Knee Surg, Sports Traumatol, Arthrosc
(2002) 10 : 233–240

KNEE

DOI 10.1007/s00167-002-0285-z

Dietrich Pape
Romain Seil
Ekkehard Fritsch
Stefan Rupp
Dieter Kohn

Prevalence of spontaneous osteonecrosis of the medial femoral condyle in elderly patients

Received: 1 July 2001
Accepted: 24 January 2002
Published online: 9 April 2002

D. Pape (✉) · R. Seil · E. Fritsch · S. Rupp
D. Kohn
Department of Orthopedic Surgery,
University of Saarland,
Kirrbergerstrasse,
66421 Homburg, Germany
e-mail: address: Dr.D-Pape@t-online.de,
Tel.: +49-6841-164520

Abstract Aseptic osteonecrosis of the medial femoral condyle has recently been reported as a complication of arthroscopic surgery. The time interval between the onset of symptoms and pathognomonic MRI changes (diagnostic window) is not known for osteonecrosis of the knee. To determine the prevalence of early-stage spontaneous osteonecrosis of the knee (SONK) we prospectively examined 176 patients by MRI between May 1998 and December 1999. In six patients MRI revealed a bone marrow edema pattern and subtle subchondral bone changes in the medial condyle consistent with early-stage SONK (prevalence of 3.4%); in the 53 patients older than 65 years the prevalence was 9.4%. In 10 patients (5.7%) the bone and marrow changes on MRI imaging either resolved on follow-up MRI and were regarded as transient epiphyseal lesions or were considered to be reactive changes due to underlying degenerative articular disease. Including MRI in the preoperative diagnostic procedures could avoid missing the diagnosis of avascular necrosis before planning an operative treatment of suspected meniscal tears in elderly patients.

Keywords Spontaneous osteonecrosis · Medial condyle · Relevance, elderly

Introduction

The knee is the second most common location for osteonecrosis (ON) but the exact prevalence of this disease is unknown [20]; ON of the femoral condyle can present as a spontaneous or a secondary clinical entity. Spontaneous ON of the medial femoral condyle (spontaneous osteonecrosis of the knee, SONK) is typically a disease of the elderly, presenting with severe knee pain of sudden onset and unilateral involvement with a predilection for the medial femoral condyle, as described by Ahlback et al. [2, 3] in 1968. Secondary ON differs from this in terms of clinical presentation, location, and extent of the lesions, since it affects younger patients, with insidious onset of vague pain and also involvement of the lateral knee compartment [23]. These differences in clinical and radiographic presentation may be due to the different causes, although the pathogenic mechanism remains unknown. Arthroscopic surgery has recently been associated with avascular necrosis of the knee, although the incidence of "postarthroscopic" ON is rare [7, 21, 27, 29]. Whether arthroscopy may play a pathogenic role in the natural sequence of ON remains disputed [7, 17].

In its early stages SONK is difficult to diagnose, as it presents with intense pain mimicking meniscal symptoms and with normal findings on conventional radiography [30]. Findings on magnetic resonance imaging (MRI) might also be normal at this stage, as a so-called "window period" has been noted between the onset of symptoms and the appearance of signal changes in MRI [6, 32]. The purpose of this prospective study was to determine the prevalence of early-stage SONK in the elderly who present with a sudden onset of knee pain in the absence of a trauma history. Knowing the prevalence of early-stage SONK might be of paramount clinical and medicolegal

importance since it may contribute to avoid unnecessary intra-articular surgery.

Patients and methods

Patients

We used MRI to examine all patients older than 50 years who presented with potential medial meniscus symptoms between May 1998 and December 1999. Patients included in the study met the following criteria: (a) a sudden onset of knee pain over the medial joint line, (b) no a history of trauma or hyperuricemia, (b) normal or nearly normal radiographic findings (incipient stage I of a four-stage course according to Soucacos et al. [30]) at first presentation, and (d) no risk factors for ON such as intra-articular application or oral intake of glucocorticoids, no hemoglobinopathies, no history of systemic lupus erythematosus, renal transplant, hyperlipidemia, deep water diving, or ON affecting the opposite knee. Patients with a previous arthroscopy who were referred to our clinic for persisting pain were excluded from the study. The 176 patients who met the inclusion criteria included 98 men and 78 women, with a mean age of 59.5 years.

