

Osteonecrosis of the Femoral Head in Adults

Andrew B. Old, AB

Brian J. McGrory, MD

Osteonecrosis of the femoral head (ONFH) is a potentially debilitating condition of unclear etiology that affects up to 20,000 persons in the United States each year.¹ ONFH in adults can be devastating as it typically occurs in a relatively young population (age, 35–40 yr). The disease is usually progressive,² and without treatment, ONFH frequently results in loss of the joint space, secondary osteoarthritis, and destruction of the hip joint. ONFH accounts for approximately 10% of the primary total hip arthroplasties performed in the United States.^{3,4}

The pathogenesis of ONFH remains unclear, but this disorder is considered a final common pathway for many diseases that lead to altered blood supply to the femoral head and cell death within the femoral head. Histologically, ONFH is characterized by dead osteocytes, necrotic marrow elements, and lack of vasculature in a defined region in the femoral head; in most cases, these changes lead to subsequent collapse of the subchondral bone. ONFH commonly occurs after direct trauma, such as hip dislocation or femoral neck fracture. The etiology of atraumatic ONFH is not well understood, and often one or more risk factors are involved, such as corticosteroid use and alcoholism.

Multiple therapeutic options are available for ONFH. Although surgical and nonsurgical interventions have been advocated, a universal algorithm has yet to be adopted in ONFH treatment.⁵ Both the appropriate course of treatment and its degree of success are thought to be dictated by the etiology and severity of the disease. Most experts believe that early diagnosis is vital if the patient is to benefit from conservative treatment.^{6–8} Given the importance of early diagnosis and prompt management, clinicians should know the causes, risk factors, clinical presentation, and diagnostic work-up of ONFH in adults and be familiar with currently accepted treatment.

ETIOLOGY

Many direct and associated factors can predispose a person to ONFH (**Table 1**).^{1,9–11} Established traumatic etiologies include hip dislocation and femoral neck fracture, although ONFH does not occur in all cases of these injuries. Direct nontraumatic causes include radiation and dysbaric osteonecrosis (caisson disease).

TAKE HOME POINTS

- The etiology of osteonecrosis of the femoral hip (ONFH) includes traumatic (eg, hip dislocation) and nontraumatic causes (eg, radiation osteonecrosis). Common associated risk factors for ONFH include alcoholism and high-dose steroid therapy.
- Young patients presenting with atraumatic groin pain and 1 or more risk factors should be considered for the onset of ONFH.
- Anteroposterior and frog-leg lateral radiographs should be obtained as part of the work-up; however, early-stage ONFH is not visible on radiographs.
- Magnetic resonance imaging should be performed when ONFH is suspected but not obvious on radiographs.
- Nonsurgical management is often used for small, asymptomatic lesions in which subchondral bone collapse is absent.
- Surgical interventions attempt to preserve the femoral head (early stage) or replace the proximal femur or hip joint (late stage).

The most common nontraumatic associated risk factors are alcoholism and high-dose corticosteroid therapy (> 2 g of prednisone or its equivalent in 2–3 mo).¹² Steroid dose packs typically contain less than 100 mg of prednisone given over a 7-day period and therefore should not increase the risk of ONFH. However, if high-dose steroids are prescribed, the patient's bone health should be carefully monitored with clinical examinations to evaluate for joint pain and loss of motion. Less commonly diagnosed nontraumatic risk factors include coagulation disorders,¹³ genetic polymorphisms (variations in the human genome), and many chronic diseases. The

Mr. Old is a medical student, University of Vermont College of Medicine, Burlington, VT. Dr. McGrory is co-director, Maine Joint Replacement Institute, Portland, ME, and a clinical associate professor, University of Vermont College of Medicine, Burlington, VT.

