Small-Diameter Percutaneous Decompression for Osteonecrosis of the Shoulder

Kevin L. Harreld, MD, German A. Marulanda, MD, Slif D. Ulrich, MD, David R. Marker, BS, Thorsten M. Seyler, MD, and Michael A. Mont, MD

Abstract

Core decompression of the humeral head has previously been used as a joint-preserving procedure for treatment of symptomatic osteonecrosis of the shoulder. In this article, we describe a new decompression technique, which involves multiple small-diameter (3-mm) percutaneous perforations.

In our study population (early-stage disease), shoulder arthroplasty was avoided in all 15 patients (26 shoulders) for a mean follow-up of 32 months (range, 24-41 months). Of the 26 shoulders, 25 had successful clinical and functional outcomes (University of California Los Angeles shoulder score, >24 points), and 1 showed radiographic progression of the disease but has not needed further operative treatment.

We compared our decompression results with those of a nonoperative historical control group, identified through a literature search. There was a 48% (143/299) rate of progression to arthroplasty in the control group at a follow-up ranging from 2 to 4.5 years.

This outpatient, percutaneous perforations technique appears to be a low-morbidity method for relieving symptoms and deferring shoulder arthroplasty in patients with symptomatic osteonecrosis of the humeral head.

Dr. Harreld is Resident Physician, Department of Orthopaedic Surgery, Wake Forest University Baptist Medical Center, Winston-Salem, North Carolina.

Dr. Marulanda is Resident Physician, Department of Orthopaedics and Sports Medicine, University of South Florida College of Medicine, Tampa, Florida.

Dr. Ulrich is Resident Physician, Department of Orthopaedic Surgery, Union Memorial Hospital, Baltimore, Maryland.

Mr. Marker is Medical Student, Johns Hopkins School of Medicine, Baltimore, Maryland.

Dr. Seyler is Resident Physician, Department of Orthopaedic Surgery, Wake Forest University Baptist Medical Center, Winston-Salem, North Carolina.

Dr. Mont is Director, Center for Joint Preservation and Reconstruction, Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore, Baltimore, Maryland.

Address correspondence to: Michael A. Mont, MD, Center for Joint Preservation and Replacement, Sinai Hospital of Baltimore, 2401 West Belvedere Avenue, Baltimore, MD 21215.

Am J Orthop. 2009;38(7):348-354.

After the femoral head, the humeral head is the most common site of symptomatic osteonecrosis.[1-3] Atraumatic osteonecrosis of the humeral head is a multifactorial entity in which the final common pathway results in disrupted blood supply, increased intraosseous pressure, and bone death.[1,4-7] Necrosis of juxta-articular bone segments results in articular collapse and loss of the normal joint architecture, resulting in pain and loss of shoulder function.[8] Although the humeral head is the second most common site of symptomatic osteonecrosis, incidence is significantly less than that in the hip.[9] Consequently, much of the information regarding the disease has been extrapolated from findings in the femoral head.[9,10] In addition, many treatment modalities have been adapted from techniques used in the hip.

Few authors have described the results of treatment of osteonecrosis specifically in the shoulder. The majority of techniques reported in the literature focus on the use of hemiarthroplasty or total shoulder arthroplasty (TSA) for the treatment of late-stage disease.[11-18] Fewer reports describe results of early-stage treatments, which have included arthroscopic débridement,[19-22] arthroscopically assisted core decompression,[23,24] and bone grafting.[25,26] LaPorte and colleagues[27] and Mont and colleagues[28] reported results of core decompression with a single large-diameter trephine.