At initial presentation, all patients underwent a radiological evaluation which included anteroposterior, lateral, and 30° posteroanterior weight-bearing views. The degree of osteoarthritis was graded according to the International Knee Documentation Committee (IKDC) criteria ("normal," "nearly normal," "abnormal," and "very abnormal" [5]).

Analysis of imaging methods

Initial MRI was performed not earlier than 6 weeks after the onset of symptoms. Bone marrow edema (BME) in an epiphysis on MRI is a nonspecific finding associated with several diagnoses, such as posttraumatic fractures, ON, reactive changes due to underlying degenerative articular disease, and transient conditions referred to as "transient osteoporosis" or "transient BME syndrome" [10]. Lecouvet et al. [14] recently described MRI characteristics for differentiating between transient epiphyseal lesions and early irreversible ON.

We suspected early irreversible ON if a BME pattern together with at least two of three indicative features of early irreversible ON was present on initial MRI. A BME pattern on MRI was regarded as an ill-defined marrow edema of low signal intensity on T1-weighted images and of intermediate to high signal intensity on T2-weighted images [10]. MRI criteria for early irreversible ON comprised: (a) a subchondral area of low signal intensity on T2-weighted images, (b) a focal epiphyseal contour depression, and (c) lines of low signal intensity located deeply in the affected condyle [14].

Since not all MRI examinations were performed at our institution, imaging equipment and protocols were not standardized. The MRI findings were interpreted by the prevailing radiologists, or, if inconclusive, the images were presented to a senior radiologist at our institution.

Further progression to collapsed SONK on conventional radiography confirmed the MRI findings and was mandatory to diagnose SONK.

Patient follow-up

All patients with signs of BME were initially treated conservatively with an exercise program, protected weight bearing with crutches, and anti-inflammatory medication for a minimum of 6 weeks [25]. Patients presenting with BME were referred to follow-up MRI 6 weeks after initial diagnosis and completion of conservative therapy. In cases of persisting BME a control MRI 6 months after initial diagnosis was performed. Arthroscopic débridement was performed after failure of conservative treatment in cases with clinical and radiographic progression of the disease to stage II ("slight flattening of the medial condyle" according to Soucacos et al. [30]) and with concomitant unbearable pain. Total knee arthroplasty was performed if clinical symptoms and radiographic changes progressed to stage III ("radiolucent line due to subchondral bone necrosis=crescent sign in conventional radiographs") or IV ("medial femoral condyle collapse in plain radiographs" [30]).

Results

Prevalence of ON according to MRI

MRI examination revealed a pattern of BME in the medial femoral condyle in 16 (9%) of the 176 patients; 5 men, 11 women, mean age 62 years). MRI characteristics in 6 of these 16 (37.5%; 1 man, 5 women, mean age 67 years) were indicative of early irreversible ON [14], yielding a prevalence of SONK of 3.4% with regard to all 176 patients enrolled in the study (Fig. 1b, c). The 53 patients older than 65 years included five of the six patients with early irreversible signs of ON on initial MRI; among this elderly cohort the prevalence of early-stage SONK was thus 9.4%.

All of the six patients showing signs of early irreversible ON on MRI progressed radiographically to stage II (n=3) or III (n=3; Fig. 1d) a mean of 6.5 months (range 3–9), thus confirming the initial MRI findings. Ten of the 16 patients (62.5%) with BME did not show any radiographic signs of ON in the further radiographic follow up or presented with resolution of MRI findings and clinical symptoms 6 weeks after the begin of conservative treatment. In 6 of 10 patients BME persisted 6 weeks after initial MRI diagnosis. In these patients follow-up MRI 4–6 months after initial diagnosis revealed complete resolution of MRI changes consistent with a transient BME. In the other four patients BME on MRI was considered to be a reactive change due to underlying degenerative articular cartilage disease (Figs. 2, 3).