Table 1. Risk Factors Associated with Osteonecrosis of the Femoral Head in Adults

Direct

Traumatic

- Hip dislocation
- Femoral neck fracture
- Surgical exposure of the femoral neck

Nontraumatic

- Radiation
- Dysbaric phenomena/decompression sickness (caisson disease)
- Sickle cell crisis

Associated factors

Alcoholism

Smoking

Hypercortisolism

Coagulation disorders

- Hemophilia
- Thrombophilia
- Hypofibrinolysis

Genetic polymorphisms

Chronic diseases

- HIV infection
- Storage diseases (Gaucher disease)
- Hemoglobinopathies/thalassemia
- Chronic kidney disease
- Cushing's disease
- Pancreatitis
- Gout/hyperuricemia
- Systemic lupus erythematosus
- Polyarteritis
- Hyperlipidemia/hyperlipoproteinemia
- Hyperparathyroiditis
- Diabetes mellitus
- Endotoxin reactions
- Serum sickness
- Toxic shock
- Inflammatory bowel disease
- Chemotherapy
- Nephrotic syndrome

Data from references 1, 9–11.

exact relationship between these associated diagnoses and the development of ONFH is not completely understood. However, most of these conditions are associated with negative changes in microcirculation to the femoral head, suggesting that lack of blood supply may be an initiating mechanism in the pathologic process.

Approximately 20% of ONFH cases appear to be idiopathic in origin with no associated risk factors.³

DIAGNOSIS

Initial Evaluation

The diagnosis of ONFH is frequently overlooked because the symptoms are often nonspecific and because the early stages of ONFH are not visible on radiographs. A focused history and thorough physical examination along with the judicious use of magnetic resonance imaging (MRI), however, can help identify the initial onset of ONFH. Young patients presenting with atraumatic groin pain and a history of 1 or more of the aforementioned risk factors should be considered carefully for the onset of ONFH. The pain is generally described as a throbbing, deep pain that develops gradually; however, more advanced stages of ONFH may be associated with a sharp catching pain. As is the case with other hip pathology, patients also may describe pain radiating to the buttocks or to the ipsilateral knee. Stiffness, limping, and need of support to climb stairs are common. Patients may report difficulty putting on shoes and socks because of hip irritability and stiffness. Examination should include observation of the gait, palpation of the soft tissues and bony prominences of the hip and pelvis, range of motion assessment of the hip and lumbar spine, and neurovascular testing. The Stinchfield test for hip irritability is also useful.¹⁴ Because ONFH may be found bilaterally in up to 80% of patients,² both hips should be carefully examined.

Imaging Studies

Standard anteroposterior and frog-leg (Lowenstein) lateral radiographs should be obtained as part of a patient's work-up. A pelvis radiograph is best as it determines if the condition is bilateral and also provides a comparison for the affected hip. It may be difficult to delineate small areas of ONFH on plain radiographs, but the most common early findings are alternating areas of sclerosis and lucency (**Figure 1**). The presence of the crescent sign (**Figure 2**) corresponds with late-stage disease; this finding reflects the discrepancy in densities of the femoral head due to subchondral bone collapse. It should be noted that radiographs might underestimate the degree of articular cartilage damage, especially on the acetabular side.

When ONFH is suspected but not obvious on plain radiographs, MRI should be performed. A typical finding is a crescentic signal change with a well-defined distinct border (**Figure 3**).¹⁵ A distinct low-signal line on T1-weighted images outlines the necrotic lesion. Bone edema (**Figure 4**), which has a more diffuse low signal, surrounds

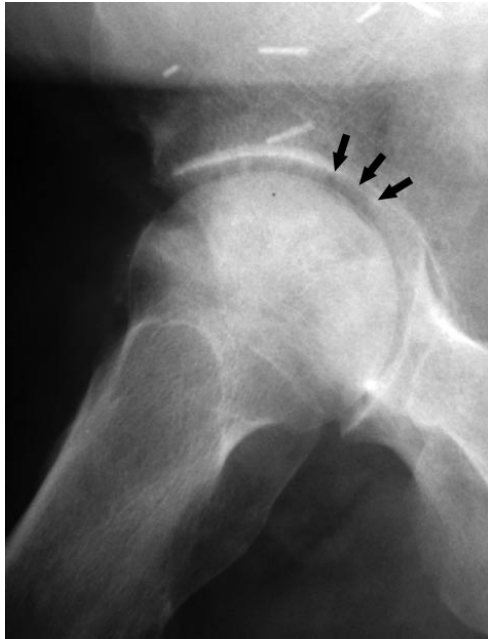


Figure 1. Frog-leg lateral radiograph of the femoral head in a 46-year-old man with Steinberg stage III osteonecrosis. Note the crescent sign (arrows), a hallmark of osteonecrosis caused by the discrepancy in densities of the femoral head due to subchondral bone collapse.