Over the past decade, Dr. Mont has been using a new technique of multiple small-diameter percutaneous perforations for treatment of osteonecrosis in a variety of joints. This technique allows improved access to the entire lesion or access to multiple lesions. It was reported to successfully relieve pain and delay arthroplasty in both hips and knees.[29,30] In treatment of osteonecrosis of the femoral head, 71% of hips (80% of stage I hips, 57% of stage II hips) had a successful clinical result at a mean follow-up of 2 years (range, 20-39 months), and there were no surgical complications with use of the technique.[29] In the setting of osteonecrosis of the knee, arthroplasty was avoided in 97% of patients (59/61 knees) at a mean follow-up of 3 years (range, 2-4 years).[30]

Given this success, the technique was applied to treat osteonecrosis of the humeral head. In this article, we present the results of applying this technique to the shoulder in patients who had early-stage disease but no collapse of the humeral head. In addition, we compare our findings with those of a nonoperative historical control group and present early clinical and radiographic outcomes data in relation to various demographic and radiographic variables.

Materials and Methods

Over an 18-month period, Dr. Mont performed 26 core decompressions of the humeral head in 15 patients with symptomatic early-stage (precollapse) osteonecrotic lesions of the humeral head. All procedures were performed using the percutaneous small-diameter perforations technique. All patients presented with pain in the affected shoulder as the chief complaint. Study inclusion criteria were Ficat and Arlet[31] stage I or II disease as modified by Cruess[3] for the humeral head. Stage I osteonecrosis denotes absence of radiographic changes and requires magnetic resonance imaging (MRI) for identification. Stage II osteonecrosis shows demonstrable changes on plain radiographs—including sclerosis of the superior portion of the humeral head and/or focal subchondral osteolysis without fracture. Stage III osteonecrosis shows presence of crescent sign, indicating subchondral collapse and loss of humeral head sphericity. Stage IV osteonecrosis denotes widespread trabecular failure and articular collapse with secondary arthritic changes of the humeral head. Stage V osteonecrosis shows progressive arthritic changes involving the glenoid articular surface. Patients presenting with any sign of radiographic collapse (stages III-V) or a diagnosis of posttraumatic osteonecrosis were excluded from the study. All patients were prospectively studied for a minimum of 2 years after the index procedure. No patients were lost to follow-up. Radiographic and clinical outcomes were assessed at postoperative clinical visits. The study was approved by our institutional review board, and all patients provided informed consent for the surgical procedure and for participation in this study.

Twenty-six shoulders in 15 (8 male, 7 female) patients (mean age, 37 years; range, 15-50 years) were followed for a mean of 32 months (range, 24-41 months). Multiple risk factors were represented in the study population (Table I). Previously, 9 patients (16 shoulders) had received high-dose corticosteroids (>2 g/mo, minimum of 3 months[32,33]). Two of these corticosteroid-treated patients (4 shoulders) had severe asthma, 1 patient (2 shoulders) had systemic lupus erythematosus, 1 patient (2 shoulders) had acute lymphocytic leukemia, 1 patient (1 shoulder) had inflammatory bowel disease, and 4 patients (7 shoulders) had other corticosteroid-associated comorbidities. Three patients (5 shoulders) had an underlying diagnosis of sickle cell disease. One patient (2 shoulders) had a history of human immunodeficiency virus with exposure to protease inhibitors. One patient (1 shoulder) had a history of alcoholism as a contributing factor for osteonecrosis (>400 mL/wk), as defined by Matsuo and colleagues.[34] Nine patients (14 shoulders) had undergone prior core decompression on the symptomatic shoulder.

Table I. Risk Factors

Risk Factor	Patients (n)	Shoulders (n)
Steroids (total)	9	16
Asthma	2	4
Systemic lupus erythematosus	1	2
Acute lymphocytic leukemia	1	2
Inflammatory bowel disease	1	1
Other	4	7
Sickle cell disease	3	5
HIV	1	2
Alcohol abuse	1	1
HLA B27, spondyloarthropathy	1	2
Prior core decompression	9	14

Abbreviation: HIV, human immunodeficiency virus.