Clinical findings and radiographic evaluation

At the initial presentation patients with ON reported acute onset of pain without apparent trauma and recurrent swelling after full weight bearing. Clinical examination revealed medial joint line tenderness, effusions, and restricted motion of the affected knee. On routine radiographs (anteroposterior, lateral, and 30° posteroanterior weight-bearing views), all patients with ON demonstrated "normal" (1/6 patients) or "nearly normal" (5/6 patients) radiographic findings in the knee compartment involved according to the IKDC criteria [5] (Table 1). In patients without ON (n=160) "nearly normal," "abnormal," and

Fig. 1a–d A 67-year-old man with a 3-week history of spontaneous knee pain (Table 1). **a** Anteroposterior conventional radiography of the left knee with normal osseous findings on initial presentation. **b** Coronal T2-weighted MRI (2000/80 TR/TE) 9 weeks after onset of symptoms shows a subchondral area of low signal intensity. The medial condyle shows a moderate increase in signal intensity suggestive of edema. **c** Sagittal T1-weighted MRI (415/20 TR/TE) through the medial compartment shows ill-defined region of decreased signal intensity and subtle focal epiphyseal contour depression (*arrow*). **d** Four months after the onset of symptoms a radiolucent lesion of the of the left medial femoral condyle has developed, indicating stage III osteonecrosis according to Soucacos et al. [30]

"very abnormal" changes were seen in 67 (42%), 40 (25%), and 22 (14%) cases, respectively. Thirty-one patients (19%) did not show any degenerative changes on routine radiography.

Perioperative findings

Of the 176 patients presenting with knee pain 160 (160) did not have any lesion suspicious for ON on either MRI or radiography. Of these 160 patients 104 (65%) were treated with arthroscopy for meniscal and/or cartilage pathology. In 56 patients (35%) no arthroscopy was performed because the symptoms showed complete resolution and/or the patients preferred conservative treatment or refused surgery. In the 104 patients who agreed to surgery and who did not show signs of ON on MRI, arthroscopy revealed a tear of the medial meniscus in 75 (72%), a tear of the lateral meniscus in 48 (37%), and both in 9 (9%). In almost one-half of cases (n=51, 49%) the medial femoral condyle showed second or third degree degenerative changes, according to the classification of Noyes and Stabler [24].

Débridement was performed in five of the six SONK patients because of clinical and radiographic progression (at stage II in one, stage III in four [30]). Arthroscopy revealed a break in the articular cartilage surface in the weight-bearing surface of the medial condyle in all five patients. Degenerative meniscal pathologies were found in four of the five patients of the medial (n=4) and/or the lateral (n=2) compartment. Correspondingly, we found second to fourth degree chondromalacia [24] in the neighbor-

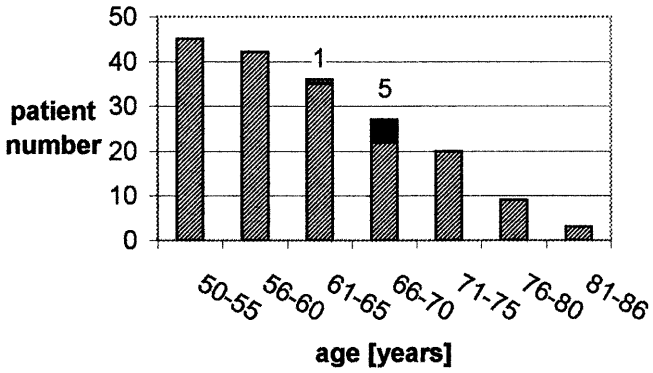

Fig. 2 Age distribution of patients enrolled in the study. Patients with MRI findings consistent with early-stage osteonecrosis of the medial femoral condyle (*black bars*) were predominantly in the age group above 65 years

ing medial femoral condyle (n=4) and medial tibial plateau (n=1; Table 1). Débridement was carried out entirely arthroscopically and comprised the removal of the osteocartilagenous flap from its crater together with loose debris from the base using a rongeur. Motorized burrs were used to complete the débridement until bleeding bone was exposed over the entire surface of the defect. Partial meniscectomy was carried out in four of the five patients in the medial compartment affected by SONK (Table 1).