Figure 2. Radiographic sclerosis shown on anteroposterior radiograph of a 46-year-old man. Note the central rarefaction and maintenance of femoral head sphericity (Steinberg stage II).

the lesion.¹⁵ Edema has a diffuse high signal in T2 images and may extend into the femoral head and neck (Figure 4). MRI also should be considered when evaluating the contralateral hip of patients with known ONFH on one side. The excellent sensitivity and specificity of MRI (99% and 98%, respectively¹²) have made most other diagnostic methods redundant. The use of technetium bone scans and computed tomography scans for ONFH evaluation has been described. However, these studies are currently utilized only when MRI is contraindicated (eg, in patients with indwelling metallic hardware that would obscure the MRI signal or those with a pacemaker) as they are otherwise thought to be less reliable than MRI⁹ and are no less expensive than the limited MRI sequence^{12,16} studies that are used specifically for ONFH. Hip arthroscopy allows the surgeon to evaluate any articular damage, but it is an invasive procedure.

Two diagnoses often mistaken for ONFH include transient osteoporosis of the hip (TOH) and hip osteoarthritis. TOH is a rare self-limited disorder commonly seen in pregnant women and patients with osteogenesis imperfecta that may have some similarities in appearance to ONFH on MRI. A major difference between these conditions on MRI is that in ONFH the changes are usually limited to a specific area of the femoral head,



Figure 3. T1 magnetic resonance imaging sequence showing a crescentic signal change with a well-defined distinct border (right hip, left side of the figure) and a normal contralateral femoral head (left hip, right side of the figure).



Figure 4. (A) T1 magnetic resonance imaging (MRI) sequence showing typical bilateral osteonecrosis of the femoral head (ONFH) lesions. Note low signal that defines the necrotic lesions. (B) T2 MRI sequence of typical bilateral ONFH lesions. Note high-signal outlining lesions and edema extending into the head in the right femur (left side of figure).

the anterior superior position (crescentic signal change), whereas in TOH there is a diffuse alteration in the MRI signal, which usually extends down to the intertrochanteric line.¹⁷ Bone loss and osteopenia are marked in TOH, whereas radiographs of a hip with ONFH usually demonstrate rarefaction.

Table 2. Steinberg Classification of Osteonecrosis of the Adult Hip

| Stage | Description |
|-------|--|
| 0 | Radiographs and MRI scan are normal |
| I | Radiographs are nondiagnostic; MRI is abnormal |
| II | Radiographs demonstrate abnormalities consistent with osteonecrosis; head is round |
| III | Radiographs reveal crescent sign |
| IV | Flattening of the femoral head |
| V | Acetabular involvement and narrowing of joint space |
| VI | Loss of joint space; advanced arthritic changes |

Note: Extent of involvement for stages I through V is designated A, B, and C. A: < 15% of the femoral head is involved; B: 15%–30% of the femoral head is involved; and C: > 30% of the femoral head is involved.

MRI = magnetic resonance imaging.

It is also common for patients with hip osteoarthritis to be incorrectly diagnosed with ONFH when an MRI is interpreted without other information. Cystic changes in the femoral head and related bone edema can be misinterpreted as ONFH, although radiographs and history easily distinguish between these 2 diagnoses.^{17,18} Radiographs in osteoarthritis demonstrate osteophytes and joint space narrowing without collapse of the femoral head; these findings are unusual in most stages of ONFH.

CLASSIFICATION

A number of classification systems for ONFH have been developed, including the Ficat and Arlet,¹⁹ ARCO (Association Research Circulation Osseous),²⁰ and Stulberg,²¹ but the Steinberg classification (**Table 2**)²² is considered most useful because it grades the severity and extent of the involvement, both of which are thought to affect prognosis.^{8,12,23} Severity focuses on the congruity of the joint surface, and the extent of disease reflects the volume of the femoral head involved. Some surgeons also consider patient age and/or the presence of symptoms to be of importance in ONFH classification.²³ Although various algorithms for osteonecrosis have been based on the staging of the lesion, each of the many staging systems available has limitations and there is no universally accepted system.

