Review Article

The Weight-Bearing Shoulder

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Abstract

The shoulder achieves a wide spectrum of motion, and in a subset of patients, including those who use manual wheelchairs and upper extremity walking aids, the shoulder also serves as the primary weight-bearing joint. Because the weight-bearing shoulder is subject to considerable joint reaction forces and overuse, a broad spectrum of pathology can affect the joint. The combination of muscle imbalance and repetitive trauma presents most commonly as subacromial impingement syndrome but can progress to other pathology. Patients with high-level spinal cord injury, leading to quadriplegia and motor deficits, have an increased incidence of shoulder pain. Understanding the needs of patients who use manual wheelchairs or walking aids can help the physician to better comprehend the pathology of and better manage the weight-bearing shoulder.

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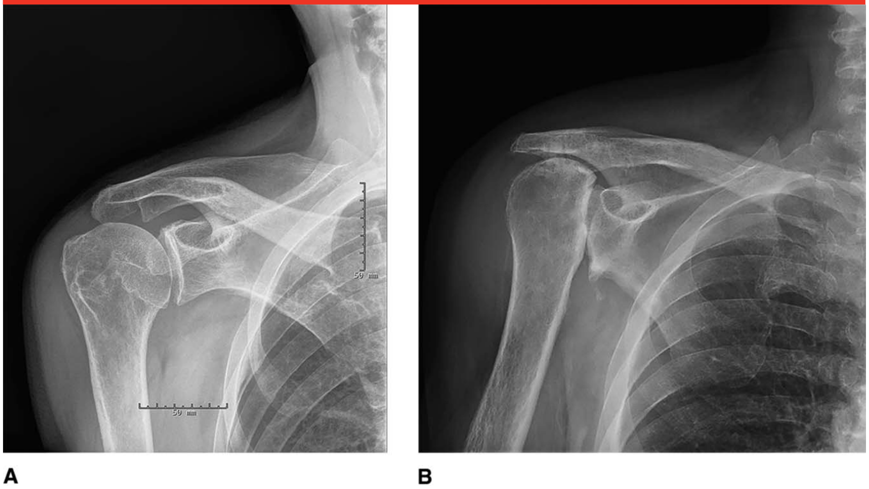
The shoulder is the most mobile joint in the human body. The widespread motion afforded by the interaction of the acromioclavicular (AC) joint, the glenohumeral (GH) joint, and the scapulothoracic joint is counterbalanced by stability, to allow lifting, pushing, and pulling. The patient who uses the upper extremity joints as the primary weight-bearing joints of the body creates a dynamic relationship between mobility and stability, which can lead to a specific subset of pathology. The most commonly affected people include manual wheelchair users (MWUs) and orthotic-assisted ambulators.

In the United States, approximately 12,000 people sustain a spinal cord injury (SCI) each year, and of the approximately 260,000 spinal cord–injured persons who reside in the United States, many use a wheelchair.[1] Robinson et al[2] estimated that the total number of MWUs in the United States in 1993 was 700,000. A 2002 US Census Bureau report indicated that that number had increased to 2.8 million people.[3] In a 2000 report on mobility device use in the United States, Kaye et al[4] noted that an additional 6.1 million people use mobility devices other than MWUs, such as canes, crutches, and walkers. People with other conditions, including lower extremity amputations, multiple sclerosis, polio, severe arthritis, and neurocognitive pathologies, can progress to dependency on the upper extremities as weight-bearing limbs. The increasing use of manual wheelchairs and mobility devices highlights the importance of recognizing shoulder pain in this group. The prevalence of shoulder pain in MWUs ranges between 30% and 73% (compared with a range between 15.4% and 24.9% of able-bodied people), and the shoulder is the most common site of upper extremity pain.[5-9] Bayley et al[5] found that the mean onset of shoulder pain was 13 years after SCI in a study of MWUs, indicating a gradual onset of pathology from

Figure 1



A, AP radiograph (Grashey view) of the right shoulder of a 78-year-old man. **B**, AP radiograph (Grashey view) of the same shoulder obtained 5 years later, demonstrating a high-riding humeral head and loss of humeral head contour consistent with rotator cuff arthropathy and osteonecrosis, respectively. After the first radiograph was obtained, the patient began full-time use of upper extremity orthotic walking aids.

increased joint reaction forces and overuse microtrauma.

