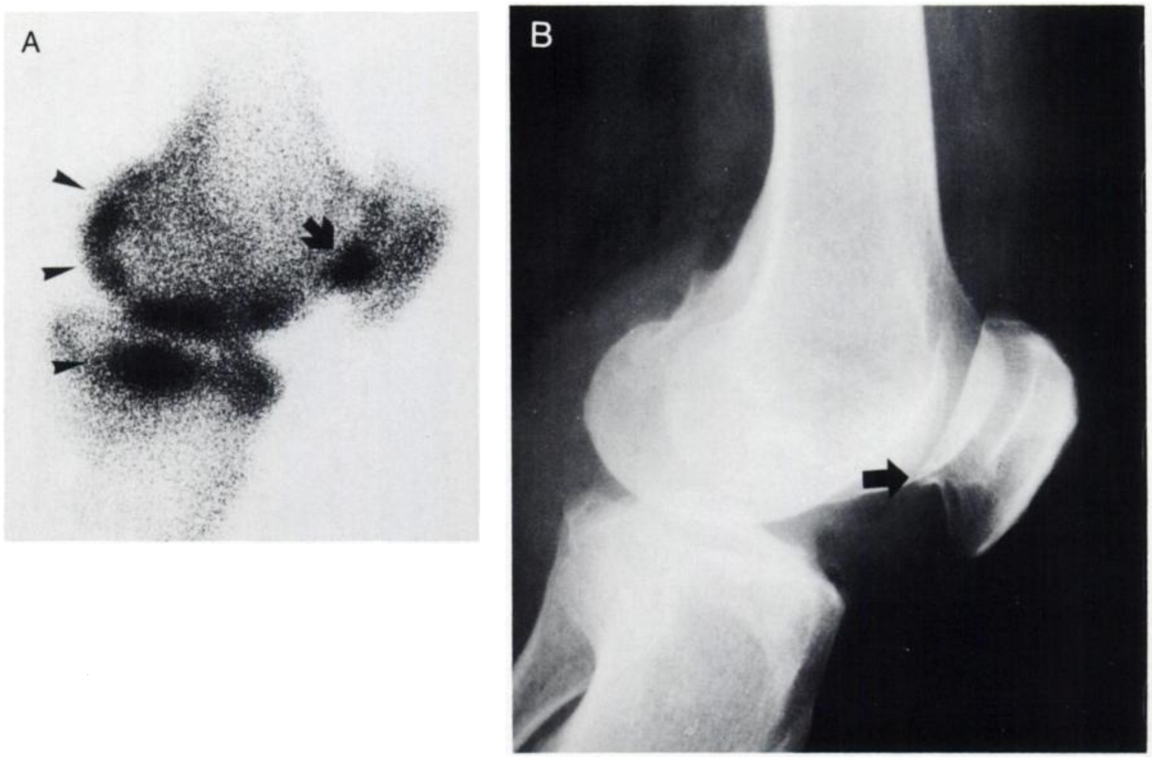

FIGURE 3. (A) Medial pinhole scintigraph of the osteoarthritic left knee and patella of Patient 7 shows small, discrete, spotty tracer uptake in the lower edge of the retropatellar facet (arrow) as well as multiple areas of spotty and segmental uptake in the femorotibial compartment, which is the site of the main pathology (arrowheads). (B) Lateral radiograph reveals an osteophyte arising from the lower edge of the retropatellar facet (arrow) and cortical irregularity and thinning of other periarticular bones, indicating degeneration.