TREATMENT

Conservative Therapy

Current ONFH treatment recommendations are controversial. Most contemporary algorithms are based on the stage of the disease, with the patient's symptoms

having a varying degree of importance.^{1,8,12,23} Both nonsurgical and surgical treatment options have been used with differing levels of success.^{1,3,8,10,24–30} Nonsurgical treatment is often advocated for small, asymptomatic precollapse lesions¹² or for patients who cannot tolerate a surgical procedure. Newer nonoperative treatment modalities (eg, bisphosphonates, statins, anticoagulants) for early-stage disease have been reviewed recently,¹² but exact indications have not yet been established. In a recent level 1 study, bisphosphonates were shown to be effective for treating Steinberg stage II and IIIC disease;²⁵ this study requires further confirmation. In a recent survey, physician members of the American Association of Hip and Knee Surgeons reported that they rarely offered statins (3% of those surveyed), anticoagulants (6%), or bisphosphonates (10%) to treat or prevent ONFH.²³ Other nonoperative approaches recently described include biophysical stimulation with pulsed electromagnetic fields³¹ and extracorporeal shock wave treatment.³²

Bisphosphonates deserve mention because there have been reports of osteonecrosis of the jaw (ONJ) associated with their use. Most reported cases of bisphosphonate-related ONJ have been in cancer patients treated with intravenous bisphosphonates, but cases have occurred in patients with other diagnoses.³³ The development of ONFH has not been reported in association with bisphosphonate use; in fact, ONFH has been successfully treated with bisphosphonates given over a 2-year period.²⁵ Clearly, further research is needed to clarify this paradox.

Surgical Interventions

Surgical interventions for ONFH either attempt to preserve the femoral head (in early-stage disease) or replace the proximal femur or hip joint (in late-stage disease). Temporizing techniques are used for intermediate disease. Core decompression aims to decrease the intraosseous pressure and possibly enhance vascular ingrowth, thereby delaying or negating the need for total hip arthroplasty. This technique utilizes a tunnel or multiple small holes that are drilled through the proximal femur into the necrotic lesion (**Figure 5**). Core decompression has had mixed results,^{11,34} but in a meta-analysis study, Castro and Barrack¹⁰ showed that its success rate was significantly higher than that of non-surgical management of early-stage disease (**Figure 6**). Surgeons surveyed²³ commonly chose core decompression for symptomatic Steinberg stage IB and IIB disease (prior to crescent sign visibility). Some surgeons also offer this approach for asymptomatic early-stage disease when lesions are of moderate or large size.^{8,23}

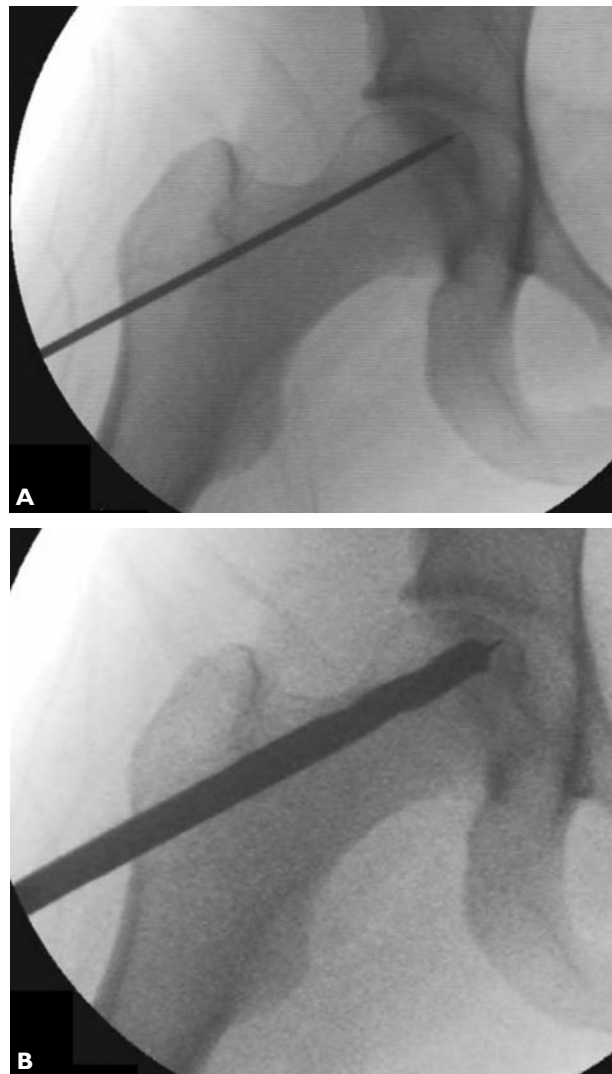


Figure 5. (A) Anteroposterior image of the guide pin inserted into the osteonecrotic region of the femoral head in a core decompression procedure. **(B)** Anteroposterior image of the cannulated drill guided by the previously placed pin in a core decompression procedure.

