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What's New in Shoulder and Elbow Surgery

By Matthew L. Ramsey, MD, Charles L. Getz, MD, and Bradford O. Parsons, MD

This annual update on shoulder and elbow surgery is a review of the most relevant studies from July 2008 through June 2009. It includes clinical and basic-science articles from The Journal of Bone and Joint Surgery (American Volume), The Journal of Bone and Joint Surgery (British Volume), the Journal of Shoulder and Elbow Surgery, and Arthroscopy: The Journal of Arthroscopic and Related Surgery. Relevant level-I and II studies from other medical journals are included where appropriate.

The level of evidence is indicated at the end of each review when it is known. Particular attention should be paid to the level-I and II studies as they represent randomized controlled studies. It should be noted, however, that level-I or II studies are not all well designed, well executed, or scientifically valid. Additional level-III and IV studies representing important topics in shoulder and elbow surgery are also included in the review.

Shoulder

General

The effect of irrigation fluid temperature on body temperature and other variables was studied by Kim and colleagues. Those investigators performed a prospective, randomized study of fifty patients undergoing arthroscopic shoulder surgery with use of either room-temperature or warmed (37°C to 39°C) irrigation fluid. There was a significant difference in the final core body temperature in the group that received room-temperature fluid as compared with the group that received warmed fluid (35.5°C compared with 36.2°C). The prevalence of hypothermia was significantly greater in the room-temperature-fluid group as compared with the warmed-fluid group (91.3% compared with 17.4%). Of the variables measured, the age of the patient and the amount of irrigation fluid used correlated with core body temperature in the room-temperature-fluid group. None of the variables that were measured correlated with core body temperature in the warmed-fluid group. (Level I)

The use of thermal devices is well established in shoulder arthroscopy. However, concern exists about the effects of heat on articular cartilage. Chondrocyte death has been shown to occur at temperatures of >45°C. Good and colleagues studied the effects of the method of heating, the water flow rate, and the location of heat application during arthroscopy on water temperature. The authors found that higher irrigation flow rates reduced the time that temperatures were elevated as compared with the no-flow condition. However, in all conditions tested, temperatures were >45°C. That study highlights the potential for high temperatures to be reached during thermal ablation, and the authors recommended minimizing its use and keeping water flow high in order to decrease temperatures.

Adhesive Capsulitis

Adhesive capsulitis is a common clinical entity in which treatment ranges from benign neglect to surgery. Jacobs and colleagues prospectively investigated the role of manipulation with the patient under anesthesia or intra-articular steroid injection with joint distention for the treatment of this condition. Patients with idiopathic adhesive capsulitis were enrolled into a prospective, randomized trial in which manipulation with the patient under general anesthesia was compared with intra-articular joint distention with a steroid solution. Fifty-three patients were followed for two years, and outcomes were measured with use of the Constant score, the Short Form-36 (SF-36), and a visual analog score. No significant difference in any of these outcome measures was found between the treatment groups. The authors concluded that
impingement with the patient under anesthesia and intra-articular steroid injection with joint distention are equally effective. (Level I)

**Impingement Syndrome/Rotator Cuff Tendinitis**

Accurate diagnosis of rotator cuff pathology is critical to initiating appropriate treatment. Hughes et al. performed a systematic review of the literature and evaluated likelihood ratios to determine the diagnostic accuracy of clinical tests for rotator cuff pathology. Thirteen studies met the inclusion criteria. The thirteen studies investigated fourteen clinical tests in eighty-nine separate evaluations of diagnostic accuracy. Only one evaluation, palpation for supraspinatus ruptures, resulted in significant positive and negative likelihood ratios. Eight of the eighty-nine evaluations resulted in either significant positive or negative likelihood ratios. However, none of these eight positive or negative likelihood ratios were found in other studies. Of the eighty-nine evaluations of clinical tests, seventy-one (80%) did not result in either significant positive or negative likelihood ratio evaluations across different studies. Overall, most tests for rotator cuff pathology were inaccurate. At best, suspicion of a rotator cuff tear may be heightened by pain with palpation, a combined Hawkins/painful arc/infra spinatus test, a Napoleon test, a lift-off test, a belly-press test, or a drop-arm test, and it may be reduced by negative results on palpation, an empty can test, or a Hawkins-Kennedy test.

Patients diagnosed with rotator cuff impingement are often started on an exercise program. However, no standardized protocol exists and the results of this treatment approach are not clearly established. Kuhn performed a systematic review of the literature to evaluate the role of exercise in the treatment of rotator cuff impingement, and, on the basis of that review, synthesized a standard evidence-based rehabilitation protocol. Eleven randomized controlled trials evaluating the effect of exercise for the treatment of impingement were identified. Data regarding demographic characteristics, methodology, and the outcomes of pain, range of motion, strength, and function were recorded. Individual components of each rehabilitation program were catalogued. Effectiveness was determined on the basis of statistical significance and clinical importance. Although many articles had methodological limitations, the data demonstrated that exercise had statistically significant and clinically important effects in terms of reducing pain and improving function but not in terms of range of motion or strength. Manual therapy augments the effects of exercise, yet supervised exercise was not different from home exercise programs. Kuhn created a gold-standard rehabilitation protocol that will be used in the future to study the nonoperative treatment of rotator cuff impingement.

When nonoperative treatment fails in patients with rotator cuff impingement, subacromial decompression is often performed, and many physicians use subacromial pain medication pumps following arthroscopic subacromial decompression. Järvelä and Järvelä performed a prospective randomized study of fifty patients in which half of the patients were managed for twenty-four hours with a subacromial pump with an infusion of 0.375% ropivacaine at a continuous rate of 5 mL/hr and the other half were not. The authors found no differences between the study groups preoperatively. After a minimum follow-up of two years, the duration of sick leave, the ability to return to work, and isometric elevation strength were not significantly different between the groups. The shoulder scores (University of California at Los Angeles [UCLA] and Constant scores) were significantly better postoperatively in both groups, although no differences were found between the two groups. The authors did not demonstrate any long-term benefit of a subacromial pain pump on recovery, return to work, or the final result after a minimum duration of follow-up of two years; however, they did not evaluate pain in the immediate postoperative period. (Level II)

The long-term outcomes for twenty-four patients (thirty-one shoulders) with impingement syndrome who were managed with an arthroscopic acromioplasty were analyzed by Odenbring et al. A group of patients who had previously undergone an open acromioplasty served as historical controls. After a minimum duration of follow-up of twelve years, twenty-four shoulders (77%) demonstrated persistent good to excellent results according to the UCLA score, with significantly better results in patients who had been managed with arthroscopic acromioplasty as compared with the control group of twenty-nine patients who had been managed with open acromioplasty. The authors demonstrated the long-term durability and superiority of arthroscopic acromioplasty as compared with open acromioplasty. (Level III)