Clinical outcome

Patients who underwent arthroscopy had a mean initial Lysholm score [5, 18] of 65 points in those without SONK (range 60–79) and 60 points in those with SONK (range 55–75). Three months after arthroscopy only patients without SONK had improved clinically, with a mean increase of 30 points (range 10–48, P<0.05). All patients with SONK showed further progression to complete articular collapse and were treated with total knee replacement a mean of 12 months on average after initial diagnosis (range 9–14 months). A pathological analysis of specimens obtained in four of the six patients at subsequent total knee replacement confirmed ON in all cases.

Among the 104 patients who agreed to arthroscopy and who showed no signs of ON on MRI no case of delayed progression of "postarthroscopic" ON was noted 3 months after the procedure. A retrospective chart review of 58 of 104 patients (55%) who presented for further follow-up at least 6 months after arthroscopy revealed no signs or symptoms of secondary ON.

Fig. 3 Patient distribution according to MRI findings indicative for bone marrow edema (*BME*) and/or early-stage spontaneous osteonecrosis of the knee (*SONK*) over time. Follow-up MRI was performed 6 weeks after completion of conservative treatment in patients with BME. In cases without resolution a final MRI was performed 6 months after initial diagnosis of BME. *Percentages* indicate prevalence

Discussion

Early-stage SONK can be difficult to diagnose as the result of the following pitfalls in the clinical setting: (a) the conventional radiographs are normal at initial presentation, (b) the pain over the medial condyle can mimic meniscus symptoms, and (c) there is a window period for the MRI method to detect SONK. These pitfalls can have a clinical and a medicolegal impact. Clinically, it has been shown that an additional arthroscopic meniscectomy in the presence of undiagnosed ON can worsen clinical symptoms and accelerate joint destruction [17]. Medicolegally, arthroscopy could be regarded as the cause of progressive SONK. Therefore a distinction between cases of ON following arthroscopic surgery and cases of preexisting but yet undiagnosed SONK should be made to avoid arthroscopy in cases of SONK.

The aim of our prospective cohort study was to determine the prevalence of SONK in elderly patients presenting with potential medial meniscus symptoms without trauma history. We observed an overall prevalence of SONK of 3.4% in patients over the age of 50 years. Considering only patients aged over of 65 years the prevalence increased to 9.4% (Fig. 1). This is surprisingly high and must be confirmed in further studies.

Until recently MRI has not been widely accepted as a reliable diagnostic method to detect early ON. Several authors prefer the use of bone scintigraphy in the early diagnosis of ON [4, 8, 9] although the advantage of this procedure has not been confirmed in all studies. Numerous authors recommend MRI as a screening modality since it provides a simultaneous evaluation of meniscal/chondral pathology, the size of the lesion, and the viability of the bone marrow [6, 7, 11, 28]. Lecouvet et al. [14] have recently described MRI characteristics which allow confident differentiation between early irreversible ON and