Bone grafting can be used in conjunction with core decompression or as a treatment option alone. Both vascularized^{29,35–37} and nonvascularized^{35,37} fibula grafts have been employed, but of the 2 procedures vascularized grafts are used more frequently.²³ Encouraging results have been obtained in select patient groups,³⁶ and surgeons offer this procedure to younger patients with earlier-stage disease. Vascularized bone grafting is a resource-intensive procedure and is performed at relatively few centers in the United States. There is a significant complication rate, and donor site morbidity is common.



Figure 6. (A) Core decompression performed in a 32-year-old man for symptomatic early-stage osteonecrosis of the femoral head. (B) Preservation of the femoral head 26 months later. Note that the head has not collapsed and remains spherical.

Osteotomies (designed to shift the weight-bearing load to a more normal portion of the affected femoral head) and hip arthrodesis (fusion) are less commonly offered by hip surgeons in the United States but may be useful in very specific patient populations (eg, teenagers or very young laborers with late-stage disease and significant symptoms).^{23,27} These procedures are offered more commonly in later-stage disease than decompression or bone grafting.²³

Total hip arthroplasty remains the treatment of choice among hip and knee surgeons for Steinberg stage IIIB and more advanced ONFH when pain, stiffness, and disability cannot be controlled by non-surgical means (**Figure 7**). Traditional and resurfacing hemiarthroplasty (replacing only the femoral portion of the joint) and resurfacing total hip replacement (replacing the surface of the femoral head in conjunction with the acetabulum) are not offered as frequently²³ and appear to be less reliable as compared with traditional total hip arthroplasty.³⁸⁻⁴⁰ Recently, however, there has been enthusiasm among some investigators who anticipate better results from resurfacing due to improvements in techniques and biomaterials.¹⁷ Unfortunately, studies with long-term follow-up have shown less positive outcomes of total hip arthroplasty in patients with ONFH as compared with osteoarthritis patients.^{41,42} Surgical treatment options continue to evolve, and biomaterials and techniques that have been developed over the past 5 to 10 years will hopefully improve results and thus make total hip arthroplasty in patients with advanced ONFH more acceptable, even for younger patients.



Figure 7. (A) Anteroposterior radiograph of advanced stage osteonecrosis of the femoral head (ONFH). Note the loss of joint space and collapse of the femoral head. (B) Total hip arthroplasty performed for advanced stage ONFH.

SUMMARY

Adult ONFH is a potentially devastating and commonly progressive illness affecting patients in the prime of their life. Direct and associated risk factors should be considered when evaluating a patient with possible ONFH. Patients suspected of having ONFH

should be given a thorough physical examination, supported by anteroposterior and lateral hip radiographs. MRI evaluation with focused coronal images of both hips should be obtained unless bilateral disease is already evident or the etiology is unilateral trauma. Regular and prolonged follow-up is necessary for patients with associated risk factors or direct trauma to the femoral neck.⁴³

Treatment of adult hip ONFH is usually based on the stage of the disease. Nonsurgical treatments are being developed, but exact indications are not yet clear. For those with moderate or large sized lesions without subchondral collapse, core decompression is commonly utilized. Once a crescent sign is observed on radiographs (Steinberg stage III²²), hip arthroplasty is the most commonly offered treatment modality. Surgical options such as vascularized and nonvascularized bone grafting, osteotomy, and fusion may be indicated for certain patients. Techniques and devices for performing total hip arthroplasty continue to improve, and as a result, surgeons are considerably less reluctant to recommend this for young patients whose osteonecrosis has progressed to the point that some type of arthroplasty is required. Treatment algorithms for ONFH continue to evolve, and evidence-based medicine will enhance our understanding of how best to address different stages of this disease. **HP**

Test your knowledge and comprehension of this article with the Clinical Review Quiz on page 55.

Corresponding author: Brian J. McGrory, MD, Orthopaedic Associates of Portland, 33 Sewall Street, Portland, ME 04104; mjri@yahoo.com.