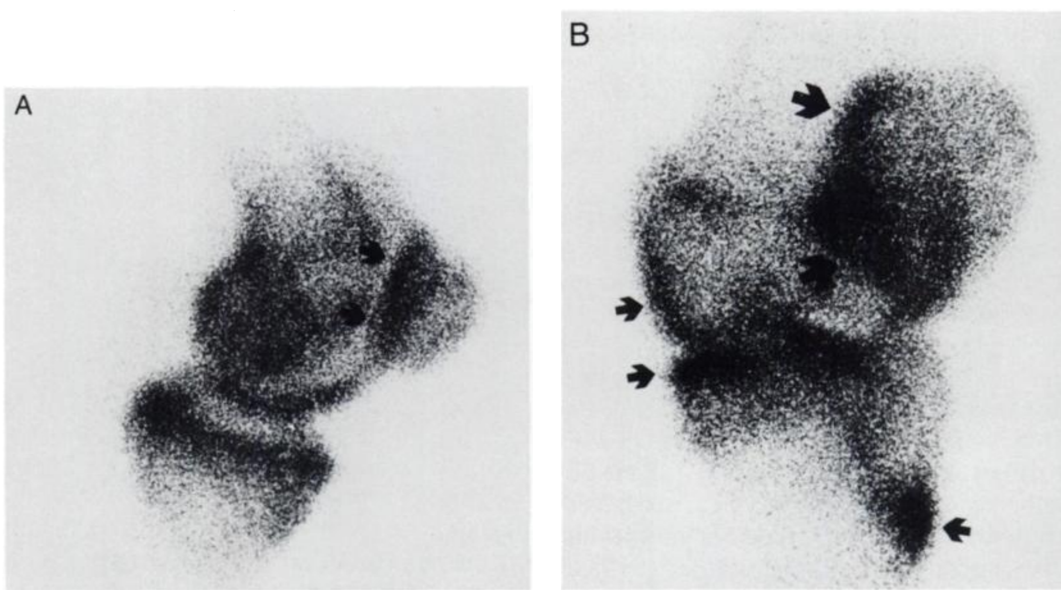

FIGURE 4. (A) Medial pinhole scintigraph of the rheumatoid arthritic left knee of Patient 13 shows diffuse tracer uptake involving the whole retropatellar facet (arrows) and a generalized increase in uptake throughout the knee joint, a sign of diffuse articular inflammation. (B) An oblique pinhole scintigraph of the left knee in Patient 18 with Reiter's syndrome also shows diffuse uptake in the whole retropatellar facet (large arrows) and scattered areas of spotty uptake in the joint margins and proximal tibiofibular articulation (small arrows).

(Fig. 6A) and did not seem to correlate with tracer uptake avidity. In Patient 6, CP was concurrent with osteoarthritis, manifesting curvilinear and linear bands of intense tracer uptake in the medial femorotibial compartment (Fig. 1F).

On the other hand, in four of six patients with knee joint osteoarthritis with patellar involvement, retropatellar tracer uptake was typically diffuse, involving the whole facet (Fig. 2); in the remaining two patients, it was spotty in mode (Fig. 3A), occurring in the lower margin of the facet, not in the central zone, and was associated with an osteophyte (Fig. 3B). Moreover, spotty and band-like areas of increased uptake were seen in the patellofemoral and femorotibial compartments which were the sites of degeneration, an important differential feature (Fig. 3A). On the whole, uptake avidity also appeared to correlate roughly with radiographic changes in this group.

Finally, in all five patients who had rheumatic arthritis and Reiter's syndrome of the knee with patellar involvement, tracer uptake was again diffuse, involving the entire retropatellar surface (Fig. 4), except for one patient in each group who respectively showed spotty uptake in the lower edge of the facet and in the patellar base. Patellar scan alterations in these two groups were similar, especially on planar views. Nonetheless, the diffuse tracer uptake in and about the knee joint on PS views in rheumatoid arthritis (Fig. 4A) differed from the spotty, periarticular, tracer uptake seen in Reiter's syndrome (Fig. 4B). The difference appeared to clearly reflect the well known, radiographic characteristics of each disease.