Clinical Evaluation

At preoperative and postoperative visits, we used the University of California Los Angeles (UCLA) shoulder rating system, as described by Amstutz and colleagues,[35] to assess clinical outcomes. With this scale, which measures clinical and functional outcomes, a maximum of 10 points is assigned to each of 3 variables (pain, function, motion), for a maximum score of 30 points. A score of more than 24 points was considered an excellent outcome, a score between 18 and 24 points a good outcome, a score of 12 to 18 points a fair outcome, and a score of under 12 points a poor outcome. Patients who received a score of 24 points or under and patients who needed a hemiarthroplasty or TSA for pain relief were considered as having unsuccessful clinical outcomes.

Various demographic subgroups were assessed to identify a prognostic effect on outcome. Factors included patient age under or over 40 years, sex, corticosteroid use, previous core decompression or other treatment on same joint, and various comorbidities. Presence of multifocal osteonecrosis (>3 anatomical sites)[36] was also studied as a predictor of outcome.

Radiographic Evaluation

Preoperative and postoperative radiographs were characterized according to size (small, medium, large) and lesion stage according to the modified Ficat and Arlet classification. Analysis included anteroposterior and axillary radiographs in all patients and 40° posterior oblique radiographs in internal and external rotation in 8 patients. Ten patients with a clinical diagnosis of osteonecrosis were found to have normal shoulder radiographs. MRI was subsequently obtained in these patients. Radiographic assessments were independently performed by Dr. Marulanda and Dr. Seyler. Before initiating the study, the variability in these authors' size characterization and classification with the modified Ficat and Arlet system was assessed. Intraobserver reliability was excellent, with agreement in all patients. Interobserver reliability was good as well, with agreement in 90% of patients. For the study, any discrepancy in size or classification between these 2 observers was then assessed by a third author until a unanimous decision was reached for best estimate of size and stage. Size and stage of lesion were assessed for effect on patient outcome.

Surgical Technique and Rehabilitation

Each procedure was performed with the patient under general anesthesia and in either the supine or beach-chair position on a standard operating table. A 3.2-mm Steinmann pin