REFERENCES

1. Mont MA, Lonner JH, Ragland PS. Osteonecrosis of the hip. In: Barrack RL, editor. Orthopaedic knowledge update: hip and knee reconstruction 3. 3rd ed. Rosemont (IL): American Academy of Orthopaedic Surgeons; 2006: 511-9.
2. Steinberg ME, Larcom PG, Strafford B, et al. Core decompression with bone grafting for osteonecrosis of the femoral head. Clin Orthop Relat Res 2001;(386):71-8.
3. Mont MA, Hungerford DS. Non-traumatic avascular necrosis of the femoral head. J Bone Joint Surg Am 1995;77:459-74.
4. Mont MA, Seyler TM, Marker DR, et al. Use of metal-on-metal total hip resurfacing for the treatment of osteonecrosis of the femoral head. J Bone Joint Surg Am 2006;88 Suppl 3:90-7.
5. Lieberman JR, Berry DJ, Mont MA, et al. Osteonecrosis of the hip: management in the 21st century. Instr Course Lect 2003;52:337-55.
6. Hernigou P, Poignard A, Nogier A, Manicom O. Fate of very small asymptomatic stage-I osteonecrotic lesions of the hip. J Bone Joint Surg Am 2004; 86-A:2589-93.
7. Ohzono K, Saito M, Takaoka K, et al. Natural history of nontraumatic avascular necrosis of the femoral head. J Bone Joint Surg Br 1991;73:68-72.
8. Hungerford DS, Jones LC. Asymptomatic osteonecrosis: should it be treated?

- Clin Orthop Relat Res 2004;(429):124-30.
9. Scheiber C, Meyer ME, Dumitrescu B, et al. The pitfalls of planar three-phase bone scintigraphy in nontraumatic hip avascular osteonecrosis. Clin Nucl Med 1999;24:488-94.
10. Castro FP, Barrack RL. Core decompression and conservative treatment for avascular necrosis of the femoral head: a meta-analysis. Am J Orthop 2000;29:187-94.
11. Camp JF, Colwell CW. Core decompression of the femoral head for osteonecrosis. J Bone Joint Surg Am 1986;68:1313-9.
12. Mont MA, Jones LC, Hungerford DS. Nontraumatic osteonecrosis of the femoral head: ten years later [published erratum appears in J Bone Joint Surg Am 2006;88:1602]. J Bone Joint Surg Am 2006;88:1117-32.
13. Krorompilias AV, Ortel TL, Urbaniak JR. Coagulation abnormalities in patients with osteonecrosis. Orthop Clin North Am 2004;35:265-71, vii.
14. McGrory BJ. Stinchfield resisted hip flexion test. Hosp Physician 1999;35: 41-2.
15. Cherian SF, Laorr A, Saleh KJ, et al. Quantifying the extent of femoral head involvement in osteonecrosis. J Bone Joint Surg Am 2003;85-A:309-15.
16. May DA, Disler DG. Screening for avascular necrosis of the hip with rapid MRI: preliminary experience. J Comput Assist Tomogr 2000;24: 284-7.
17. Vande Berg BE, Malghem JJ, Labaisse MA, et al. MR imaging of avascular necrosis and transient marrow edema of the femoral head. Radiographics 1993;13:501-20.
18. Vande Berg BC, Malghem JJ, Lecouvet FE, et al. Idiopathic bone marrow edema lesions of the femoral head: predictive value of MR imaging findings. Radiology 1999;212:527-35.
19. Arlet J, Ficat R. Forage-biopsie de la tete femorale dans l'osteonecrose primitive. Observations histo-pathologiques portant sur huit forages. Rev Rheumat 1964;31:257.
20. Gardeniers J. ARCO committee on terminology and staging (report from the Nijmegen meeting). ARCO News Letter 1991;3:153.
21. Stulberg BN. Osteonecrosis. In: Callaghan JJ, Dennis DA, Paprosky WG, Rosenberg AG, editors. Orthopaedic knowledge update: hip and knee reconstruction. 1st ed. Rosemont (IL) American Academy of Orthopaedic Surgeons; 1995:87-97.
22. Steinberg ME, Hayken GD, Steinberg DR. A quantitative system for staging avascular necrosis. J Bone Joint Surg Br 1995;77:34-41.
23. McGrory BJ, York SC, Iorio R, et al. Current practices of AAHKS members in the treatment of adult osteonecrosis of the femoral head. J Bone Joint Surg Am 2007;89:1194-204.
24. Mont MA, Carbone JJ, Fairbank AC. Core decompression versus nonoperative management for osteonecrosis of the hip. Clin Orthop Relat Res 1996;(324):169-78.
25. Lai KA, Shen WJ, Yang CY, et al. The use of alendronate to prevent early collapse of the femoral head in patients with nontraumatic osteonecrosis. A randomized clinical study. J Bone Joint Surg Am 2005;87:2155-9.
26. Hungerford DS. Osteonecrosis: avoiding total hip arthroplasty. J Arthroplasty 2002;17(4 Suppl 1):121-4.
27. Shannon BD, Trousdale RT. Femoral osteotomies for avascular necrosis of the femoral head. Clin Orthop Relat Res 2004;(418):34-40.
28. Mont MA, Etienne G, Ragland PS. Outcome of nonvascularized bone grafting for osteonecrosis of the femoral head. Clin Orthop Relat Res 2003; (417):84-92.
29. Urbaniak JR, Coogan PG, Gunneson EB, Nunley JA. Treatment of osteonecrosis of the femoral head with free vascularized fibular grafting. A long-term follow-up study of one hundred and three hips. J Bone Joint Surg Am 1995;77:681-94.
30. Beaulieu PE, Schmalzried TP, Campbell P, et al. Duration of symptoms and outcome of hemiresurfacing for hip osteonecrosis. Clin Orthop Relat Res 2001;(385):104-17.
31. Massari L, Fini M, Cadossi R, et al. Biophysical stimulation with pulsed electromagnetic fields in osteonecrosis of the femoral head. J Bone Joint Surg Am 2006;88 Suppl 3:56-60.
32. Wang CJ, Wang FS, Huang CC, et al. Treatment for osteonecrosis of the femoral head: comparison of extracorporeal shock waves with core decompression and bone-grafting. J Bone Joint Surg Am 2005;87:2380-7.
33. Merck. Statement by Merck & Co., Inc. regarding Fosamax (alendronate sodium) and rare cases of osteonecrosis of the jaw. Available at www.merck.com/newsroom/press_releases/product/fosamax_statement.html. Accessed 18 Sep 2007.
34. Lavernia CJ, Sierra RJ. Core decompression in atraumatic osteonecrosis of the hip. J Arthroplasty 2000;15:171-8.
35. Kim SY, Kim YG, Kim PT, et al. Vascularized compared with nonvascularized