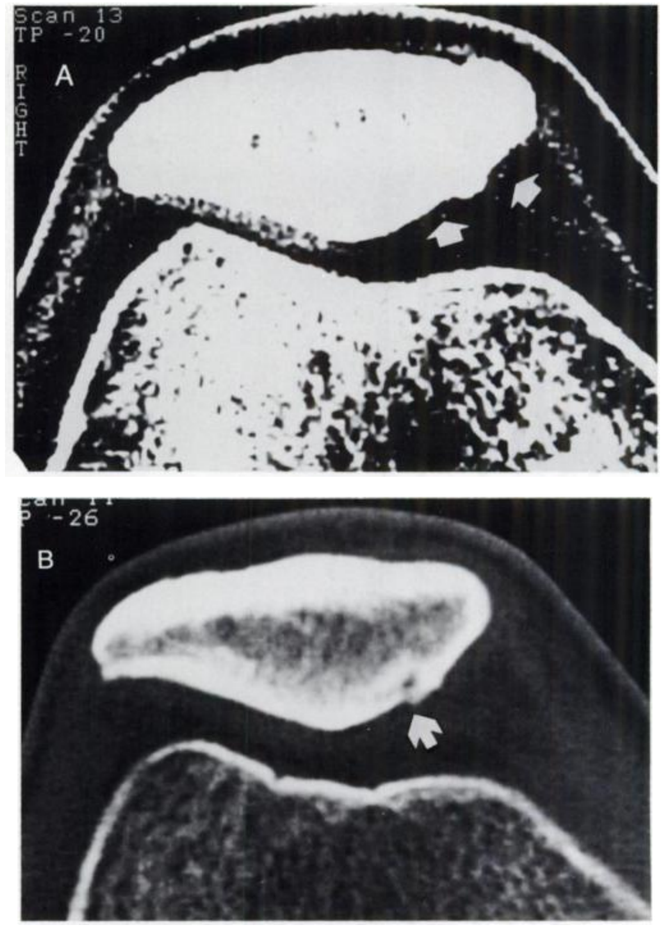

FIGURE 5. (A) An axial measure-set CT scan through the right patella in Patient 1 (Fig. 1A) with CP shows denudation of retropatellar cartilage with focal bone excrescence (arrows). (B) Axial bone-mode CT scan through the same level reveals focal osteophyte and cyst in the ridged area between media and odd facets (arrow).

Case Presentations

Patient 1. A 61-yr-old male was referred for imaging studies of the right, anterior knee due to pain which had persisted for 4 yr. A plain lateral x-ray of the knee was not remarkable. Subsequent measure-set and bone-set axial CT scans through the patella delineated cartilage denudation with a small, focal subchondral excrescence and cyst in the medial facet about the ridge (Fig. 5). A medial pinhole scan of the patella portrayed a small, spotty area of moderately intense tracer uptake sharply localized in the central zone of the facet (Fig. 1A, bottom). No extrapatellar scan abnormality was seen.

Patient 4. A 42-yr-old female was referred for a bone scan of the right, anterior knee due to pain which had persisted for 3 yr. The admission plain lateral x-ray of the knee demonstrated classic focal sclerosis with the "excavation" sign as well as small, spotty osteolysis in the subchondral bone of the central facet (Fig. 6A). Subsequent high-resolution axial CT scans of the patella demonstrated roughening and thinning of the retropatellar cartilage as well as a small, focal, cystic change in the lateral aspect of the central facet (Fig. 6B). A medial PS view of the patella portrayed a small, spotty area of markedly increased tracer uptake localized in the central zone of the facet (Fig. 1D, bottom). It was accompanied by comparatively less intense uptake in the rest of the patella. No extrapatellar scan change was observed.

Patient 6. A 70-yr-old female was referred for a postmastectomy follow-up bone scan, which showed a "hot patella" on the right knee. Pinhole scintigraphy was performed which clearly depicted small, spotty tracer uptake in the upper central facet (Fig. 1F, bottom). In addition, thick curvilinear and linear bands of intense tracer uptake were noted in the medial femorotibial compartment, indicating concurrent osteoarthritis. A plain lateral x-ray revealed small, spotty osteolysis in the upper central facet (Fig. 7A). Subsequent high-resolution axial CT scans through the patella revealed markedly thinned retropatellar cartilage with underlying cystic change in the medial facet and central ridge (Fig. 7B).

DISCUSSION

Chondromalacia patellae, considered to be caused by traumatic insults to the retropatellar hyaline cartilage and early senisence, is a syndrome of patellofemoral pain commonly occurring in adolescents and young adults as well as older subjects (*2,4,5*). Clinically, two different varieties are noted with regard to age and symptoms. One type manifests with patellar pain and crepitus in young adults and

FIGURE 6. (A) Lateral x-ray of the right knee in Patient 4 with chondromalacia patellae shows a small, spotty lysis in the central retropatellar facet (arrow) and bone sclerosis with "excavation" (vertical, opaque meniscus-like shadow about arrow). Neither osteophyte nor other articular alterations are present. (B) A low-window-set axial CT scan through the patella reveals both roughened and thinned facet cartilage and subchondral cystic change (arrowheads).

adolescents and the other typically affects older people, occasionally in concurrence, but not necessarily in association, with osteoarthritis in the patellofemoral and femporotibial compartments (*5*).