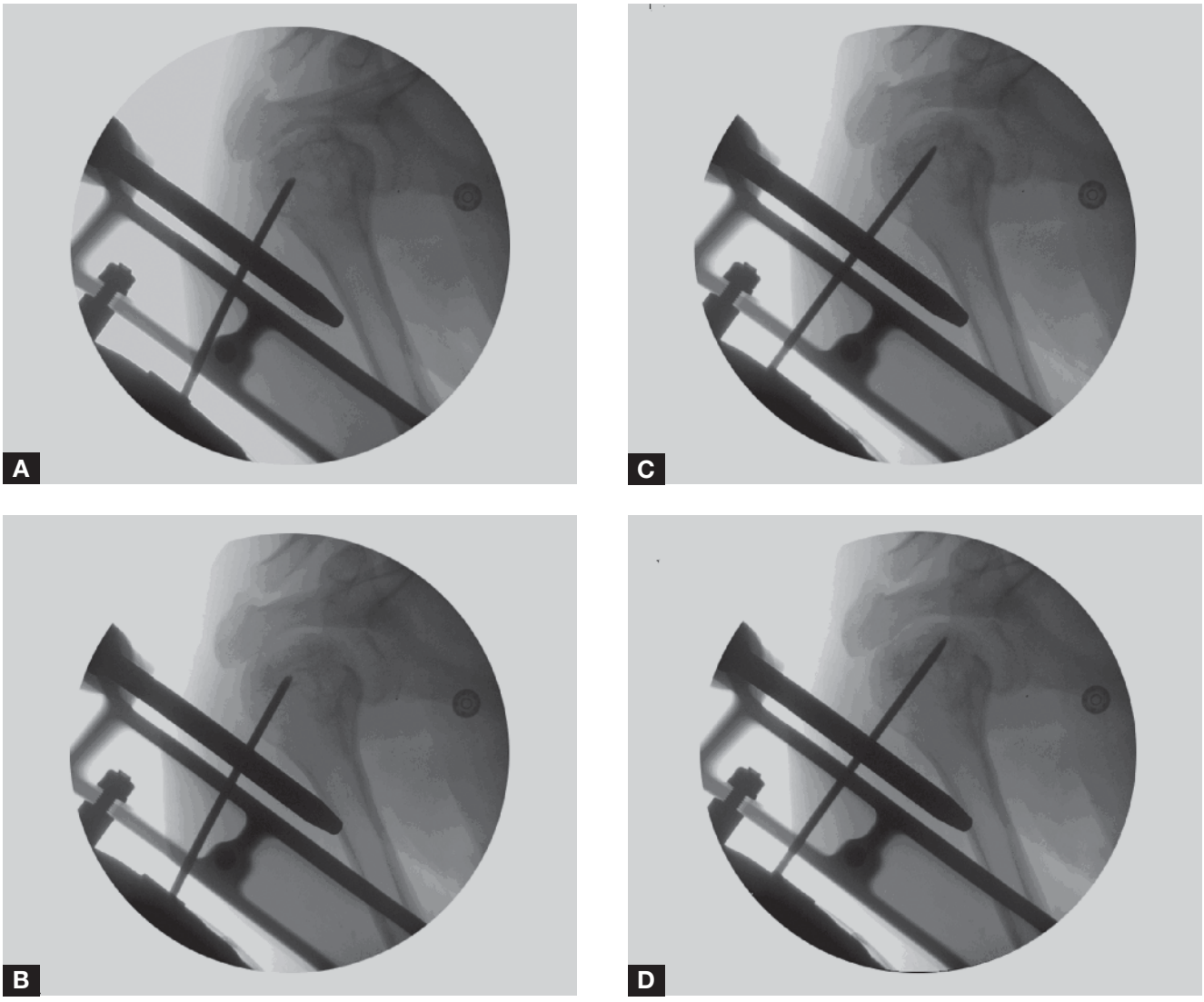

Figure. Intraoperative fluoroscopy images show (A-D) passage of Steinmann pin from lateral cortex to lesion in proximal medial portion of humeral head.

was inserted percutaneously, lateral to the bicipital groove, to avoid injury to the ascending branch of the anterior humeral circumflex artery, which is thought to represent the main blood supply to the humeral head.[37] Under fluoroscopic guidance, the pin was advanced until it reached the desired location in the epiphyseal region, as determined by preoperative radiograph or MRI (Figure). The predominance of lesions was medial in the humeral head. Two passes through the area of the lesion were performed for smaller lesions, or 3 passes for larger lesions. All passes were made using one common entry point. During pin advancement, caution was taken to avoid penetration of the overlying cartilage. After the perforations were made, the wound was closed with a simple interrupted nylon suture. Any bleeding from the pin site was easily controlled with direct pressure before wound closure.

The arm was maintained in a sling for 3 days after surgery. Active-assisted forward flexion, abduction, and rotation exercises were then introduced as tolerated. Heavy lifting and overhead activities were restricted for the first 8 weeks. Patients who remained asymptomatic after 8 weeks were allowed to resume all usual activities of daily living. High-impact loading activities were restricted until 1 year.

Data Analysis

Data were compiled and tabulated with use of Excel spreadsheets (Microsoft, Redmond, Wash). Descriptive statistics were calculated using SigmaStat for Windows Version 3.0 (SPSS, Chicago, Ill). For statistical analyses, a Student *t* test with 95% confidence intervals was used for the varying demographic and radiographic subgroups to evaluate their effect on successful or unsuccessful outcomes as defined by the UCLA score. As noted earlier, a successful outcome was defined as a UCLA score of over 24 points, and an unsuccessful outcome was defined as a UCLA score of 24 points or under or a need for hemiarthroplasty or TSA. The demographic subgroup analyses included age, sex, presence of multiple joint involvement, prior shoulder decompression

or other procedure, risk factor for development of osteonecrosis, and other comorbidities. Radiographic subgroup analysis included lesion size and stage according to the modified Ficat and Arlet classification.