(continued on page 56)

(from page 19)

- fibular grafts for large osteonecrotic lesions of the femoral head. *J Bone Joint Surg Am* 2005;87:2012-8.
36. Marciniak D, Furey C, Shaffer JW. Osteonecrosis of the femoral head. A study of 101 hips treated with vascularized fibular grafting. *J Bone Joint Surg Am* 2005;87:742-7.
 37. Plakseychuk AY, Kim SY, Park BC, et al. Vascularized compared with nonvascularized fibular grafting for the treatment of osteonecrosis of the femoral head. *J Bone Joint Surg Am* 2003;85:589-96.
 38. Schmalzried TP. Total resurfacing for osteonecrosis of the hip. *Clin Orthop Relat Res* 2004;(429):151-6.
 39. Ito H, Matsuno T, Kaneda K. Bipolar hemiarthroplasty for osteonecrosis of the femoral head. A 7- to 18-year followup. *Clin Orthop Relat Res* 2000;(374):201-11.
 40. Lee SB, Sugano N, Nakata K, et al. Comparison between bipolar hemiarthroplasty and THA for osteonecrosis of the femoral head. *Clin Orthop Relat Res* 2004;(424):161-5.
 41. Chiu KH, Shen WY, Ko CK, Chan KM. Osteonecrosis of the femoral head treated with cementless total hip arthroplasty. A comparison with other diagnoses. *J Arthroplasty* 1997;12:683-8.
 42. Kim YH, Oh SH, Kim JS, Koo KH. Contemporary total hip arthroplasty with and without cement in patients with osteonecrosis of the femoral head. *J Bone Joint Surg Am* 2003;85-A:675-81.
 43. Old AB, McGrory BJ. Delayed osteonecrosis following reduction and internal fixation of a femoral neck fracture. *J Surg Orthop Adv* 2006;15:86-9.

Copyright 2008 by Turner White Communications Inc., Wayne, PA. All rights reserved.