The underlying cause of pain in patients with impingement syndrome is not entirely clear. Henkus et al. performed a prospective randomized study of patients undergoing surgery for the treatment of impingement syndrome after the failure of nonoperative treatment in an attempt to determine whether intrinsic or extrinsic factors caused the pain. Patients were randomized to receive arthroscopic bursectomy or arthroscopic bursectomy combined with subacromial decompression. The type of acromion was classified, according to the method of Bigliani, as flat (type I), curved (type II), or hooked (type III). Fifty-seven patients with a mean age of forty-seven years were followed for an average of 2.5 years. No significant difference was noted between treatment groups. The authors found that the type of acromion and the severity of symptoms before surgery had a greater influence on the clinical outcome than the type of treatment did. As a result, they concluded that impingement is likely an intrinsic condition as opposed to being caused by external pressure. (Level I)

**Acromioclavicular Joint**

Corticosteroid injections are a mainstay of treatment for arthritis of the acromioclavicular joint. However, the long-term effectiveness of steroid injection for the treatment of acro-
mioclavicular joint arthritis is not well known. Hossain et al. prospectively followed twenty-five shoulders in twenty patients for five years after intra-articular steroid injection (1 mL of 40 mg/mL methylprednisolone acetate [Depo-Medrone; Pharmacia, Sandwich, Kent, England] and 1 mL of 2% lignocaine). Significant improvement was noted when the average pretreatment Constant score (61 points) was compared with the scores six months (81 points) and twelve months (86 points) after treatment. The average score at five years (81 points) was significantly decreased in comparison with the twelve-month score, but it was still improved in comparison with the pretreatment score. The authors demonstrated that intra-articular steroid injection of the acromioclavicular joint results in improvement for at least twelve months and that the benefit can last for as long as five years. However, pain relief tends to diminish over time.

The acromioclavicular joint is part of a complex upper extremity linkage system, and injury to this joint can result in dysfunction of other elements in the linkage system. Gumina et al. hypothesized that acromioclavicular joint dislocation may result in a SICK scapula syndrome (scapular malposition, inferior medial border prominence, coracoid pain and malposition, and dyskinesia of scapular movement). Thirty-four patients with chronic type-III acromioclavicular dislocations were evaluated for scapular dysfunction. Of the thirty-four patients in the study, twenty-four (70.6%) had abnormal scapular mechanics and fourteen (58.3%) of these twenty-four patients were classified as having SICK scapula syndrome. Outcomes measured with use of the Simple Shoulder Test (SST) and the Constant score were significantly lower in patients with scapular dyskinesia. These findings suggest that shoulder dysfunction following type-III acromioclavicular dislocation is related to altered scapular mechanics. (Level IV)

**Rotator Cuff**

**Full-Thickness Tears**

Rotator cuff tears are known to occur normally in the aging shoulder. Moosmayer et al. clinically and radiographically evaluated 420 asymptomatic shoulders in patients who were fifty to seventy-nine years of age. Full-thickness tears were found to increase with aging, with an overall prevalence of 7.6% in the study population. Stratification according to the decade of life (fifties, sixties, and seventies) showed an increasing prevalence of tears: 2.1%, 5.7%, and 15%, respectively. Flexion strength was reduced significantly in patients with rotator cuff tears. The authors confirmed that rotator cuff tears are part of the normal aging process. However, in the patient population that they studied, the increase in prevalence of tears with increasing age was less than previously reported.

A similar study was performed by Kim and colleagues. Asymptomatic volunteers were screened with ultrasonography for rotator cuff tears, and then strength testing was performed. Among 237 patients, forty-one had a tear in at least one shoulder. The rate of asymptomatic tears increased significantly with age: 0% in patients forty to forty-nine years old, 10% in patients fifty to fifty-nine years old, 20% in patients sixty to sixty-nine years old, and 41.7% in patients seventy years old or more. Strength decreased with increasing age and in the presence of tears, suggesting that previously reported normative strength data may have included a significant number of individuals with asymptomatic tears. Additionally, the ratio of abduction strength to external rotation strength was significantly decreased in shoulders with a large-to-massive full-thickness tear as compared with shoulders with an intact rotator cuff. This finding suggests that when there is a substantial decrease in abduction strength in relation to external rotation strength, the presence of an asymptomatic full-thickness tear should be suspected in that shoulder.

Those two studies demonstrated that there is an age-related increase in the prevalence of rotator cuff tears. However, other factors, including a genetic predisposition, may play a role. Tashjian et al. combined genealogical data with clinical diagnostic data to test for the presence of excess familial clustering of rotator cuff tears with use of two well-established methods (the Genealogical Index of Familiarity test and the estimation of relative risks in relatives). The Genealogical Index of Familiarity test in patients diagnosed with a rotator cuff tear before the age of forty years showed significant excess relatedness for individuals with close and distant relationships (as distant as third cousins). The relative risk of rotator cuff disease in the relatives of patients diagnosed before the age of forty years was significantly elevated for second-degree and third-degree relatives. These observations strongly support a heritable predisposition to rotator cuff disease. (Level III)

Superior migration of the humeral head is an indicator of rotator cuff deficiency. However, the size of the tear required to produce this radiographic finding is not well understood. Keener et al. attempted to correlate proximal humeral migration with rotator cuff tear size, location, and pain. Ninety-eight asymptomatic and sixty-two symptomatic individuals underwent ultrasonic evaluation to determine rotator cuff tear size and radiographic evaluation to determine the degree of proximal humeral migration. Tears extending into the infraspinatus tendon were associated with greater humeral migration than was seen in association with isolated supraspinatus tears, and humeral migration resulting from symptomatic rotator cuff tears was greater than that resulting from asymptomatic tears. Additionally, there was a critical size for tendon tears (175 mm²) resulting in humeral migration in painful shoulders. Although both pain and tear size influenced glenohumeral kinematics in symptomatic shoulders, only tear size was an independent predictor of humeral migration. (Level II)

Symptomatic rotator cuff tears often require surgical repair. Unfortunately, it is well known that not all surgically repaired rotator cuff tears heal, and we do not have a thorough understanding of the factors that influence healing. Oh et al. evaluated seventy-eight patients who were managed for...
full-thickness rotator cuff tears. Functional results and anatomic results (specifically, cuff integrity) were analyzed one year postoperatively in an effort to identify factors impacting outcome. Functional outcomes were improved in all patients and did not correlate with rotator cuff healing. The presence of infraspinatus fatty degeneration was identified as the most important independent predictor of a retear. However, tear size and patient age also had an influence on retear rates. A similar analysis was performed by Nho et al. A group of 127 patients were followed prospectively for a minimum of two years after arthroscopic rotator cuff repair in order to determine factors that affect outcome. Patient age and tear size were found to impact anatomic outcome (cuff integrity). Intraoperative factors impacting anatomic outcome included a need for additional procedures such as treatment of the biceps tendon and acromioclavicular resection. The authors demonstrated a ninefold increase in the recurrence rate for a multiple-tendon tear with associated pathology as compared with a single-tendon tear. The authors concluded that early intervention for isolated single-tendon tears might optimize both anatomic and clinical outcomes.