Historical Control Group

Although we do not consider withholding surgery the optimal treatment option (given previous studies[27,28] and our previous experience with this technique), we recognize that some physicians use nonoperative methods in treating osteonecrosis of the humeral head. To compare the results of core decompression with a baseline of natural progression, we searched the literature to identify a group of historical controls. We searched the National Library of Medicine, the National Institutes of Health, and EMBASE for articles describing the natural history of the disease in patients treated nonoperatively. Our key search terms were shoulder, humeral head, osteonecrosis, and avascular necrosis. The initial search was refined by adding natural history and nonoperative. We found 6 reports describing the results of nonoperative management.[4,7,38-41] Two were focused only on a patient population with shoulder osteonecrosis resulting from sickle cell disease.[40,41] As that population was not representative of our current study population, we discuss these 2 reports separately. From the other 4 studies, we identified 299 shoulders. Minimum follow-up was 2 years (range, 2-4.5 years). Studies were evaluated for rate of progression to arthroplasty. Results were stratified with regard to Ficat and Arlet stage at presentation (when this information was available from the study).

Results

Core decompression by multiple small-diameter percutaneous perforations was successful (UCLA score >24) in 25 (96%) of 26 shoulders. At final follow-up, arthroplasty had not been performed in any patient. One shoulder had a fair outcome as defined by a postoperative UCLA score of 14 points and radiographic progression of the lesion with a subchondral fracture. This patient had multiple joint involvement, including the hip, knee, elbow, and ankle, in addition to large bilateral shoulder lesions, and was human leukocyte antigens (HLA) B-27–positive with spondyloarthropathy. The patient with the unsuccessful outcome had a UCLA score that improved from 11 (preoperative) to 14 (postoperative). The contralateral shoulder had a good outcome, with a UCLA score that improved from 17 (preoperative) to 26 (postoperative). At final follow-up (25 months), this patient had moderate pain in the unsuccessful shoulder and no pain in the successful shoulder. The pain was well controlled with oral medication, and there was no impending need for further operative management.

With core decompression, UCLA scores improved by a mean of 13 points (range, 3-17 points) ($P<.0001$). Mean UCLA score improved from 14 points (range, 10-22 points) before surgery to 27 points (range, 14-30 points) at final follow-up after surgery (Table II). All 3 variables assessed with the UCLA score (pain, function, power and motion) independently demonstrated statistically significant improvement (Table II). After percutaneous perforations, pain scores showed the most improvement. Mean pain scores improved from 2.9 to 8.8 points ($P<.0001$), mean function scores improved from 5.2 to 8.8 points ($P<.0001$), and mean power and motion scores improved from 6.2 to 8.9 points ($P<.0001$).

Discussion

Core decompression of the humeral head with a large-diameter trephine has proved to be an effective treatment for osteonecrosis of the humeral head, with the most efficacious results being found in stage I and II disease.[27,28] However, limitations of this conventional technique were noted by Chapman and colleagues.[23] Using an arthroscopic technique, they noted that use of a large-diameter trephine, as described by LaPorte and colleagues[27] and Mont and colleagues,[28] requires an open incision with use of the deltopectoral interval and blunt dissection down to the proximal humerus. This technique carries with it increased risks for surgical site infection and postoperative morbidity because of associated soft-tissue dissection. Furthermore, multiple passes cannot be performed with a large-diameter core because of increased risk for fracture. Dr. Mont recently modified the original technique and developed a new percutaneous technique. We believe this technique diminishes the risks associated with traditional large-diameter core decompression. Furthermore, it has distinct advantages. Removal of a smaller diameter core allows for more than one pass through the lesion, which should result in improved coverage of the lesion. In addition, it allows for access to multiple lesions. The passes are made from a common starting location on the cortex so that the cortical bone is violated in only one location, with a small-diameter Steinmann pin. The technique is minimally invasive; only one percutaneous puncture site is used. This multiple–percutaneous perforations technique is performed as an outpatient procedure and, in our experience, results in rapid recovery and resumption of activities of daily living. Patients note immediate pain relief and have a high rate of satisfaction with the procedure.