The combination of muscle imbalances and repetitive trauma presents most commonly as subacromial impingement syndrome and can progress to rotator cuff tear, biceps tendinopathy, AC arthrosis, GH arthritis, and osteonecrosis of the humeral head[5,10-12] (Figure 1). Akbar et al[13] found that 63% of long-term MWUs will have a rotator cuff tear, compared with 15% of a matched able-bodied group.

Regardless of the extent of disease present, a symptomatic shoulder in a patient who relies on the limb for weight bearing and propulsion poses a challenge to the treating orthopaedic surgeon. Nonsurgical management can avoid the debilitating effect that surgery and recovery can have on MWUs or persons who require long-term use of walking aids. For example, rotator cuff repair may require sling immobilization and extended postoperative dependence, including a reduced ability to self-transfer and mobilize.[14] Prolonged immobilization can lead to a dramatic decline in functional capacity.[5] At the same time, aggressive surgical treatment may be necessary to prevent further deterioration of the joint and to maintain the ability to perform activities of daily living (ADLs) over the long term. In a patient with a weight-bearing shoulder, the goal is painless function and motion with preservation of the native joint. Joint preservation becomes increasingly important because arthroplasty options may be limited, and recovery from such surgery may be extensive.

Anatomy

Moseley and Goldie[15] proposed that the anterior humeral circumflex, suprascapular, and subscapular arteries are the main contributors to the blood supply of the rotator cuff. Chansky and Iannotti[16] described the anterior humeral circumflex artery and the suprascapular artery as the suppliers of the anterior portion of the rotator cuff, and the posterior humeral circumflex artery as the supplier of the posterior portion of the rotator cuff. Most discrepancies center around the vascularity in the critical impingement zone. Neer[17] first described the concept of subacromial impingement, in which pain is generated in the subacromial space on elevation or internal rotation of the humerus. Impingement occurs on the tendinous portion of the rotator cuff when it is compressed by the coracoacromial (CA) ligament or the anterior third of the acromion, and impingement is exacerbated with abduction to 80°. The area most susceptible to impingement injury is a relatively avascular region of the supraspinatus tendon lying 1 cm proximal to its insertion.[18] When the arm is held in a functional position, this region has limited perfusion, which is further compromised during shoulder internal rotation and axial loading by the humerus. During wheelchair use, the shoulder often is rotated internally and abducted. In addition, transfers and weight-relief maneuvers axially load the shoulder joint still further, leading to repetitive trauma. Lastly, during upper extremity weight bearing, superior migration of the humeral head and narrowing of the subacromial space occur.[1,11]

Biomechanics of the Weight-Bearing Shoulder: Demands and Kinematics

The spectrum of pathology appreciated in a weight-bearing shoulder joint is the result of the unique demands associated with wheelchair use, transfers, and weight-relief maneuvers. Specific muscle groups are activated during each phase of wheelchair propulsion, and the shoulder joint sustains repetitive and continuous load during the push phase of propulsion, which can predispose MWUs to pathology of the upper extremity.

Manual Wheelchair Use

Forces During Manual Wheelchair Use

Manual wheelchair use can be classified into two phases: propulsion and arm repositioning with power absorption. The push phase consists of 25% to 35% of the propulsion cycle, and the remainder of the cycle occurs during the recovery or repositioning phase.[19] The shoulder joint is subject to a repetitive and continuous load during the push phase of the wheelchair propulsion cycle, predisposing MWUs to upper extremity pathologies.[5] Higher-intensity wheelchair propulsion increases superior shoulder joint forces, which can result in superior translation of the humeral head and the subsequent compression of the subacromial structures against the overlying acromion.[20] Shoulder joint reaction forces during wheelchair propulsion have been shown to increase from 54.4 N ± 13.5 N during slower speeds to 75.7 N ± 20.7 N at higher speeds.[21] Peak shoulder joint loading was found to occur when the arm was extended and internally rotated. During free propulsion, peak shoulder joint forces work mainly in the posterior and superior directions, producing a peak resultant force of 51 N.[20] During fast and inclined propulsion, peak vertical force increases by >360%, and the posterior force increases as much as 167%. In one study of 33 MWUs, those who experienced higher posterior forces, lateral forces (abduction moments), or extension moments during propulsion were more likely to exhibit CA ligament edema.[12] Physical examination revealed that higher superior forces and internal rotation moments were associated with increased signs of shoulder pathology.