The clinical and anatomic outcomes of arthroscopic rotator cuff repairs are being studied with increased frequency. One such study was performed by Levy and colleagues. One hundred and two consecutive patients undergoing arthroscopic rotator cuff repair were prospectively followed and assessed after an average duration of follow-up of thirty-six months on the basis of the Constant score and ultrasonography. The surgical repair technique differed according to the tear configuration. The size of the tear correlated inversely with the Constant score, with patients who had smaller tears having better scores. Retears were observed in 19% of the patients. While patients with retears had improved Constant scores, they demonstrated significantly lower Constant scores than did those with healed repairs. Overall, 92% of patients in the series were satisfied with the outcome. Deutsch et al. prospectively reported the results for patients undergoing repair of single-tendon and two-tendon rotator cuff tears with use of an arthroscopic single-row technique. Twenty-one patients had single-tendon repair, and eighteen had a two-tendon repair. Follow-up magnetic resonance imaging scans were performed at a minimum of one year to determine the anatomic integrity of the repair. The scans showed that 90% of single-tendon repairs and 83% of two-tendon repairs were intact. Recurrent tear was associated with tears that required more mobilization of the retracted rotator cuff tissue. Pain, elevation, satisfaction, and American Shoulder and Elbow Surgeons (ASES) scores were significantly improved when measured at an average of thirty-eight months after surgery.

The technique that is used to repair rotator cuff tears varies widely, and no specific method has been proved to be superior to another. Double-row arthroscopic rotator cuff repair has gained in popularity, and some studies have shown better footprint coverage and improved biomechanics in association with this repair. Two studies specifically evaluated repair technique with respect to patient outcomes and rotator cuff integrity. In the first study, Burks and colleagues performed a randomized controlled trial of forty patients to compare the results of single and double-row rotator cuff repair. Patients were followed clinically and underwent magnetic resonance imaging studies at six weeks, three months, and one year after repair. The average preoperative anteroposterior tear size was 1.8 cm. A mean of 2.25 anchors were used for single-row repair, and a mean of 3.2 anchors were used for double-row repair. There were two retears at one year in each group. There were two additional shoulders that had severe thinning in the double-row repair group at one year. At one year, there were no differences in terms of any of the postoperative measures of motion or strength. Similarly, the outcome scores at one year showed no significant differences between the groups. The authors concluded that, for this group of patients with small rotator cuff tears, there were no clinical or magnetic resonance imaging differences between rotator cuff tears repaired with a single or double-row technique. (Level I)

In another study, Grasso et al. evaluated the results of single-row compared with double-row arthroscopic rotator cuff repair. Eighty patients with a full-thickness rotator cuff tear underwent arthroscopic repair with suture anchors. They were randomly divided into two groups of forty patients according to repair technique. The results were evaluated with use of the Disabilities of the Arm, Shoulder and Hand (DASH) and Work-DASH self-administered questionnaires, normalized Constant scores, and muscle strength measurement. At the time of the two-year follow-up, several independent variables were evaluated, including baseline scores; age; sex; dominance; the location, shape, and area of the cuff tear; tendon retraction; fatty degeneration; treatment of the biceps tendon; and rotator cuff repair technique (anchors or anchors and side-to-side sutures in the longitudinal portion of the rotator cuff tear). Comparisons between the groups did not show significant differences for any of these variables. Univariate and multivariate analysis showed that only age, sex, and baseline strength significantly and independently influenced the outcome. The differences between the repair techniques were not significant. The authors concluded that, at the time of short-term follow-up, arthroscopic rotator cuff repair with the double-row technique showed no significant difference in terms of clinical outcome in comparison with single-row repair. (Level I)

Anterosuperior rotator cuff tears involve the subscapularis and supraspinatus and are much less common than posterosuperior tears involving the supraspinatus and infraspinatus. Namdari et al. reported on a consecutive series of thirty patients with traumatic anterosuperior rotator cuff tears who were managed with open repair. Outcome measures were assessed after a mean duration of follow-up of fifty-six months with use of the DASH, Constant, and SST scores. All scores
were significantly improved at the time of the latest evaluation following the repair, and there was excellent restoration of range of motion and strength. Infraspinatus involvement, a greater extent of the supraspinatus tear, and having a Workers’ Compensation claim negatively impacted the outcome.

Workers’ Compensation status has been shown to negatively affect the outcome of rotator cuff repair. However, no report to date has accounted for confounding factors in the statistical analysis. Henn and colleagues reported the outcomes for 125 patients who underwent a rotator cuff tear repair and were followed prospectively for one year prior to the settlement of their compensation claim. Outcomes were assessed with the SST, the DASH index, three visual analog scales (shoulder pain, shoulder function, and quality of life), and the Short Form-36 (SF-36). Preoperatively, patients with a Workers’ Compensation claim had significantly lower scores on the SST and SF-36. One year postoperatively, patients with a Workers’ Compensation claim reported worse performance on the SST, the DASH, all three visual analog scales, and the SF-36. Multivariate analysis controlling for age, sex, comorbidities, smoking, marital status, education, duration of symptoms, work demands, expectations, and tear size confirmed that Workers’ Compensation status was an independent predictor of worse DASH scores. (Level I)

Partial-Thickness Tears

The treatment of symptomatic partial-thickness rotator cuff tears remains controversial. One method involves completing the tear and performing a full-thickness repair. Kamath et al. reported on the functional and anatomic outcomes for forty-one patients (forty-two shoulders) who had high-grade partial-thickness rotator cuff tear repairs that were converted to a full-thickness tear and then were repaired arthroscopically. As assessed with ultrasonography, the overall rate of healing was 88%, and the mean ASES score improved from 46.1 to 82.1 points. Patients who had a healed rotator cuff were significantly younger than those with a persistent cuff defect (mean age, 51.8 compared with 62.6 years). The authors postulated that cytokines may play a role in rotator cuff healing. However, cellular and vascular contributions to healing likely play an equally important role.

Simon et al. examined the response of osteoblasts to mechanical stress. The osteoblasts were harvested from the greater tuberosity and acromion of eight patients with a large chronic rotator cuff tear. Osteoblasts that are exposed to mechanical strain normally increase alkaline phosphatase activity and nitric oxide release. The authors found that osteoblasts derived from the tuberosity had no apparent response to mechanical stimulation, whereas those derived from the acromion showed an increase in alkaline phosphatase activity and nitric oxide release. The authors concluded that failure of repair of the rotator cuff may be due, at least in part, to a compromised capacity for osteoblasts in the greater tuberosity to adapt mechanically following surgery.

Vascularity of the rotator cuff also may play a role in healing. Levy and associates utilized laser Doppler flowmetry to evaluate rotator cuff vascularity in normal and diseased states. Rotator cuffs in patients with impingement were found to have altered flowmetry in comparison with normal rotator cuffs (in patients with shoulder instability) and torn rotator cuffs. Blood flow was higher along the edges of torn cuff tendons in comparison with normal cuffs, which the authors thought to represent an attempt at healing. They concluded that there was no evidence for lack of vascularity in the torn rotator cuff.

A variety of animal models have been used to facilitate the study of rotator cuff tears. Perry and coauthors utilized a rat model to study the effect of isolated supraspinatus or multiple rotator cuff tendon tears on the integrity and mechanical properties of the remaining intact rotator cuff. The rats were divided into three tendon-detachment groups: supraspinatus tendon detachment, supraspinatus and infraspinatus tendon detachment, and supraspinatus and subscapularis tendon detachment. The remaining (intact) rotator cuff tendons had decreased mechanical properties in the presence of rotator cuff tears. Interestingly, the remaining (intact) subscapularis and infraspinatus tendon cross-sectional areas increased, despite their decreased mechanical properties. The authors speculated that these alterations could lead to further tendon damage and tear progression.