The objective results of this technique are comparable with results of traditional large-diameter decompression. Mont and colleagues[28] reported 5-year follow-up for 30 shoulders with osteonecrosis treated with large-diameter (range, 6-10 mm) trephines. For the 14 shoulders with stage I or II disease, all outcomes were good (UCLA score, >24) or excellent (UCLA score, >27) at final follow-up. LaPorte and colleagues[27] reported on 63 shoulders with osteonecrosis treated with large-diameter core decompression with a mean follow-up of 10 years. Thirty-three shoulders had stage I or II disease. Outcomes were successful (UCLA score, >24) in 15 (94%) of 16 shoulders with stage I disease and in 15 (88%) of 17 shoulders with stage II disease. In comparison, our study results demonstrated that, in early follow-up, the multiple perforations technique was at least as effective as conventional large-diameter core decompression; it had a mean postoperative UCLA score of 27 points and successful outcomes in 25 (96%) of 26 patients (Table III).

Table II. University of California Los Angeles (UCLA) Shoulder Scores[a]

	Mean Score (Range)	
	Preoperative	Postoperative
Pain	2.9 (1-4)	8.8 (4-10)
Function	5.2 (4-8)	8.8 (5-10)
Power and motion	6.2 (5-10)	8.9 (5-10)
Total	**14 (10-22)**	**27 (14-30)**

[a]*P*<.0001 for each preoperative–postoperative comparison.

Demographic and radiographic subgroup analyses failed to show a significant impact on final UCLA score. Age, sex, multiple joint involvement, prior shoulder decompression, risk factors for development of osteonecrosis, lesion size, and modified Ficat and Arlet stage all failed to show a statistically significant effect on outcome (*P*>.05). However, this information should not be interpreted as demonstrating that these variables do not have an effect on outcomes. The small number of patients in this study may have precluded finding a significant relationship.

Arthroscopic débridement with loose body removal has been described as a more conservative surgical option in the patient population with early-stage disease,[20] and several authors have advocated arthroscopy in the treatment of humeral head osteonecrosis.[19,21,22] Baillon and Hutsebaut[19] suggested that arthroscopy might facilitate placement of osteochondral grafts in the shoulder in a manner similar to that used in the knee. However, further description or results of such a technique do not appear in the literature. The other 2 publications regarding arthroscopy[23,24] are case reports in which patients had a significant complaint of locking in the shoulder. The reported efficacy of the technique in these patients may relate to alleviation of mechanical systems by concomitant arthroscopic soft-tissue débridement. Overall, follow-up regarding arthroscopic débridement is lacking in the literature, and more studies are needed. As just noted, an arthroscopic decompression technique was described in 2 separate case reports.[23,24] Although there may be a role for this technique, the literature includes only case reports, and follow-up outcome data are not available.

Our study demonstrates that decompression achieved with multiple small-diameter percutaneous perforations is effective in relieving pain, improving function, and increasing power and motion as measured by the UCLA score. The technique appears to be a safe, minimally invasive alternative for pain control and disease stabilization in earlier stages of the disease. We found no surgical complications among the patients in this study. In addition, the technique does not adversely affect future treatment options. Arthroplasty remains a valid surgical alternative in the event that decompression fails.