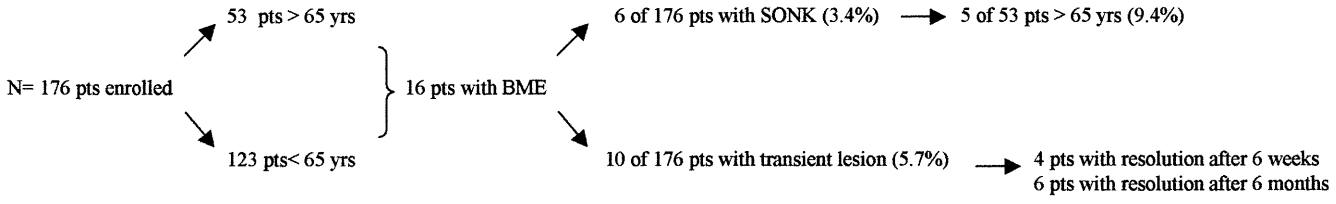

Table 1 Clinical data of SONK patients; radiographic according to Soucacos et al. [30] (*ASC* arthroscopy, *CM* chondromalacia [24], *SONK* early-stage spontaneous osteonecrosis of the medial condyle, *g* grade, *LFC* lateral femoral condyle, *LMT* lateral meniscus tear, *LTP* lateral tibial plateau, *MMT* medial meniscus tear, *MFC* medial femoral condyle, *MTP* medial tibial plateau, *OA* osteoarthritis graded according to IKDC criteria [5], *n* normal, *nn* nearly normal, *a* abnormal, *va* very abnormal, *S1* stage 1, *S2* stage 2, *S3* stage 3, *S4* stage 4, *PLM* partial lateral meniscectomy, *PMM* partial medial meniscectomy, *TKR* total knee replacement)

Patient no.	Age (years)	Sex	Duration of symptoms prior to MRI (weeks)	OA on initial conventional radiographs [5]	Findings on initial MRI	Findings on ASC [24]	Procedure at ASC	Radiographic evaluation of SONK [30] at subsequent surgery after initial diagnosis (months)	Geographic association between SONK and CM, meniscus tear at TKR
1	64	F	6	Normal	SONK, MMT, G2–3 CM of MFC/MTP	MMT, G4 CM of MFC, G3 CM patella, G2 CM MTP	Débridement, PMM	S4, TKR after 9 months	+
2	67	M	9	Nearly normal	SONK, MMT, G2 CM of MFC	MMT, G3 CM of MFC	Débridement, PMM	S4, TKR after 11 months	+
3	66	F	8	Nearly normal	SONK, G2 CM of LFC	MMT, G2 CM of MFC and LFC	Débridement, PMM	TKR after 14 months	+
4	68	F	9	Nearly normal	SONK, LMT, G3 CM of LTP	LMT, G4 CM of LTP	Débridement, PLM	TKR after 12 months	+
5	66	F	14	Nearly normal	SONK, MMT, LMT, G3 CM of MFC/MTP	MMT, G3 CM of MFC, G2 CM of MTP	Débridement, PMM	TKR after 13 months	+
6	72	F	7	Nearly normal	SONK, MMT, G3 CM of MFC	no ASC	No ASC	TKR after 14 months	+
Summary	Mean 67 (64–72)	5 F, 1 M	8.8	1 nearly normal, 5 nearly normal	SONK 6, MMT 4, LMT 2, CM MFC 4, CM MTP 2, CM LFC 1, CM LTP 1	MMT 4, LMT 1, G4 CM MFC 1, G3 CM MFC 2, G2 CM MFC 1, G2 CM MTP 2, G2 CM LFC 1, G3 CM LTP 1	Débridement 4, PMM 4, PLM 1	6 TKR after 12 months on average (9–14)	6/6 adjacent MMT and CM MFC

Table 2 Survey of studies describing cases of osteonecrosis (*ON*) following arthroscopic knee surgery without trauma history. Four of five studies did not consider the diagnostic window of the MRI method to rule out preexisting osteonecrosis; in only a minority of studies was a complete evaluation of potential concomitant risk factors for ON performed (preceding trauma, diagnostic window of MRI, age distribution of ON) (*ASC* arthroscopy, *CM* chondromalacia, *MFC* medial femoral condyle, *MMT* medial meniscus tear)