The role of inflammatory cells and their products in tendinopathy is not completely understood. The effect of these pro-inflammatory cytokines on tendinopathy was investigated by Millar and Murrell in a rat tendon overuse model, and their levels were compared with human rotator cuff tendon cytokine levels under several conditions. Increased levels of pro-inflammatory cytokines were observed both in the rat tendon overuse model and in the supraspinatus and subscapularis tendon tissue in patients with rotator cuff tears, but not in the rotator cuff tissue of patients without a tear. The authors postulated that cytokines may play a role in tendinopathy.

The effect of corticosteroids on tendon properties is poorly understood, and current data are contradictory and diverse. Utilizing a rat model of tendon injury, Mikolyzik et al. studied the effect of a single-dose corticosteroid injection on the biomechanical properties of rotator cuff tendon. Rats were randomly assigned to one of four study groups: control,
tendon tear, steroid exposure, and tendon tear plus steroid exposure. Transient weakness of both the intact and torn tendons occurred at one week after the injection. The biomechanical changes noted at one week were transient as the steroid-exposed groups returned to the control level at three weeks.

A great deal of research is being directed at the regeneration of rotator cuff tissue through the use of matrix grafts and growth factors. Ide and colleagues studied the effect of fibroblast growth factor-2 (FGF-2) on rotator cuff healing in a rat model. Acute 3 x 5-mm defects were created in the supraspinatus tendons and were repaired with acellular dermal matrix or acellular dermal matrix with FGF-2. The animals were killed and tested at two, six, and twelve weeks. Beginning at six weeks, the ultimate strength of the tendon was significantly greater in the FGF-2-treated group. At twelve weeks, the strength of the FGF-2-treated tendons was significantly greater than that of the tendons of untreated animals and was not significantly different from that of controls. These findings suggest that the application of FGF-2 to rotator cuff repairs may speed healing. Seerhamer and colleagues investigated the ability of recombinant human bone morphogenetic protein-12 (rhBMP-12) to accelerate healing in a sheep rotator cuff repair model. A variety of carriers for rhBMP-12 were investigated. The mechanical properties of the repairs that were treated with an rhBMP-12/hyaluronan sponge and an rhBMP-12/collagen sponge were 2.1 and 2.7 times greater, respectively, than the loads for the untreated repairs and were 33% and 42% of the value for the normal tendon at eight weeks. The maximum loads for the repairs treated with rhBMP-12 and a Type-I or Type-I/III collagen sponge were 2.1 times greater than those for the repairs treated with the Type-I/III collagen sponge alone. Histological evaluation demonstrated accelerated healing of the rhBMP-12-treated repairs in comparison with the untreated repairs. However, the biochemical measurements were not equivalent to those of normal tendon at eight weeks.

**SLAP/Glenohumeral Instability**

The ability to diagnose a SLAP (superior labrum, anterior and posterior) lesion through physical examination has been reported in many studies to be highly sensitive and specific, accurate, valid, and reliable. Calvert and colleagues performed a systematic review of the literature to determine if there was sufficient evidence to support the validity and reliability of physical examination tests used to diagnose SLAP lesions. Sackett's guidelines were applied to all articles, and confidence intervals and likelihood ratios were determined. Fifteen of twenty-nine relevant studies met the criteria for inclusion. Only one article met all of Sackett's critical appraisal criteria. On the basis of their critical review of the literature, the authors concluded that the current literature lacks the validity necessary to recommend any specific test for the diagnosis of SLAP lesions.

The natural history of glenohumeral dislocation is poorly understood. Hovelius and Saeboe used a multicenter registry to identify 257 shoulders with a primary dislocation that were enrolled prospectively and were followed for twenty-five years. Of the 229 patients who were alive, 223 (97%) had radiographic follow-up. Among all patients, 44% had normal findings, 19% had mild arthropathy, 9% had moderate arthropathy, and 17% had severe arthropathy on radiographic evaluation. Patients who did not have any further dislocations had significantly lower rates of moderate or severe arthritis (18%), compared with a rate of 39% for those who had at least two dislocations and 26% for those who underwent surgical stabilization. Risk factors for moderate or severe arthropathy included alcoholism, an age of more than twenty-five years at the time of the initial dislocation, and the occurrence of the dislocation during high-energy sporting activities. Patients with mild arthropathy at ten years were significantly more likely to have progression to moderate or severe arthropathy at twenty-five years than were patients with a normal joint at ten years. (Level I)

The arthroscopic treatment of glenohumeral instability requires that a level of expertise be achieved and retained. The retention of arthroscopic skills learned in a surgical skills simulator was tested by Howells and colleagues. Six fellowship-trained lower extremity surgeons were instructed in the use of an arthroscopic Bankart repair during three sessions over a period of one month. The surgeons exhibited a significant learning curve during these training sessions as measured on the basis of the time of repair, the total path length of the surgeon's hands, and the number of movements. The process was repeated six months later, with no intervening performance of the procedure. The learning curve at six months was a repeat of the initial learning curve. This study objectively demonstrated a loss of all of the initial improvement in the performance of an arthroscopic Bankart repair following a six-month interval in which the surgeons did not perform the procedure. This study highlights the importance of repetition in maintaining a high level of arthroscopic skill.

Traumatic anterior instability of the shoulder is associated with a high rate of recurrence in young patients. The use of nonoperative or operative treatment and the optimum surgical approach for this condition have been debated. Brophy and Marx performed a systematic review of the literature to identify studies comparing operative with nonoperative treatment of traumatic anterior shoulder instability and studies comparing open with arthroscopic stabilization. Surgical treatment, either open or arthroscopic, was associated with a significantly lower rate of recurrent instability at the time of the two-year follow-up (7% compared with 46%) and at longer-term follow-up (10% compared with 58%) for patients with first-time traumatic anterior shoulder dislocation. The rates of recurrent instability were roughly equal after arthroscopic stabilization with suture anchors and open stabilization with anchors (6.4% compared with 8.2%). The
established. Kircher et al. The treatment of chondral defects in the shoulder is not well
Glenohumeral Arthritis
provided that a large Hill-Sachs lesion is not present. Failed open stabilization, can lead to satisfactory outcomes,
concluded that revision arthroscopic stabilization, even after
Ontario shoulder instability score was 68.2 points. The authors
follow-up for the group was thirty-six months. Four patients
with recurrent anterior instability were managed with ar-
riors appears to have results similar to those of an open
approach involving suture anchors in terms of recurrent
instability.

Recurrent instability following failed previous anterior
stabilization can be a devastating problem. Many authors have
advocated open stabilization following the failure of surgical
treatment. Patel and colleagues reviewed their clinical ex-
perience with revision arthroscopic stabilization. Forty patients
with recurrent anterior instability were managed with ar-
throscopic capsulolabral reconstruction. The mean duration of
follow-up for the group was thirty-six months. Four patients
had recurrent instability following the revision surgery. The
average ASES score was 81.1 points, and the mean Western
Ontario shoulder instability score was 68.2 points. The authors
concluded that revision arthroscopic stabilization, even after
failed open stabilization, can lead to satisfactory outcomes,
provided that a large Hill-Sachs lesion is not present.