The alterations in the retropatellar cartilage vary according to disease stage: softening and swelling in the first stage; fissuring in the second stage; fibrillation with a "crab meat" appearance in the third stage; and thinning, ulceration and denudation with the exposure of the subchondral bone in the fourth stage. Following the setting of the last stage, focal subchondral hyperosotosis or osteophyte and cystic change may ensue. Epidemiologically, Goodfellow et al. (*4*) recognized two different types of cartilaginous changes, surface and basal. The former type, being age-dependent, increases in incidence precipitously with age and likely predisposes to osteoarthritis in later years, whereas the latter type affects adolescents and young adults, causing prolonged femoropatellar pain to be treated by "excision of the disc of [the] affected cartilage."

The primary imaging diagnostic approach is plain radiography which plays a limited role in the classic forms of CP, in which alterations are shallowly confined in the cartilage (*6*). However, as illustrated in Figures 6A and 7A, focal bone sclerosis and "excavation" in the retropatellar facet have been reported to be reliable signs (*7*) and spotty osteolysis or osteopenia in the central retropatellar facet is characteristic of CP with subchondral bone involvement. Arthrography and CT scans are sensitive and decisive means of diagnosis in both early and established cases, but they are invasive and costly.

As demonstrated in these six patients, a CT scan modified with the measure-set technique (*24*) is efficient for delineating roughening, thinning and denudation of cartilage as well as associated bone aberration and cystic change (*8,9*). MRI shows promise for qualitative imaging of cartilaginous disorders (*10–12*), but is costlier and not readily available.

Bone scanning has been used in the diagnosis of pain in the anterior knee, particularly in CP reported Dye et al. and Kohn et al. (*13,14*), where extremely high sensitivity was reported. One of the first publications describing a systematic bone scan study on CP was probably that of Dye and Boll who found increased patellar uptake in 54% of their patients with anterior knee pain (*13*). More specifically, they included eight cases of surgically verified CP, 7 of which manifested "hot patella." A bone scan study on a series of 50 "highly selected" cases with CP by Kohn et al. resulted in a sensitivity of 100% (*14*). It was apparent, however, that these studies were based on planar scintigraphy, the specificity of which is obviously low. In actuality, the descriptive terms they employed were mere "hot patella" and "focal uptake" which are neither clearly de-