	Brahme et al. [7]	Johnson et al. [13]	Muscolo et al. [21]	Prues-Latour et al. [27]	Santori et al. [29]
Patients with ON in total (*n*)	7	7	8	9	2
ON in MFC and without trauma history (*n*)	5	4	8, trauma history?	6	2
Mean duration of symptoms in patients with ON in MFC prior to MRI (weeks)	?	12 (6–28)	8 (1–28)	26 (3 days–72 weeks)	?
Patients examined within diagnostic window of MRI (*n*)	?	0	5	2	1
Mean age (years)	60.5 (42–72)	60 (41–79)	65 (54–75)	69 (58–82)	34 (21–47)
Age <65 years (*n*)	?	3	3	1	2
Age >65 years (*n*)	?	1	5	5	–
MMT at ASC (*n*)	5	3	8	8	2
CM of MFC at ASC (*n*)	5	4	4	7	–

transient epiphyseal lesions of the human medial condyle. This is of paramount medicolegal importance since arthroscopy has recently been associated with the progression of ON. In rare cases worsening symptoms after arthroscopy have been related to ON-like MRI changes [7, 13, 21, 27, 29].

To our knowledge, five clinical studies have reported about ON evolving after routine arthroscopic knee surgery. All cases of "postarthroscopic" ON were diagnosed by MRI. The majority of these patients were evaluated retrospectively, and preexisting ON was not excluded [7, 21, 27, 29] (Table 2). Johnson et al. [13] defined the diagnostic window of the MRI method as the time between the onset of symptoms and pathognomonic MRI changes. This study group arbitrarily chose 6 weeks as the minimal time interval between the onset of symptoms and MRI examination as an inclusion criteria for patients. This decision was based on a laboratory model by Nakamura et al. [22] who surgically induced ON of the femoral head in a canine model and demonstrated that it may take up to 4 weeks after surgery for the MRI to become positive.

The exact length of the diagnostic MRI window for detecting SONK in humans remains unknown since the applicability of animal experiments to the clinical setting is uncertain. In a clinical MRI study Lecouvet et al. [14] found a mean interval of 10 weeks between the onset of symptoms and subsequent MRI and noted a high prognostic value of the MRI method. This even longer diagnostic interval might contribute to the high sensitivity and specificity of the MRI method in detecting early irreversible SONK. Soucacos et al. [30] noted a natural four-stage course of SONK and found partly inconclusive MRI findings only in the earliest stage of ON (incipient stage). Bjorkengren et al. [6] reported a correlation between early abnormalities in T2-weighted MRI and further progression of the disease. In their study the duration of the disease at the time of the MRI examination ranged from 1 to 58 months (mean: 18 months). In summary, these data speak in favor of a delayed MRI examination after the onset of knee pain [6, 13, 14, 30].

Our study protocol considered the suspected window period as suggested by Johnson et al. [13]. All our patients were referred to an MRI examination not earlier than 6 weeks after the onset of symptoms. Although the Johnson et al. inclusion criteria were similar to ours, they found no case of early stage ON at the preoperative MRI examination. This could be related to the lower mean age in his patients (60 vs. 67 years in our study) and may be due to their study protocol since their data were reviewed retrospectively. Furthermore, the MRI criteria [7, 15, 26] used in their study may have a lower prognostic value than ours [14].

The cause of ON is increasingly being paid attention but remains unknown. A number of factors have been associated with the development of SONK of the medial femoral condyle, such as trauma, resultant microfractures, primary vascular insufficiency, and meniscal tears [7, 17]. Secondary ON, however, has been related to an altered mechanical force transmission after arthroscopic chondral and/or meniscal débridement [7, 21] with a subsequent overload of the medial joint aspect [29].

As in many other previous studies, our perioperative findings seemed to confirm a relationship between degenerative changes and SONK. A geographic association was found between ON and meniscus tears/chondromalacia in four of six SONK patients during arthroscopic débridement. However, arthroscopic knee surgery is frequently

carried out in elderly patients with degenerative lesions of menisci and cartilage. Still, the prevalence of postarthroscopic ON is low. According to the literature, joint-preserving procedures such as arthroscopic débridement, core decompression and high tibial osteotomy have achieved good results in 70–80% of cases of ON [12, 19, 20, 31].