Glenohumeral Arthritis
The treatment of chondral defects in the shoulder is not well
established. Kircher et al. reported the results for seven pa-
tients who were managed with autologous osteochondral
transplantation for the treatment of a full-thickness chondral
defect of the shoulder. This group of patients had been pre-
viously evaluated after an average duration of follow-up of 32.6
months. In this update, the average duration of follow-up was
extended to 8.75 years. The mean Constant score improved
significantly until the time of the latest follow-up, despite
significant radiographic progression of osteoarthritis. Pro-
gressive osteoarthritis did not correlate with the original size of
the chondral defect or the Constant score at the time of the
latest follow-up. Magnetic resonance imaging scans demon-
strated a congruent joint surface at the site of the defect, with
incorporation of the osteochondral grafts. While the authors
demonstrated continued satisfactory results despite radi-
ographic progression of osteoarthritis, the question remains
whether this treatment truly affects the natural history of
chondral defects.

Osteonecrosis
Osteonecrosis of the humeral head is a disabling condition that
can lead to joint destruction, pain, and functional limitations.
When structural collapse of the humeral head occurs, re-
placement is often the only treatment available. The results of
cementless humeral surface replacement for the treatment of
osteonecrosis were reviewed by Raiss et al. in a study of
seventeen patients with symptomatic posttraumatic (nine pa-
tients) or atraumatic (eight patients) osteonecrosis. The area of
the avascular lesion averaged 18.6% of the humeral head. After
a mean duration of follow-up of three years, the range of
motion and the postoperative Constant score were signifi-
cantly improved. No implants demonstrated loosening, and no
revisions were required. The results were superior in the
atraumatic group in comparison with the posttraumatic group.

Outcomes of Shoulder Arthroplasty
Modern prosthetic designs for replacement of the proximal
part of the humerus provide the ability to restore anatomy
through variable geometry. Pearl et al. evaluated five fictitious
prosthetic scenarios in order to determine how much prost-
thetic geometry is needed in order to achieve a minimum
standard of anatomic reconstruction. A computer model was
used to analyze the ability to anatomically reconstruct the
center of rotation and articular arc by changing the inclination
angle, head height, radius of curvature, and offset. In the
model, increasing complexity of humeral designs was com-
pared with a known proximal humeral database. Acceptable
anatomic restoration was achieved in association with the
following variable design parameters: two inclination angles,
three head heights with four radii of curvature (twelve head
sizes), and two offset positions.

The role of humeral head offset in terms of the stability
of the glenoid component following total shoulder arthro-
plasty is poorly understood. Nuttall et al. evaluated the im-
pact of twelve non-offset and ten offset humeral head
components on glenoid component micromovement with use
of stereoradiometric techniques over a two-year period. The
authors found that non-offset heads increased glenoid mi-
cromotion in all three scapular planes in comparison with
offset heads. This study suggests that nonanatomic re-
construction of the center of rotation may have an adverse
effect on glenoid fixation.

As glenoid component longevity is a concern following
total shoulder arthroplasty, particularly in young patients,
other methods of glenoid resurfacing have been explored. Soft-
tissue resurfacing of the glenoid, with arthroplasty of the
humeral head, has been proposed as a viable treatment option
for younger patients with symptomatic osteoarthritis of the
shoulder. Elhassan et al. reported on thirteen patients under
the age of forty years (average age, thirty-four years) who
underwent either humeral head resurfacing or hemi-
arthroplasty combined with biologic resurfacing of the glen-
oid. The glenoid was resurfaced with an Achilles tendon
allograft in eleven patients, fascia lata in one, and anterior
capsule in one. The results were poor in the majority of pa-
tients, with ten of the thirteen having a conversion to total
shoulder arthroplasty at an average of fourteen months. Two
patients had development of an infection, and only one patient
had improved function and range of motion with no pain. At
the time of revision surgery, the allograft was found to be
absent from the glenoid surface, and thick scar tissue, which
may have been a graft remnant, was found at the perimeter of
the glenoid. On the basis of these results, the authors
recommended against the use of biologic resurfacing of the glenoid.

Total shoulder arthroplasty in patients with Parkinson disease presents substantial challenges. However, very little information exists about the outcome of total shoulder arthroplasty in this patient population. Kryzak and colleagues investigated the overall results, risk factors for an unsatisfactory outcome, and rates of failure following total shoulder arthroplasty in patients with Parkinson disease. Forty-three patients were followed for an average of eight years and were found to have significant improvement in terms of pain, abduction, and external rotation. However, eight of forty-three patients underwent revision during the study period and, overall, 47% of the patients were found to have an unsatisfactory result, including a higher prevalence of early instability in comparison with that following total shoulder arthroplasty in patients with primary osteoarthritis.

Implant retrieval during revision of a failed shoulder arthroplasty can provide critical information about implant performance. However, few studies have evaluated the results of implant retrieval in the shoulder. Nho and colleagues analyzed seventy-eight glenoid components that were retrieved at the time of revision surgery with regard to nine modes of damage. Scratching, pitting, and burnishing were the most common types of polyethylene wear, with most wear occurring in the inferior quadrant of the glenoid component. Shoulder radiographs that were made before retrieval were found to underestimate the presence of glenoid loosening.

Complications of Shoulder Arthroplasty
The number of total shoulder arthroplasties has steadily increased as the population ages. As the number of shoulder arthroplasties has increased, so have the number and types of complications. Several reports have highlighted the complications of shoulder arthroplasty. Cil et al. reviewed a cohort of patients who had undergone revision shoulder replacement for the treatment of aseptic loosening of the humeral component. The mean duration of follow-up was seven years. Pain was significantly reduced following revision surgery, and functional gains were modest but significant. While the primary goal of surgery was to address a loose humeral stem, only two glenoid components were left unrevised. Thirty-five patients had undergone thirty-eight procedures, with a 71% rate of good or excellent results according to the modified Neer rating system. Intraoperative fracture occurred in six cases (16%), and reoperation for the treatment of stem loosening was performed for four patients. On the basis of these results, the ten-year survival rate for stems that were revised because of aseptic loosening was 89%.

Intraoperative periprosthetic fractures of the humerus during shoulder replacement are an uncommon complication. Athwal et al. reported on their institutional experience with forty-five intraoperative humeral fractures that occurred over a twenty-two-year period. Thirty-one fractures occurred during primary shoulder arthroplasty, and fourteen occurred during revision arthroplasty. Four fractures displaced postoperatively and were then treated nonoperatively; all four healed. Significant relative risks for intraoperative fracture were female sex, revision surgery, and press-fit implants.