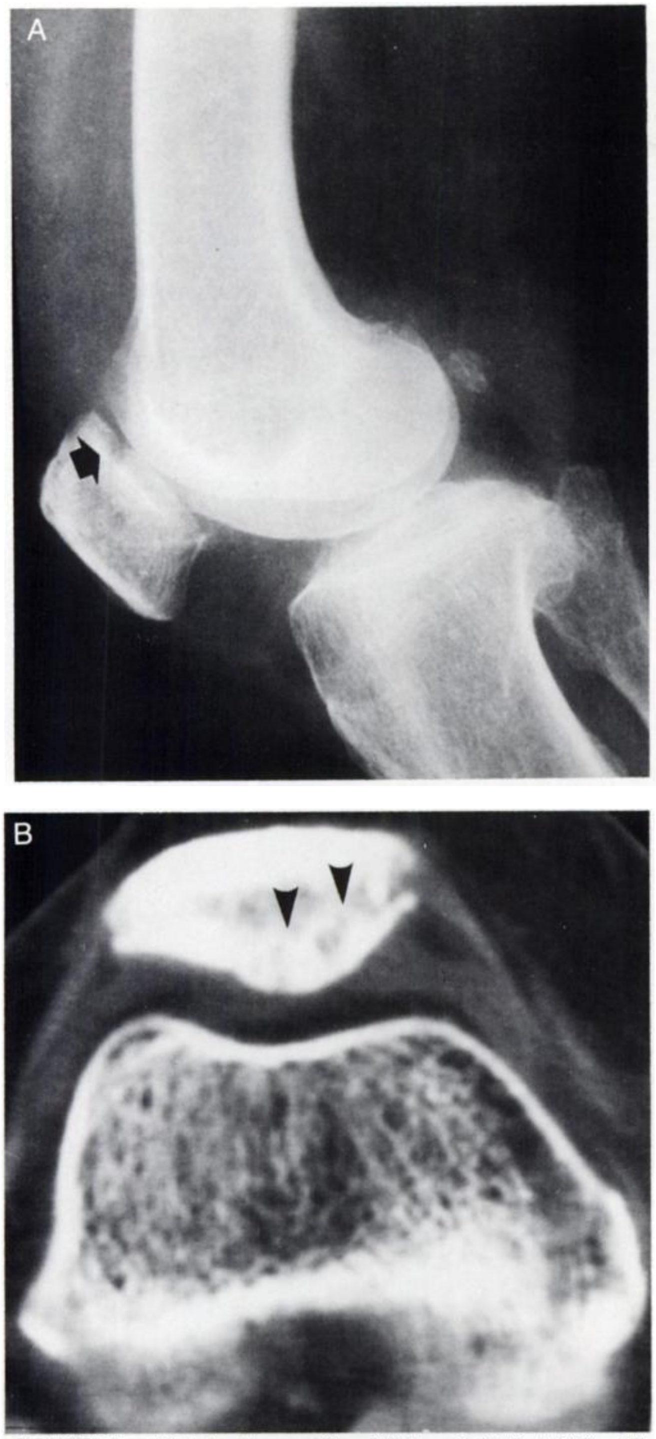

FIGURE 7. (A) Lateral x-ray of the right knee in Patient 6 (Fig. 1F) with chondromalacia patellae and concurrent osteoarthritis shows classic spotty osteolysis in the upper central, retropatellar facet (arrow) and periarticular bone irregularity and osteophytosis. (B) An axial CT scan through the patella demonstrates cysts and bone aberrations in medial facet (arrowheads). Note marked thinning and slight irregularity of the femoral condylar cortex.

fined nor specific (*15*). Furthermore, Butler-Manuel et al. have documented a record low sensitivity of 38.9% in their series of 18 cases of CP (*16*).

The usefulness of PS with enhanced resolution has been described in many bone and joint diseases (*17–23*). In this series, PS was prospectively applied to six older patients with CP. It is likely that the patients in our series are a surface variant with related subchondral bone alteration; (*4*) typical examples of CP that occur in older subjects without osteoarthritis (*5*). In five patients, CT changes were obvious with subchondral bone cyst(s) and osteophytosis, and cartilage thinning was evident in four patients.

The planar spot views showed diffuse "hot patella" signs which were nonspecific in five patients and were ill-defined with spotty uptake in one patient (Fig. 1, top row). In contrast, PS in five of six patients disclosed a distinct pattern characterized by small, spotty uptake sharply localized in the central (Figs. 1A, B and D, bottom) and upper central (Figs. 1E and F, bottom) zones of the retropatellar facet. In one patient, the uptake was segmental, but well confined to the retropatellar facet proper (Fig. 1C, bottom). Our observation is in good accord with that of Insall et al. (*5*) who pointed out that the central zone of the patellar facet is the classic site for CP. In one patient, osteoarthritis was concurrent in the same knee, showing classic curvilinear and band-like tracer uptake in the medial femorotibial compartment (Fig. 1F, bottom). On both the x-ray and CT scan, the patella was free of significant arthrotic change in this patient, ruling out the possibility of mere coincidence for any close association between CP and osteoarthritis (Fig. 7). The presence of an obvious osteophyte in an osteoarthritic patella further clarifies this point (Fig. 3).

In contrast to the spotty uptake characteristically localized to the central retropatellar facet in CP, the patellar uptake in 12 of 16 patients with patellar involvement as a part of more or less widely spread osteoarthritis, rheumatoid arthritis and Reiter's syndrome in the knee was typically diffuse, affecting the whole retropatellar facet. The phenomenon was anticipated since the pathologic changes in the synovium, cartilage and subchondral bone in diseases are multifocal or diffuse within a joint. Tracer uptake was spotty and discrete in two patients with osteoarthritis (Fig. 3A) and in the patients with rheumatoid arthritis and Reiter's syndrome, but none were found in the central facet. Such uptake at the inferior edge of the retropatellar facet or the patellar base is presumably due to bone degeneration with osteophytosis that may well be a consequence of the protracted course of the main disease (Fig. 3B). The presence of alterations in the knee joint strongly supports the secondary nature of the patellar change.

In conclusion, the small, spotty tracer uptake sharply localized in the central retropatellar facet in PS is characteristic of CP in older subjects. The sign appears pathognomonic when it occurs singly without other scan abnormalities in the knee joint.