Kinematics During Manual Wheelchair Use

Kinematic and electromyography data have delineated the activation of specific muscle groups for each phase of wheelchair propulsion.[22] The middle deltoid, acting as a shoulder flexor, is the primary contributor to total mechanical power during the initial third of the push phase. Thereafter, the pectoralis major, anterior deltoid, and infraspinatus muscles generate most of the total mechanical power. At the end of the push phase, the middle deltoid, subscapularis, and latissimus dorsi muscles act to absorb the arm's power. Of all the muscles involved, the infraspinatus muscle contributes more to hand-rim propulsion power than any other muscle during the push phase of wheelchair propulsion. However, as a rotator cuff muscle, the infraspinatus is also responsible for GH joint stabilization. Because of its dual roles in generation of hand-rim power and joint stabilization, the infraspinatus muscle may be more susceptible to fatigue than other rotator cuff muscles.

Muscle Imbalances

In a case-controlled clinical and isokinetic analysis of 19 paraplegic and 20 able-bodied male athletes, Burnham et al[10] found that the shoulders of wheelchair athletes were considerably stronger in all directions compared with the shoulders of younger, able-bodied, moderately fit, male athletes. The paraplegic athletes were stronger in abduction, adduction, external rotation, and internal rotation by 62%, 23%, 61%, and 57%, respectively, compared with able-bodied male athletes. The ratio of abduction to adduction strength was considerably higher in the paraplegic cohort, indicating a relative weakness in shoulder adductors in this population. The relative increased strength of the abductors, primarily the deltoid muscle, theoretically creates a pull on the humeral head in a cephalad direction. The authors of the study proposed that the migration of the humeral head can lead to a narrowing of the acromiohumeral head distance unless the migration is balanced by the shoulder adductors, the rotator cuff muscles, and the larger latissimus dorsi and teres major muscles. In the same study, the shoulder strength of wheelchair athletes with rotator cuff impingement was compared with that of wheelchair athletes without impingement. The authors reported that the shoulders with rotator cuff impingement syndrome were weaker in adduction and external and internal rotation than those without the syndrome.

The authors of a prospective cohort study examined the baseline shoulder strength of paraplegic MWUs.[23] The MWUs were observed longitudinally over 3 years, and lower shoulder adduction torque was found to be a substantial predictor of the development of shoulder pain. Mulroy et al[24] performed a randomized trial using a home-based program focused on increasing the strength of the shoulder external rotators and found that improving external rotation strength was the strongest factor for reducing shoulder pain in wheelchair users. Based on these data, the authors proposed that inadequate adductor strength contributes to the development of the shoulder pathology but, after pain is present, strengthening of the external rotators is critical for pain reduction. In the higher-level SCI groups, an increased prevalence of rotator cuff disease, which correlates with greater muscle imbalances and reduced trunk control, has been reported.[25]

Transfers and Weight-Relief Maneuvers

Forces During Wheelchair Transfer

MWUs use the upper body to transfer in and out of the wheelchair. They also perform pressure-relief maneuvers to elevate and adjust the body and relieve excessive pressure on specific areas of the lower body. During wheelchair transfer or weight-relief maneuvers, the shoulder joint experiences increased stresses. Weight-relief maneuvers can generate approximately 44 Nm of force on the GH joint, which is two times greater than the propulsion forces required to ascend a ramp and three times greater than level wheelchair propulsion forces.[26,27] In able-bodied persons, unilateral net moments on the shoulder when moving from sitting to standing measure 16 Nm and lifting a suitcase generates 28 Nm.[28] A common method of transferring in and out of a wheelchair involves pivoting the body while in a seated position. During these seated pivot transfers, the shoulder is subjected to more posteriorly directed forces, whereas simple weight-relief maneuvers subject the shoulder to more superiorly directed forces.[29]

Kinematics During Wheelchair Transfer

Large muscle groups help to stabilize the trunk and shoulders during wheelchair transfers and weight-relief maneuvers. During these movements, the most active muscle is the triceps, which allows elbow extension push-off to elevate the body off the chair.[30] However, the latissimus dorsi and pectoralis major muscles are also active during these actions.[31] These muscle groups help to elevate the upper body and stabilize the trunk during the maneuver, especially at low levels of shoulder flexion.