We saw a rapid progression of joint destruction in all our SONK patients despite conservative treatment and arthroscopic débridement. Total knee replacement, as the only surgical option for the treatment of stage IV lesions, was performed on average 12 months after initial presentation (Table 1). This is a poor outcome compared to that in other studies of SONK with similar therapeutic regimen [19]. However, previous studies may have included patients with transient BME pattern of signal intensity changes on MRI. In our patients with similar changes BME was self-limiting, and full recovery was achieved without intervention, as described in former MRI studies [10, 14].

There are certain limitations to our study. We did not examine the opposite knee joint to rule out potential similar MRI changes of a different cause. MRI protocols were not standardized since these examinations were performed at different institutions. Nevertheless, all patients with SONK on initial MRI showed pathognomonic features on follow-up conventional radiography, such as epiphyseal collapse and subchondral bone fractures [1, 2], thus confirming the diagnosis. Moreover, the pathological analysis of specimens obtained in four of six patients at subsequent total knee replacement confirmed ON as well.

Conclusion

We can summarize our findings as follows:

1. Our clinical results confirmed the prognostic value of the MRI criteria according to Lecouvet et al. [14].
2. The prevalence of early-stage SONK in patients over 65 years with medial knee pain and without trauma history was 9.4%.
3. When these elderly patients present with normal conventional radiographs, an MRI should be performed not earlier than 6 weeks after the onset of symptoms to rule out preexisting early stage SONK.
4. A diagnosis of SONK may avoid unnecessary arthroscopy.

Acknowledgements This study was supported by grants from the Medical College of the University of Homburg, Germany.

References

1. Aglietti P, Insall JN, Buzzi R, Deschamps G (1983) Idiopathic osteonecrosis of the knee. Aetiology, prognosis and treatment. J Bone Joint Surg Br 65:588–597
2. Ahlback S (1968) Osteonecrosis of the knee-radiographic observations. Calcif Tissue Res [Suppl 36]
3. Ahlback S, Bauer GC, Bohne WH (1968) Spontaneous osteonecrosis of the knee. Arthritis Rheum 11:705–733
4. Al-Rowaih A, Wingstrand H, Lindstrand A, Bjorkengren A, Thorngren KG, Gustafson T (1990) Three-phase scintimetry in osteonecrosis of the knee. Acta Orthop Scand 61:120–127
5. Benedetto KP (1992) Score des IKDC (International Knee Documentation Committee). Deutschsprachigen Arbeitsgemeinschaft für Arthroskopie, no. 4
6. Bjorkengren AG, AlRowaih A, Lindstrand A, Wingstrand H, Thorngren KG, Pettersson H (1990) Spontaneous osteonecrosis of the knee: value of MR imaging in determining prognosis. AJR Am J Roentgenol 154:331–336
7. Brahme SK, Fox JM, Ferkel RD, Friedman MJ, Flannigan BD, Resnick DL (1991) Osteonecrosis of the knee after arthroscopic surgery: diagnosis with MR imaging. Radiology 178:851–853
8. Greyson ND, Lotem MM, Gross AE, Houpt JB (1982) Radionuclide evaluation of spontaneous femoral osteonecrosis. Radiology 142:729–735
9. Gupta SM, Foster CR, Kayani N (1987) Usefulness of SPECT in the early detection of avascular necrosis of the knees. Clin Nucl Med 12:99–102
10. Hayes CW, Conway WF, Daniel WW (1993) MR imaging of bone marrow edema pattern: transient osteoporosis, transient bone marrow edema syndrome, or osteonecrosis. Radiographics 13:1001–1011
11. Healy WL (1991) Osteonecrosis of the knee detected only by magnetic resonance imaging. Orthopedics 14:703–704
12. Jacobs MA, Loeb PE, Hungerford DS (1989) Core decompression of the distal femur for avascular necrosis of the knee. J Bone Joint Surg Br 71:583–587
13. Johnson TC, Evans JA, Gilley JA, DeLee JC (2000) Osteonecrosis of the knee after arthroscopic surgery for meniscal tears and chondral lesions. Arthroscopy 16:254–261
14. Lecouvet FE, van de Berg BC, Maldague BE, Lebon CJ, Jamart J, Saleh M, Noel H, Malghem J (1998) Early irreversible osteonecrosis versus transient lesions of the femoral condyles: prognostic value of subchondral bone and marrow changes on MR imaging. AJR Am J Roentgenol 170: 71–77
15. Lotke PA, Ecker ML (1985) Osteonecrosis of the knee. Orthop Clin North Am 16:797–808
16. Lotke PA, Steinberg ME (1985) Osteonecrosis of the hip and knee. Bull Rheum Dis 35:1–8
17. Lotke PA, Abend JA, Ecker ML (1982) The treatment of osteonecrosis of the medial femoral condyle. Clin Orthop 109–116
18. Lysholm J, Gillquist J (1982) Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. Am J Sports Med 10:150–154
19. Miller GK, Maylahn DJ, Drennan DB (1986) The treatment of idiopathic osteonecrosis of the medial femoral condyle with arthroscopic debridement. Arthroscopy 2:21–29

