Avascular necrosis of the humeral head can be a debilitating process. Known precipitators include long-term use of steroids, ethanol abuse, radiation, sickle cell disease, various forms of storage diseases, or idiopathic “bad luck.”

Grading or staging of humeral head AVN has been modified from the system of Ficat for humeral head AVN. As in other joints, grade I represents pain without plain radiographic changes, but with magnetic resonance imaging, evidence of a loss of vascularity. Grade II demonstrates an area of radiographic sclerosis and loss of circulation on both plain radiograph and magnetic resonance imaging without subchondral collapse. Grade III is evidenced by an area of similar findings with subchondral collapse. Grade IV demonstrates subchondral and articular collapse. Grade V (end-stage disease) represents biarticular arthrosis of the humeral head and glenoid (Fig. 1).

Classic symptoms include pain, stiffness, loss of mobility, night pain, and decreased function. Management of AVN of the proximal humerus has been separated into nonoperative and operative approaches. Nonoperative approach, including observation, has been relegated only to those early cases in grade I or II where no significant subchondral collapse has
Figure 1  Stages of humeral head avascular necrosis (AVN). Stage I: Radiograph appears normal, and magnetic resonance imaging (MRI) shows early fascial necrosis. Stage II: Radiograph and MRI show areas of subchondral sclerosis. Stage III: Subchondral collapse is observed in both plain radiographs and MRI. Stage IV: Articular degeneration is noted above area of necrosis and collapse of the humeral head. Stage V: Biarticular degeneration is noted involving both the humeral head and glenoid.

Figure 2  (A) Stemmed humeral head replacement arthroplasty restores articular congruity but removes substantial bone stock. (B) Cup resurfacing arthroplasty preserves humeral head bone stock while resurfacing the entire humeral articular surface. (C) “Hemi-Cap” arthroplasty replaces only the focally diseased area of articular surface while preserving healthy surrounding cartilages.
been noted. Surgical management has included core decompression and bone grafting of various techniques. With subchondral or articular collapse, some form of prosthetic replacement arthroplasty, however, is needed to restore motion and function, while relieving pain.

Classically, prosthetic replacement has required extensive bone resection with large stemmed implants being either cemented or pressed-fit to restore normal congruity to the humeral head, providing a stemmed metal implant, which can articulate with a relatively intact and healthy glenoid surface. This, however, has required the removal of a subsequent considerable amount of proximal humeral bone stock, later revision of such a procedure if glenoid erosion were to occur, requiring total shoulder arthroplasty, has required extensive dissection.

More recently, subtotal final techniques for localized resurfacing of the humeral articular surface without significant removal of bone stock has demonstrated significant advances in preservation of natural anatomy, allowing minimal bone removal while providing an environment, which allows simpler more straightforward revision to total shoulder arthroplasty should that at a later date be required.

Clearly, the degree of AVN should dictate the degree of prosthetic replacement. This article will focus on the indications for focal resurfacing (“hemi-cap”), management of entire humeral head involvement with total resurfacing or “cup arthroplasty” of the humeral head, conservative resurfacing of both articular surfaces of the humeral head and glenoid, and indications when formal total shoulder arthroplasty with a stemmed implant with or without total shoulder resurfacing is indicated.

Historically, humeral head replacement arthroplasty, as designed by Neer, has evolved from monoblock implants and has given way to modular designs, which allow ability to match stemmed implants to the diameter of the humeral canal and articular surfaces to the anatomy of the humeral head. However, use of these stemmed implants require substantial bone resection, which, in fact, make revision challenging. Cup arthroplasty, as pioneered by Copeland, resurfaces the entire articular surface of the humeral head, but in doing so, preserves humeral head intramedullary canal integrity using a localized fixation stem and a centered “ongrowth” surface, which bonds to the humeral head. This preserves humeral head and intramedullary canal integrity and allows relatively easy revision surgery. The concept of a “hemi-cap” has only recently evolved. This procedure replaces only the focally diseased articular surface, preserves the surrounding articular cartilage (assuming it is intact and healthy), restores the surface geometry that is being replaced, and allows easy revision should