Limitations of this study included the small cohort (26 shoulders) and the relatively short follow-up (mean, 32 months). Cohort size may have precluded identification of significant predictors of outcome in our subgroup analyses. A larger series with longer follow-up will further help assess positive and negative predictors of outcome. Another limitation to this study is lack of a randomized, nonoperative control group. Our practice environment made inclusion of such a group difficult. Many patients in this study traveled a considerable distance seeking a conservative surgical treatment option after previously being informed that their only surgical option was arthroplasty. In our prestudy experience with this technique, it was demonstrated to be a low-risk, reliable method of pain relief. Consequently, we thought that potential randomization of such patients to a nonoperative treatment group, when a reliable pain-relieving procedure was readily available, was not appropriate.

For comparison with a control group, we searched the literature to identify a group of nonoperatively managed patients (Table IV). We established a historical control patient group from 4 identified studies. Although reporting method varied between these studies, they all provided information regarding rate of progression to arthroplasty. The overall group consisted of 299 shoulders. There was a 48% (143 patients) rate of progression to arthroplasty at a mean follow-up ranging from 2 to 4.5 years. It should be noted that only patients with stage I and II osteonecrosis were included in this study, whereas the historical control group included some patients with osteonecrosis at more advanced stages. Lack of information regarding Ficat and Arlet stage at presentation in most reports in the control group prohibited stratification of results of the entire group to specific stages. However, 2 reports presented results specifically regarding Ficat and Arlet stage.[4,39] Reporting on 16 patients with osteonecrosis of the humeral head, Rutherford and Cofield[39] found that 2 (18%) of 11 with stage II or III osteonecrosis progressed to arthroplasty at a mean of 4.5 years. Expanding on that work and including some of the same patients, Hattrup and Cofield[4] followed the history of 200 shoulders (151 patients) with osteonecrosis of the humeral head. Using Kaplan-Meier survivorship analysis, they found that, within 3 years of diagnosis, 42% of shoulders with stage I or II disease progressed to shoulder replacement. This specific group of patients most

Table III. Results of Core Decompression for Osteonecrosis of Humeral Head

Study	Technique	Success Rate,[a] Stages I and II	Mean Follow-Up
LaPorte et al[27]	Single large trephine	30/33 (91%)	10 years
Mont et al[28]	Single large trephine	14/14 (100%)	66 months
Current study	Multiple small-diameter perforations	25/26 (96%)	32 months

[a]UCLA score, >24.

Table IV. Literature Review of Natural History of Nonoperative Management

Study	Shoulders	Progression to Arthroplasty (%)	Follow-Up at Time of Surgery
Hattrup & Cofield[4]			
Total	200 (38 lost to follow-up)	97 (49%)	
Stage I	4	1 (25%)	Unknown
Stage II	22 (6 lost to follow-up)	7 (32%)	Within 3 years for all patients
L'Insalata et al[38]—*results not stratified by stage, but authors noted radiographic progression in 70% of stages I to III*			
Total	65	35 (54%)	13 patients at presentation 22 patients at mean of 2 years (4 months–17 years)
Cruess[7]—*6 patients in nonoperative group were unable to use arm above shoulder*			
Total	18	4 (22%)	Between 2 and 4.5 years
Rutherford & Cofield[39]			
Total	16	7 (44%)	Mean, 4.5 years
Stage II/III	11	2 (18%)	
Stage IV/V	5	5 (100%)	
David et al[40]—*sickle cell disease only; osteonecrosis not present in all patients; only 53% (73 patients) had shoulder symptoms*			
	138 patients	2 patients (1.4%)	Unknown
Milner et al[41]—*sickle cell disease only; osteonecrosis in 141 patients at start of study; another 149 patients developed osteonecrosis during study*			
	290	1 patient (0.3%)	5.6 years

closely approximates the current study population, which consists only of patients with stage I or II osteonecrosis.