Scapular positioning may play an important role in GH impingement during manual wheelchair maneuvers. Nawoczenski et al[32] used electromyography and motion capture systems to detect increased anterior tipping and internal rotation of the scapula and decreased scapular upward rotation and external rotation of the humerus during the beginning of the hold phase of a weight-relief raise. The authors of the study suggested that these mechanics negatively affect the available subacromial space and place the patient at increased risk for injury or shoulder pain. Morrow et al[1] evaluated scapular kinematics in 12 asymptomatic MWUs over three maneuvers: level propulsion, ramp propulsion, and a weight-relief lift. At all tested maneuvers, the investigators found poor anatomic alignment as evidenced by an externally rotated GH joint and an anterior tilted and internally rotated scapula.

The position of the head relative to the hips also can alter the forces the GH joint undergoes during a wheelchair transfer. The head-hips transfer technique takes advantage of the voluntary movement available to the head and trunk to move the involuntary lower body.[33] To perform this technique, the MWU brings the head down toward the hips and pushes it to the opposite side of the transfer direction. By forcing the head down and to the opposite side, the user is able to push the lower body in the opposite direction toward the area of intended transfer. Changing the transferring pattern from a trunk upright style, in which the upper body is held erect by the trunk and arms, to the head-hips technique, considerably reduces the superior forces produced at the shoulder.[33]

Patient History and Physical Examination

A thorough patient history and physical examination should include a complete musculoskeletal examination to evaluate the location and severity of pain, joint range of motion (ROM), and muscle strength as well as a full neurologic examination, including an examination of the cervical spine. The latter examination should evaluate sensory function, reflexes, and provocative maneuvers, using the Tinel sign or Phalen maneuver if carpal tunnel syndrome is suspected or the Adson test if thoracic outlet syndrome is suspected. For patients with SCI, a complete assessment includes an evaluation of the effects of the injury on overall function, ADLs, and activity levels. On gross inspection, periscapular and shoulder muscle atrophy may be present in 30% to 50% of wheelchair users with shoulder pain.[34] One overlooked cause of atrophy in these patients may be suprascapular nerve impingement as a result of the repetitive nature of the injury.[35] When the clinician evaluates for signs of impingement, approximately one third of wheelchair athletes will have positive supraspinatus and Hawkins tests.[36] Documenting muscle imbalances is important in predicting the development and determining optimal management of shoulder impingement pain.

Imaging

A complete set of shoulder radiographs—including a standard AP view in external rotation, a Grashey view (AP oblique with internal rotation), an outlet or Neer view, and an axillary view—should be obtained to evaluate for the large spectrum of diseases possible in a weight-bearing shoulder. The presence of degenerative changes on shoulder radiographs in patients with weight-bearing shoulders has been reported to range from 32% to 72%, with a predilection toward the AC joint, followed by the GH joint.[37,38] This range compares with a prevalence of 16% in an able-bodied elderly Korean population, which is the only population-based and radiographic-based prevalence study on shoulder osteoarthritis.[39] Assessment of humeral head height and acromiohumeral distance may indicate impingement or loss of rotator cuff function. More accurate assessment of rotator cuff integrity typically requires advanced imaging, such as MRI, ultrasonography, or CT arthrography. Of these three modalities, MRI is the only reported modality used in investigating pathology specific to the weight-bearing-shoulder population of MWUs.[40]