20. Mont MA, Baumgarten KM, Rifai A, Bluemke DA, Jones LC, Hungerford DS (2000) Atraumatic osteonecrosis of the knee. J Bone Joint Surg Am 82: 1279–1290
21. Muscolo DL, Costa-Paz M, Makino A, Ayerza MA (1996) Osteonecrosis of the knee following arthroscopic meniscectomy in patients over 50-years old. Arthroscopy 12:273–279
22. Nakamura T, Matsumoto T, Nishino M, Tomita K, Kadoya M (1997) Early magnetic resonance imaging and histologic findings in a model of femoral head necrosis. Clin Orthop 68–72
23. Narvaez J, Narvaez JA, Rodriguez-Moreno J, Roig-Escofet D (2000) Osteonecrosis of the knee: differences among idiopathic and secondary types. Rheumatology (Oxf) 39:982–989
24. Noyes FR, Stabler CL (1989) A system for grading articular cartilage lesions at arthroscopy. Am J Sports Med 17:505–513
25. Patel DV, Breazeale NM, Behr CT, Warren RF, Wickiewicz TL, O'Brien SJ (1998) Osteonecrosis of the knee: current clinical concepts. Knee Surg Sports Traumatol Arthrosc 6:2–11
26. Pollack MS, Dalinka MK, Kressel HY, Lotke PA, Spritzer CE (1987) Magnetic resonance imaging in the evaluation of suspected osteonecrosis of the knee. Skeletal Radiol 16:121–127
27. Prues-Latour V, Bonvin JC, Fritschy D (1998) Nine cases of osteonecrosis in elderly patients following arthroscopic meniscectomy. Knee Surg Sports Traumatol Arthrosc 6:142–147
28. Ritter MA, Eizember LE, Keating EM, Faris PM (1991) The survival of total knee arthroplasty in patients with osteonecrosis of the medial condyle. Clin Orthop 108–114
29. Santori N, Condello V, Adriani E, Mariani P (1995) Osteonecrosis after arthroscopic medial meniscectomy. Arthroscopy 11:220–224
30. Soucacos PN, Xenakis TH, Beris AE, Soucacos PK, Georgoulis A (1997) Idiopathic osteonecrosis of the medial femoral condyle. Classification and treatment. Clin Orthop 82–89
31. Valenti NJ, Leyes M, Schweitzer D (1998) Spontaneous osteonecrosis of the knee. Treatment and evolution. Knee Surg Sports Traumatol Arthrosc 6:12–15
32. Zizic TM (1991) Osteonecrosis. Curr Opin Rheumatol 3:481–489