Infection is one of the most devastating complications following shoulder replacement. Treatment typically involves a two-stage reimplantation. However, there is little information guiding this approach. Strickland and colleagues examined the outcomes for patients who had been managed with a two-stage reimplantation for the treatment of a deep infection. After a mean duration of follow-up of thirty-five months, there were two excellent, four satisfactory, and thirteen unsatisfactory results. In twelve (63%) of the nineteen shoulders, the infection was considered to be eradicated. There were fourteen complications. This study suggests that two-stage reimplantation for the treatment of infection at the site of a shoulder replacement is associated with a high rate of unsatisfactory results, marginal success in terms of eradicating infection, and a high complication rate.

Reverse Total Shoulder Arthroplasty
Patients with proximal humeral bone loss following failed shoulder arthroplasty have limited treatment options. Reverse shoulder arthroplasty provides a salvage option for this difficult clinical challenge. Chacon et al. reported the outcomes for patients with extensive proximal humeral bone loss who underwent revision to a reverse shoulder replacement. Twenty-five patients underwent revision with a proximal humeral allograft-prosthesis composite. At the time of the five-year follow-up, the ASES and SST scores had improved significantly. Significant improvements in forward flexion (from 32.7° to 82.4°) and abduction (from 40.4° to 81.4°) also occurred. Nineteen patients (76%) reported a good or excellent subjective result, five reported a satisfactory result, and one reported an unsatisfactory result. Radiographic signs of allograft incorporation were present at the metaphysis in twenty-one patients (84%) and the diaphysis in nineteen patients (76%).

Posterior rotator cuff deficiency can limit the ability to regain external rotation with reverse shoulder replacement. Some surgeons have advocated latissimus dorsi transfer in association with reverse total shoulder arthroplasty for the treatment of this problem. Favre et al. performed a biomechanical study and established that the best site for attachment of the latissimus transfer in order to produce the strongest external rotation moment is on the posterior aspect of the greater tuberosity, adjacent to the teres minor insertion.

Scapular notching is a unique complication of reverse total shoulder arthroplasty. Lévigne et al. performed a review of 326 consecutive patients (337 shoulders) undergoing primary (269 shoulders) or revision (sixty-eight shoulders) reverse shoulder arthroplasty. Scapular notching correlated with length of follow-up, being observed in 62% of the shoulders after an average duration of follow-up of forty-seven...
months. Factors that were significantly associated with an increased prevalence of notching included cuff tear arthropathy, grade-3 (or greater) fatty infiltration of the infraspinatus, preoperative superior tilt of the native glenoid, an anterosuperior surgical approach, and superior placement of the glenosphere base plate.

Fractures
Proximal Humeral Fractures
Fractures of the lesser tuberosity are rare injuries, and operative treatment is generally recommended for displaced fractures. However, the outcome of operative treatment of this injury is not well established. Robinson et al.\textsuperscript{50} reviewed the results for twenty-two patients with isolated lesser tuberosity fractures. Seventeen patients who were medically fit for surgery and had a displaced fracture were managed with open reduction and internal fixation, whereas five patients were managed nonoperatively. At the time of the two-year follow-up, excellent restoration of shoulder function was observed in operatively managed patients on the basis of the Constant, DASH, and SF-36 outcome measures, with all patients returning to their previous employment.

The most appropriate approach for the surgical treatment of displaced proximal humeral fractures remains unclear. Bastian and Hertel\textsuperscript{51} compared osteosynthesis with hemiarthroplasty for the treatment of proximal humeral fractures. The results for seventy-six of the ninety-eight patients who were enrolled in the study were reported after a mean duration of follow-up of five years. The median Constant-Murley score and Subjective Shoulder Value (SSV) were similar between the two groups. Osteonecrosis was noted in six of the forty patients who were managed with osteosynthesis. The authors concluded that osteosynthesis with preservation of the humeral head is worth considering when a stable anatomic reduction can be obtained. Poor bone quality and comminution are indications for hemiarthroplasty. Südkamp and colleagues\textsuperscript{52} reported the functional outcomes and the rate of complications in a multicenter study involving locking plate fixation of proximal humeral fractures. One hundred and eighty-seven patients with a mean age of 62.9 years were enrolled. The average range of motion and the mean Constant score for the injured shoulders improved between three and twelve months after surgery. Twelve months after surgery, the mean Constant score was 70.6 points (85.1\% of the score for the unaffected side) and the mean DASH score was 15.2 points. Sixty-two complications were encountered in fifty-two (34\%) of the 155 patients who were available at the time of the one-year follow-up. Twenty-five complications (40\%) were related to incorrect surgical technique and were noted at the end of the operative procedure. The most common complication, noted in twenty-one patients (14\%), was intraoperative screw perforation of the humeral head. Twenty-nine patients (19\%) had an unplanned second operation within twelve months after the fracture. This study highlights the importance of using proper surgical technique when performing this operation.

One of the most critical elements in the fixation of proximal humeral fractures is bone quality. Percutaneous pin fixation traditionally has been reserved for younger patients with good bone quality. Bogner and colleagues\textsuperscript{53} reported the results of percutaneous pin fixation of displaced three and four-part fractures with use of the Humerusblock technique (Synthes, Oberdorf, Switzerland) in patients more than seventy years of age. This technique utilizes a metal block fixed to the humerus through which crossed Kirschner wires are placed and are locked to the block, thereby increasing the rigidity of fixation. Fracture displacement or pin migration occurred in five patients (10\%), osteonecrosis occurred in four patients (8\%), and deep infection occurred in one patient (2\%). After an average duration of follow-up of 33.8 months, the mean Constant-Murley score was 61.2 points (range, 35 to 87 points) for patients with three-part fractures and 49.5 points (range, 18 to 87 points) for patients with four-part fractures. The authors concluded that percutaneous fixation with a Humerusblock is a satisfactory alternative to replacement and traditional techniques of internal fixation.

When hemiarthroplasty is performed for the treatment of displaced proximal humeral fractures, reestablishing humeral length is critical for a satisfactory result. Normal anatomic landmarks that are used to establish humeral height are often disrupted by the fracture. The pectoralis major insertion has been proposed to be a reliable landmark to guide the reproduction of humeral length in this setting. Greiner et al.\textsuperscript{54} reviewed twenty-one patients (Group 1) who had replacement with use of the pectoralis major as a reference for humeral length and nine patients (Group 2) for which it was not used. Group 1 showed significantly better clinical and radiographic results in comparison with Group 2. Clinical outcome depended significantly on greater tuberosity healing and centering of the prosthetic head in the glenoid.

Clavicular Fractures
Historically, the treatment of clavicular fractures has predominantly been nonoperative. The use of a sling or figure-of-eight immobilization and therapeutic ultrasound has been presented in the literature. However, the effects of these different methods for the nonoperative treatment of acute middle-third fractures have not been clearly established. Lenza and colleagues\textsuperscript{55} searched several databases for randomized and quasi-randomized controlled trials evaluating the nonoperative treatment of acute middle-third clavicular fractures. The primary outcomes that were evaluated were pain, shoulder function, health-related quality of life, and time to return to previous activities. Three trials were included in the review. Two trials compared the figure-of-eight bandage with an arm sling. However, those trials were underpowered and were compromised by poor methodology. The third trial, which evaluated therapeutic ultrasound, was also underpowered but...
had a low risk of bias. The trial found no significant difference between low-intensity pulsed ultrasound and placebo in terms of the time to clinical fracture-healing or in terms of any of the other reported outcomes. The authors concluded that there is insufficient evidence from randomized controlled trials to determine which methods of conservative treatment are the most appropriate for acute middle-third clavicular fractures in adolescents and adults.