An assessment of acute changes in the rotator cuff and surrounding soft tissues using ultrasonography after propulsion activity in MWUs demonstrated no substantial changes in kinetics; however, the purpose of this study was not the assessment of pathology in weight-bearing shoulders.[41] MRI-based studies have reported a high prevalence of three common findings: rotator cuff pathology, CA ligament thickening, and degeneration of the AC joint.[12,13] In a case series, Morrow et al[40] evaluated 10 MWUs with anterolateral shoulder pain using noncontrast 3-Tesla MRI. The average duration of manual wheelchair use was 14.5 ± 9.7 years, and the average patient age was 38 years. Of all participants, 50% had tears of the supraspinatus tendon at its insertion, whereas 60% had tears in at least one of the rotator cuff tendons. After the supraspinatus, the subscapularis was affected most frequently, followed by the infraspinatus. No bursal-sided tears were observed, and intrasubstance tears were more common than articular-sided tears. Three subscapularis tears occurred, and all 10 shoulders had subscapularis tendinopathy. The predominance of anterior rotator cuff tears was similar to that of an able-bodied population. Similarly, 9 of 10 shoulders had biceps tendinopathy, and 4 MWUs had tears in the proximal biceps. All participants had AC joint arthrosis, and 7 of 10 had CA ligament thickening. Three participants had labral irregularities and six had labral tears, predominantly posterior-based. The study is limited greatly by the sample size, but highlights the expected MRI findings in the weight-bearing shoulder population. Further assessment is required, using arthrography-based studies for labral and capsular analysis and correlation with clinical symptomology.

Nonsurgical Management

Initial management of MWUs should be nonsurgical. Increasing investigation into this subgroup of patients with shoulder pain shows that preventive measures should be used to help preserve the native shoulder.

Typical preliminary treatment modalities include NSAIDs, corticosteroid injections, physical therapy, and the avoidance of aggravating maneuvers. Weight-relieving transfers produce the highest shoulder forces in MWUs; intra-articular pressures are as high as 280 mm Hg.[5] However, it can be difficult to avoid this load-bearing and repetitive activity. In 1992, the US Department of Health and Human Services recommended executing weight-relieving movements every 15 minutes to prevent pressure ulcers.[27] Hydraulic lifts provide a way to avoid transfers at home but are not practical for mobile use. Instead, weight-relief shifts and body leans—as opposed to body lifts—may be beneficial. During a treatment period for MWUs, use of a motorized wheelchair for mobility may help avoid repetitive start, stop, and ramp movements.[2]

When patients present with multiple sources of shoulder pain, corticosteroid injections may be therapeutic and diagnostic for pain at the AC joint, bicipital sheath, subacromial space, and GH joint. The senior author (M.S.S.) prefers ultrasonography-guided injections for the biceps and GH joint. To prevent iatrogenic degeneration, repeat injections to the same area of the shoulder are limited to only one in a 6-month period (or longer), with the total number of injections limited to three within a 2-year span.

Kinematic studies have demonstrated changes in scapular motion and muscle imbalances in weight-bearing shoulder patients, compared with able-bodied patients. Burnham et al[10] advocate adductor strengthening with the arms below shoulder level for active treatment and prophylactic management in MWUs. A home-based program focused on increasing strength in the shoulder external rotators is a strong factor in reducing shoulder pain in MWUs.[29]

Additional prophylactic rehabilitation focuses on scapular kinetics. Increased anterior tilt, increased internal rotation, and decreased upward rotation of the scapula have been reported to reduce the subacromial space and play a role in impingement syndrome.[42] Scapular protraction leads to increased anterior tilt and internal rotation. Morrow et al[1] recommend preventive strength and endurance training of the periscapular muscles to help prevent muscle fatigue as well as scapular protraction. Similarly, posture training to encourage scapular retraction also may be helpful.[10] A thorough multidisciplinary checklist for preventing shoulder pain has been developed by Fattal et al[14] (Table 1).

Surgical Management

A paradox exists in the management of shoulder pain in patients who use

Table 1

Preventive Strategies to Minimize Shoulder Pain in Patients Who Use the Upper Extremities for Bearing Weight