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REFERENCES

1. Büdinger K. Über Ablösung von Gelenkteilen und verwandte Prozesse. *Dtsch Zeitschr Chir* 1906;84:311–365.
2. Wiles P, Andrews PS, Devas MB. Chondromalacia of the patella. *J Bone Joint Surg* 1956;38B:95–113.
3. Aleman O. Chondromalacia posttraumatica patellae. *Acta Chirur Scand* 1928;63:149–190.
4. Goodfellow J, Hungerford DS, Woods C. Patello-femoral joint mechanics and pathology. 2. Chondromalacia patellae. *J Bone Joint Surg* 1976;58B: 291–299.
5. Insall J, Falvo KA, Wise DW. Chondromalacia patellae: a prospective study. *J Bone Joint Surg* 1976;58A:1–8.
6. Resnick D, Niwayama G. Chondromalacia patellae and other patellar syndromes. In: Resnick D, Niwayama G, eds. *Diagnosis of bone and joint disorders, 2nd ed.* Philadelphia: Saunders; 1988:1455–1458.
7. Lund F, Nilsson BE. Radiologic evaluation of chondromalacia patellae. *Acta Radiol Diagn* 1980;21:413–416.
8. Boven F, Bellemans MA, Geurts J, Potvliege R. A comparative study of the patello-femoral joint on axial roentgenogram, axial arthrogram, and computed tomography following arthrography. *Skeletal Radiol* 1982;8:179–181.
9. Boven F, Bellemans MA, Geurts J, Boeck HD, Potvliege R. The value of computed tomography scanning in chondromalacia patellae. *Skeletal Radiol* 1982;8:183–185.
10. Yulish BS, Montanez J, Goodfellow DB, Bryan PJ, Mulopulos GP, Modic MT. Chondromalacia patellae: assessment with MR imaging. *Radiology* 1987;164:763–766.
11. Hayes CW, Sawyer RW, Conway WF. Patellar cartilage lesions: in vitro detection and staging with MR imaging and pathologic correlation. *Radiology* 1990;176:479–483.
12. McCauley TR, Kier R, Lynch KJ, Jokl P. Chondromalacia patellae: diagnosis with MR imaging. *AJR* 1992;158:101–105.
13. Dye SF, Boll DA. Radionuclide imaging of the patellofemoral joint in young adults with anterior knee pain. *Orthop Clin North Am* 1986;17:249–262.
14. Kohn HS, Guten GN, Collier BD, Veluvolu P, Whalen JP. Chondromalacia of the patella: bone imaging correlated with arthroscopic findings. *Clin Nucl Med* 1988;13:96–98.
15. Fogelman I, McKillop JH, Gray HW. The "hot patella" sign: is it of any clinical significance? *J Nucl Med* 1983;24:312–315.
16. Butler-Manuel PA, Guy RL, Heatley FW, Nunan TO. Scintigraphy in the assessment of anterior knee pain. *Acta Orthop Scand* 1990;61:438–442.
17. Danigelis JA, Fisher RL, Ozonoff MB, Sziklas JJ. Technetium-99m-polyphosphate bone imaging in Legg-Perthes disease. *Radiology* 1975;115:407–413.
18. Bahk YW. Usefulness of pinhole scintigraphy in bone and joint diseases. *Jpn J Nucl Med* 1982;19:1307–1308.
19. Bahk YW. Usefulness of pinhole collimator scintigraphy in the study of bone and joint diseases [Abstract]. In: *Abstracts of the European Nuclear Medicine Congress*. London:1985:262.
20. Bahk YW, Kim OH, Chung SK. Pinhole collimator scintigraphy in differential diagnosis of metastasis, fracture, and infections of the spine. *J Nucl Med* 1987;28:447–451.
21. Bahk YW, Chung SK, Kim SH, Jung WH. Pinhole scintigraphic manifestation of sternocostoclavicular hyperostosis. *Korean J Nucl Med* 1992;26: 155–159.
22. Kim JY, Chung SK, Park YH, Kim SH, Shinn KS, Bahk YW. Pinhole bone scintigraphic appearances of osteoid osteoma. *Korean J Nucl Med* 1992;26: 160–163.
23. Bahk YW. *Combined pinhole scintigraphic and radiographic diagnosis of bone and joint diseases.* Heidelberg, Berlin, New York: Springer-Verlag; 1994:In press.
24. Bahk YW, Lee JM. Measure-set computed tomographic analysis of internal architectures of lumbar disc: clinical and histologic studies. *Invest Radiol* 1988;23:17–23.