L'Insalata and colleagues[38] reported on 65 shoulders (42 patients). Thirty-five shoulders (54%) eventually underwent surgery. Of these, 13 (37%) had surgery shortly after presentation, and the other 22 (63%) underwent surgery a mean of 2 years after diagnosis (range, 4 months–17 years). Surgeries consisted of 19 TSAs, 15 hemiarthroplasties, and 1 arthrodesis. All patients had stage III, IV, or V disease at time of surgery, but radiographic stage at presentation was either unknown or unreported. However, the authors reported that 21 (70%) of 30 shoulders initially in stage I, II, or III demonstrated a pattern of progression. Furthermore, evidence of radiographic progression was associated with a poor outcome ($P = .0001$) with sensitivity of 88%, specificity of 100%, and positive predictive value of 100%.

In 1976, Cruess[7] reported a lower incidence of arthroplasty; only 4 (22%) of 18 patients in his study underwent the procedure. Although the Ficat and Arlet classification was not used, patients with either early or advanced disease were included. One explanation for the finding of a lower rate of arthroplasty, despite inclusion of advanced disease in this group, is the period during which the study was conducted—the early 1970s, when shoulder arthroplasty was in its relative infancy (the Neer prosthesis had been designed in the early 1950s). One could expect that the indications for surgery were more restricted then, and the surgeon's threshold to perform such a procedure higher. This is evidenced by the fact that 6 of the remaining 14 patients who were managed without arthroplasty had limited active range of motion and "inability to use the arm above the shoulder."[7] It is likely that, in later studies, many similar patients underwent arthroplasty, resulting in higher rates.

We believe that comparison with these historical controls reveals that the multiple–small-diameter percutaneous perforations technique is capable of delaying the need for arthroplasty. Shoulder replacement surgery has not been performed in any shoulder in the study population at nearly 3-year follow-up. It should be noted, however, that osteonecrosis caused by sickle cell disease has been reported to have a more benign course than that of osteonecrosis with other etiologies.[10] David and colleagues[40] reported on 138 patients with sickle cell disease. Arthroplasty was performed in only 2 patients (1.4%). Taking into account that only 53% of the patients in the study had shoulder symptoms, the arthroplasty rate (2.7%) for symptomatic shoulders is still lower than that in the other natural history studies. Milner and colleagues[41] followed a cohort of patients with sickle cell disease to evaluate the prevalence and incidence of osteonecrosis of the shoulder in this population. In their study, 290 patients developed osteonecrosis of the shoulder, yet arthroplasty was performed in only 1 patient (0.3%). In our study population, 5 of 26 shoulders were related to sickle cell disease. It is possible that these patients bias our results, providing an artificial appearance of deferring arthroplasty. However, the majority of patients have osteonecrosis resulting from other risk factors, and any bias effect is likely minimal, as arthroplasty has been avoided in all these patients as well. Consequently, we recommend use of this technique for the treatment of modified Ficat and Arlet stage I or II osteonecrosis of the humeral head. In this setting, the technique is successful in improving pain and function and is, we believe, capable of deferring the need for arthroplasty.

Authors' Disclosure Statement

Dr. Mont wishes to note that he is a paid consultant to Stryker and Wright Medical Technology, Inc. The other authors report no actual or potential conflict of interest in relation to this article.

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This paper will be judged for the Resident Writer's Award.

Errata

In the article entitled "Management of Acute Glenohumeral Dislocations," by Michael J. Sileo, MD, Samuel Joseph, MD, Corey O. Nelson, MD, Jonathan D. Botts, MD, and James Penna, MD, published in *Am J Orthop,* 2009;38(6):282-290, Dr. Nelson's name was misspelled. The correct spelling of his name is Cory O. Nelson, MD.

In the article entitled "Sacral Stress Fractures in Children," by Jimmi Mangla, MSurg (Ortho), MBBS, Jeffrey L. Young, MD, Torita Thomas, BS, and Eldin E. Karaikovic, MD, PhD, published in *Am J Orthop*, 2009;38(5):232-236, the third author's name and degree were listed incorrectly. The correct listing for this author is "Tarita O. Thomas, MD, PhD."