Figure 3 Symptomatic grade III AVN (A) has been treated with focal “hemi-cap” arthroplasty (B and C), preserving viable surrounding articular cartilage while resecting minimal bone stock. (Color version of figure is available online.)
this be necessary at a later date. This process, however, is technically challenging because it requires precise realignment of the focal implant with the surviving articular cartilage (Fig. 2). The question that arises is When is it most appropriate to use which of the options to manage symptomatic AVN? The authors have worked out a process for approaching AVN as follows:

Grade 2-3: “Focal, less than 30%” hemi-cap replacement (Fig. 3).
Grade 2-4: 30%-50% articular surface involvement, with good bone stock cup arthroplasty resurfacing of the entire humeral head (Fig. 4).
Grade 2-4: With poor bone stock, regardless of the degree of head involvement, a stemmed hemi-arthroplasty (Fig. 5).
Figure 5 (A and B) MRI revealing grade IV involvement, with extensive collapse of supporting subchondral bone has dictated stemmed hemiarthroplasty humeral head replacement.

Figure 6 (A and B) Grade V AVN with complete head collapse and arthritic glenoid degeneration has required biarticular total shoulder replacement arthroplasty (C and D).
Figure 7 (A-J) As demonstrated in this “saw-bones” model, the surgical technique for “hemi-cap” resurfacing requires identification of the focal defect, central guide-wire placement, bed preparation, and confluent implant placement. This grade II lesion has been managed with focal surface replacement with a “hemi-cap” implant (H, I and J). (Color version of figure is available online.)
Grade 5: With biarticular disease, total shoulder arthroplasty (Fig. 6).

**Surgical Techniques**

Hemi-cap focal or "spot" resurfacing of the humeral head is performed by localizing the area of degeneration and subchondral collapse, ensuring that the peripheral support bone and articular surface is healthy, diseased surface excision, debridement of unhealthy subchondral bone, preparation of a bed for insertion of a confluent focal resurfacing implant using a "hemi-cap." This requires identification of the area of decay, central placement of guide wires, surface debridement, templating of a trial implant, and ultimately, insertion of a definitive implant to fill the defect and be congruent with the existing peripheral articular cartilage surface (Fig. 7). This technique is applicable for defects ranging from 25-mm (in diameter) to full-head lesions. The implants increase in size from 5 mm to 40 mm. Any device larger than 40 mm will now cover the entire humeral head. The largest device that can resurface the entire humeral head is an aspherical design, thus one can match the exact humeral anatomy.

**Cup Arthroplasty Resurfacing**

Total resurfacing allows a metallic surface to replace the entire articular surface. This new metallic surface is bonded to the humeral head through cintered ongrowth fixation. It preserves most of the surrounding bone stock of the humeral head and provides restoration of a normal smooth articular surface, while burning no bridges with regard to bone stock removal, preserving potential for later uncomplicated revision surgery. This technique is extremely applicable in young patients who have good bone stock and a stable joint (Fig. 8).

If these last 2 parameters are not present, this technique is not applicable. Contraindications to both of these bone-preserving procedures include poor underlying bone stock, an unstable joint, or inadequate peripheral support, such as in a fracture.
For grade V AVN where both sides of the joint are degenerated, if there is enough healthy bone support to allow resurfacing of the humeral head, then a fascial resurfacing of the glenoid, as described by Burkhead, can be performed (Fig. 9).

If, however, there is too much collapse and the humeral head will not support application of a focal or entire cup resurfacing implant, then a stemmed implant should be used either with fascial resurfacing or with a more formal synthetic resurfacing of the glenoid as in a standard total shoulder arthroplasty.

**Conclusions**

Focal (hemi-cap) or complete resurfacing (cup resurfacing) is a conservative means of restoring articular congruity to the humeral head. These techniques remove little bone, burn few bridges, offer pain relief, a smooth articular surface for enhanced motion, and provide for easy ability to perform later revision arthroplasty as needed. Stemmed implants require removal of a significant amount of bone but can be effective to provide a humeral head resurfacing with or without glenoid resurfacing as needed depending on the extent of the disease.

An understanding of the indications for these surgical procedures is paramount in using the most appropriate technique to the degree of pathology presented in this challenging spectrum of patients.

**References**