Plate fixation of clavicular fractures has been shown to provide superior results for selected fracture patterns. However, the best location for the plate has not been established. Shen et al. performed a randomized study in which the outcomes for patients who were managed with a reconstruction plate that was placed superiorly were compared with those for patients who were managed with a plate that was three-dimensionally contoured to the clavicle. Additionally, computed tomography scans in the sagittal plane were used to determine the location of the area of the densest cortical bone. Sixty-six displaced midshaft clavicular fractures were fixed with a plate that was applied superiorly, and sixty-seven fractures were treated with a three-dimensionally contoured plate. The clinical and radiographic results were evaluated four and twelve months following surgery. The superior plate group had a significantly higher rate of delayed union and symptomatic patients than did the three-dimensionally contoured plate group. Computed tomography scan comparisons of bone density showed that the cortical bone is thickest superiorly in the distal segment and anteriorly in the middle part of the shaft of the clavicle. The authors concluded that a three-dimensional reconstruction plate approximates the stress distribution and shape of the clavicle, accounting for the better results in these patients.

Smekal et al. performed a randomized, controlled clinical study in which elastic stable intramedullary nail fixation was compared with nonoperative treatment for displaced midshaft clavicular fractures. Sixty adult patients between the ages of eighteen and sixty-five years were randomized to either operative treatment with an elastic stable intramedullary nail or nonoperative treatment with sling immobilization. Fracture union was achieved in all thirty patients in the operative treatment group, whereas nonunion was observed in three of the thirty patients in the nonoperative treatment group. Also, two symptomatic malunions required corrective osteotomy in the nonoperative treatment group. Medial nail protrusion occurred in seven patients in the operative treatment group. Implant failure requiring revision surgery occurred in two patients as the result of additional trauma. The DASH and Constant scores were better in the operative treatment group throughout the first six months and at two years after the injury. Patients in the operative treatment group showed a significant improvement in terms of posttraumatic clavicular shortening and were also more satisfied with the cosmetic appearance and the overall outcome.

Nonoperative methods remain the mainstay of treatment for lateral epicondylitis; however, little quality research exists regarding the effectiveness of different nonoperative approaches. Reza Nourbakhsh and Fearon performed a randomized, double-blinded, placebo-controlled study to investigate the effect of noxious-level electrical stimulation on pain, grip strength, and functional abilities in subjects with chronic lateral epicondylitis. Eighteen subjects with chronic lateral epicondylitis were randomly assigned to the treatment group or the placebo group. Subjects received six sessions of low-frequency electrical stimulation over the palpated tender points. The intensity of electrical stimulation was set at 0 in the placebo group. Grip strength, functional status, pain intensity, and limited activity due to pain were assessed before and after treatment. Clinically important and statistically significant differences in favor of electrical stimulation were found between the treatment and placebo groups in terms of average grip strength, functional activity, pain intensity, and activity limitation due to pain. Follow-up data showed that 100% of the subjects maintained the improved function, and 83% remained pain-free for at least six months following the treatment. The results of this study indicated that symptoms of chronic lateral epicondylitis can be relieved in the short term with use of noxious-level low-frequency electrical stimulation. However, as the six-month follow-up data were collected for the treatment group only, there is no way to know if these improvements would be maintained over time.

The use of extracorporeal shock wave therapy has also been proposed for the treatment of lateral epicondylitis. Staples et al. performed a double-blinded, randomized, placebo-controlled trial to determine whether ultrasound-guided extracorporeal shock wave therapy reduced pain and improved function in patients with lateral epicondylitis. Sixty-eight patients were randomized to receive three extracorporeal shock wave therapy treatments or three treatments with a subtherapeutic dose given at weekly intervals. Outcome measures relating to pain and function were collected at six weeks, three months, and six months after the completion of the treatment. There were significant improvements in terms of almost all outcome measures for both groups over the six-month follow-up period, but there were no differences between the groups even after adjusting for the duration of symptoms. The authors concluded that there was little evidence to support the use of extracorporeal shock wave therapy for the treatment of lateral epicondylitis. These findings support the findings of recent systematic reviews of extracorporeal shock wave therapy for the treatment of lateral epicondylitis that have led to similar conclusions.

Lindenhovius and colleagues performed a randomized study in which dexamethasone with lidocaine was compared
arthroplasty may be favored over open reduction and internal fixation for these patients. Jost and colleagues reported their experience with the operative treatment of distal humeral fractures in patients with rheumatoid arthritis. Sixteen patients were followed for at least twenty-four months after either total elbow replacement (ten patients) or osteosynthesis (six patients). Mayo Elbow Performance Scores were similar in both groups. Radiographically, all fractures that underwent osteosynthesis healed and no total elbow implant was loose at the time of the latest follow-up. The authors suggested that open reduction and internal fixation can be successful when there is mild arthritic involvement. However, with severe articular involvement, total elbow arthroplasty is preferred.

Radial Head
Several radial head implant systems are designed with a smooth stem that “floats” within the medullary canal. Radiolucent lines have been noticed around these stems at the time of follow-up; however, the importance of these radiolucent lines has not been clearly established. Fehringer and colleagues, in a retrospective study, attempted to correlate radiolucent lines around radial head implants with forearm pain and function. Radiographic and clinical evaluations were performed for eighteen patients after a minimum of two years of follow-up. While the operatively treated side had a significant reduction in terms of range of motion in comparison with the uninjured side, no correlation between radiolucency around the implant stem and pain or function was demonstrated. The authors concluded that radiolucent lines around a smooth-stem radial head implant do not correlate with pain or functional limitation.

Complex Instability
Terrible triad injuries involve fractures of the coronoid process and radial head associated with dislocation of the elbow. The need to fix some or all of the elements of this injury pattern has not been well established. Fern et al. performed a biomechanical study to evaluate the effect of coronoid deficiency on varus stability in a terrible triad injury pattern. Ten cadaver elbows were used to create lateral collateral ligament injuries and radial head resections. The elbows were tested with the lateral collateral complex deficient or repaired and the radial head resected or replaced for various levels of coronoid fracture. Beyond 50% coronoid deficiency, radial head replacement and lateral collateral ligament repair alone did not restore elbow stability. These results demonstrate the need to address all elements of this injury pattern, including the coronoid fracture, when the coronoid fracture exceeds 50%.

Posteromedial rotatory instability is a relatively recently described clinical entity defined as a fracture of the anteromedial facet of the coronoid process and tensile failure of the lateral collateral ligament complex. It is not clear which coronoid injuries require internal fixation and whether repair of the lateral collateral ligament alone is sufficient. Pollock et al.
examined the effect of coronoid fragment size and lateral collateral ligament repair on elbow kinematics and stability in a cadaver model. Elbow kinematics and stability in the presence of varying coronoid fracture patterns (types I, II, and III) were assessed in the setting of lateral collateral ligament-deficient and repaired states. Type-I coronoid fractures demonstrated normal kinematics when tested with a repaired lateral collateral ligament. Conversely, some type-II and all type-III coronoid fractures demonstrated altered kinematics and varus and internal rotation instability, even with lateral collateral ligament repair. The authors concluded that the size and location of the anteromedial facet coronoid fracture may impact elbow stability and kinematics and therefore may warrant open reduction and internal fixation along with lateral collateral ligament repair.

**Distal Biceps Tendon**

A variety of surgical techniques to repair ruptures of the distal biceps tendon have been described. To date, few data exist regarding the clinical results and restoration of strength following surgical repair of the distal biceps tendon. The results of distal biceps repair with use of an EndoButton technique (Smith and Nephew, Memphis, Tennessee) were reviewed by Peeters et al. After an average duration of follow-up of sixteen months, twenty-three patients were evaluated clinically and radiographically and with isokinetic testing. The average postoperative MEPS was 94 points. The average recovery of flexion strength was 80%, and the average recovery of supination strength was 91%. Two patients developed asymptomatic heterotopic ossification. The EndoButton disengaged from the radius in three patients. The authors demonstrated that the EndoButton technique resulted in good or excellent results according to the MEPS. However, supination and flexion strength were not restored to normal with this technique.

**Collateral Ligament Injuries**

Symptomatic medial collateral ligament insufficiency of the elbow in high-performance athletes is best treated with reconstruction of the medial collateral ligament. In contrast, acute avulsion injuries of the ligament from its humeral origin with an associated disruption of the flexor-pronator muscle mass perhaps should be treated acutely with surgical repair. Richard and colleagues reviewed the outcomes for eleven athletes with an acute traumatic avulsion of the medial collateral ligament and overlying flexor-pronator mass who were managed with direct repair. After a minimum of sixteen months of follow-up, ten of the eleven patients obtained a full range of motion without valgus instability, and nine of the eleven returned to athletics. The authors concluded that acute injury resulting in this unique combination of pathologies can be treated with direct repair of the medial collateral ligament and flexor-pronator mass, facilitating a return to athletics.

**Interposition Arthroplasty**

Interposition arthroplasty is often considered to be a salvage procedure for the treatment of severe elbow arthritis when conservative treatment has failed and total joint replacement is contraindicated. Larson and Morrey reviewed their experience with interposition arthroplasty with use of an Achilles tendon allograft for the treatment of inflammatory or posttraumatic arthritis. Forty-five patients met the inclusion criteria. Seven patients (16%) required revision surgery and were excluded from the analysis. The remaining thirty-eight patients were followed for a mean of six years. The mean arc of motion improved significantly (from 51° to 97°) at the time of the six-year follow-up, as did the MEPS. However, only thirteen elbows were rated as good to excellent whereas twenty-five elbows were rated as fair to poor. Preoperative instability was associated with a significantly lower MEPS. Additionally, four of five patients who required reconstruction of both collateral ligaments in association with the interposition arthroplasty experienced a net decrease in the MEPS. On the basis of their results, the authors concluded that interposition arthroplasty should be considered to be a salvage procedure as pain and dysfunction often persist in the elbow.

**Total Elbow Arthroplasty**

The indications for total elbow arthroplasty continue to evolve. One of the most challenging populations is young patients with destruction of the elbow for whom there are no surgical alternatives other than total elbow arthroplasty. It is generally accepted that prosthetic replacement should be avoided in young patients because of an anticipated high rate of early failure. Celli and Morrey reported their experience with interposition arthroplasty with use of an Achilles tendon allograft for the treatment of inflammatory or posttraumatic arthritis. Forty-five patients met the inclusion criteria. Seven patients (16%) required revision surgery and were excluded from the analysis. The remaining thirty-eight patients were followed for a mean of six years. On the basis of the MEPS, 93% of the patients had a good or excellent outcome. Twelve elbows (22%) had a subsequent surgical procedure: four because of implant loosening, three because of triceps weakness, three because of wear, and two because of deep infection. Revision rates were significantly higher for patients with posttraumatic arthritis, suggesting that this group of patients has a higher risk of complications in comparison with patients who have inflammatory arthritis. (Level IV)

A growing number of elbow replacements are being performed for the treatment of posttraumatic conditions involving the elbow. One such condition is nonunion of the distal part of the humerus. Cil et al. reported on a cohort of ninety-one patients who underwent ninety-two semiconstrained total elbow arthroplasty procedures for the treatment of a distal humeral nonunion. Follow-up was performed
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at an average of 6.5 years. On the basis of the MEPS, seventy-seven patients (85%) were rated as better or much better but 22% demonstrated a fair or poor outcome. The rate of prosthetic survival without removal or revision for any reason was 96% at two years, 82% at five years, and 65% at both ten and fifteen years. Overall, twenty-three implants (25%) were revised or removed. Factors that increased the risk of implant failure were an age of less than sixty-five years, two or more previous surgical procedures, and a history of infection.

Total elbow arthroplasty for the treatment of ankylosis is an extremely challenging clinical situation. Peden and Morrey2 reported their experience, over a twenty-two-year period, with thirteen patients with spontaneously ankylosed elbows who were managed with a linked semi-constrained total elbow arthroplasty. The average age of the patients was fifty-four years. After an average duration of follow-up of twelve years, a mean flexion arc of 37° to 118° was observed and seven of thirteen patients had a good to excellent result according to the MEPS. However, a high complication rate was observed, and more than half of the patients required revision surgery.

Linked and unlinked total elbow arthroplasty have been used to treat a variety of pathologic conditions. Levy et al.72 evaluated the implications of linked and unlinked designs on survivorship after revision surgery. Over an eighteen-year period, 352 linked and 151 unlinked prostheses were implanted. Overall, 122 elbows (24%) required revision, including fifty-five (16%) of those with a linked prosthesis and sixty-seven (44%) of those with an unlinked prosthesis. Survivorship following the initial and revision total elbow replacement was calculated with use of Kaplan-Meier analysis. Comparisons were made between revisions that were performed after the failure of primary linked or unlinked designs. Revision of an unlinked device to a linked device was almost twice as reliable as revision of an unlinked device to another unlinked device.

Complications

Ulnar neuropathy is a recognized complication following total elbow arthroplasty in 5% to 10% of patients. However, little information is available on the surgical treatment of persistent ulnar neuropathy after elbow replacement. Rispoli and colleagues73 described their experience with the surgical treatment of this problem. They reviewed their experience with 1607 patients undergoing total elbow arthroplasty, and they identified eight patients with ulnar neuropathy who were managed with operative neurolisis. After a mean duration of follow-up of 9.2 years, six of the eight patients had improvement but only four had complete recovery.

Shoulder and Elbow Fellowships

Fellowships in shoulder and elbow surgery continue to gain in popularity. There are currently twenty-two shoulder and elbow fellowships available to interested applicants. A formalized match process has been conducted successfully for the past several years. The match process allows the fellowship applicants to interview at a number of programs without being pressured to make a choice before completing the interview process. For further information about shoulder and elbow fellowships, candidates should visit www.ases-assn.org.

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