Joint-sparing strategies
Bringing the patient to the shoulder-level environment
Lift
Verticalizing wheelchair
Adapting the patient's home environment
Therapeutic education to prevent untimely and unexpected movements
Limitation of propulsion movement: electric wheelchair
Optimization of manual propulsion: motorized wheels
Functional elbow surgery to restore symmetric propulsion of the wheelchair when relevant in patients with quadriplegia and shoulder pain
Car adaptation to minimize shoulder involvement when driving
Various technical aids for taking a shower
Storage of the wheelchair in the car
Postural correction
Postural rehabilitation to correct kyphosis
Sitting correction for wheelchair
Back-support correction for wheelchair
Progressive modulating adaptation
Postural corrections in bed
Specific shoulder muscle strategies
Joint stiffness prevention and avoidance
Muscle tone disorder (eg, major pectoralis spasticity) prevention
Balanced deltoid/major pectoralis/teres minor strengthening
Balanced anterior/posterior muscles
Selective training of external rotators (infraspinatus and teres minor)
Recentering maneuver for glenohumeral joint
Strengthening of the scapula-suspending muscles
Stretching strategies
Curtis stretching protocol: two sessions per day, holding the final position for 20 to 30 seconds, with one series of five stretching movements
Stretching of the major pectoralis (sternal and clavicular) and anterior muscles
Stretching and strengthening of the external rotators: one session per day, three series of 10 to 15 movements
Managing aggravating factors
Weight gain and obesity prevention or reduction
Muscle fatigue prevention
Endurance training
Prevention of spastic diffusion to trunk and upper limbs
Prohibition of harmful sporting activities (eg, bench press)
Adapting to new transfer techniques
Use of technical aids (eg, transfer board)
Use of pivot-transfer technique when possible or help from a third party
Adaption of transfer planes height
Use of head-hips technique

Adapted with permission from Fattal C, Coulet B, Gelis A, et al: Rotator cuff surgery in persons with spinal cord injury: Relevance of a multidisciplinary approach. *J Shoulder Elbow Surg* 2014;23(9):1263-1271.

the upper extremities for weight bearing. The optimal function of the upper extremities is essential for ADLs and for preventing a decline in overall health. However, substantial restriction can occur, even with appropriate treatment and regardless of the specific pathology. This difficult decision-making process can benefit from a multidisciplinary approach to evaluation and management. In a prospective case series of 28 SCI patients who underwent 38 shoulder surgeries after consultation with a multidisciplinary team, Fattal et al[14] noted that "the surgical decision is in fact more difficult for the patient than for the surgeon." In the study, when the patient made a decision based on input from the surgeon, the physician, the physical therapist, and the occupational therapist, no negative results occurred that could have put the validity of proceeding with surgery in question. The primary indication for surgery was pain relief. The mean pain intensity rating at rest was 0 ± 1.3 (range, 0 to 6) for surgical shoulders and 1.8 ± 2 (range, 0 to 6) for nonsurgical shoulders (unknown pain scale; statistical significance not reported). The mean preoperative and postoperative Functional Independence Measure scores were 103 ± 14.1 (range, 63 to 126) and 104 ± 10.6 (range, 81 to 120), respectively; however, the global functional status of the patient was not affected.

Surgical intervention for shoulder pathology in MWUs is divided into two broad types: nonreparative surgery and reparative surgery. Nonreparative surgery aims to reduce pain through débridement procedures and preservation of the rotator cuff. For subacromial impingement, this intervention involves resection of a hypertrophied CA ligament, bursectomy, and acromioplasty of the anterior tip. Robinson et al[2] reported their results involving subacromial decompression in six shoulders in four MWUs with Neer grade 2 or 3 impingement. All patients had postoperative pain relief, although no objective criteria for pain or function were reported. Similar decompression (open or arthroscopic distal clavicle excision) can be performed for AC joint arthrosis.

Rotator cuff tears, including partial tears, should be repaired, if possible (Figure 2). Techniques and fixation similar to those used for able-bodied patients can be used in MWUs. However, a higher incidence of intrasubstance tears may exist in this population.[40] Fattal et al[14] performed single-row repairs for partial rotator cuff tears and double-row repairs for full-thickness rotator cuff tears. Roth et al[43] performed a critical analysis review of single-row versus double-row (and transosseous-equivalent) rotator cuff repairs in an able-bodied patient population and found biomechanical advantages for double-row repair. Although level I clinical outcome studies have failed to find a substantial difference between single-row and double-row repairs, we note that these studies often are underpowered and therefore are at high risk of having a type II error. In the weight-bearing shoulder population, earlier motion, more aggressive rehabilitation, and increased loads may favor the biomechanically superior construct with regard to gap formation, load to failure, and footprint compression. Therefore, the senior author (M.S.S.) prefers to perform a double-row repair of the rotator cuff whenever technically feasible.

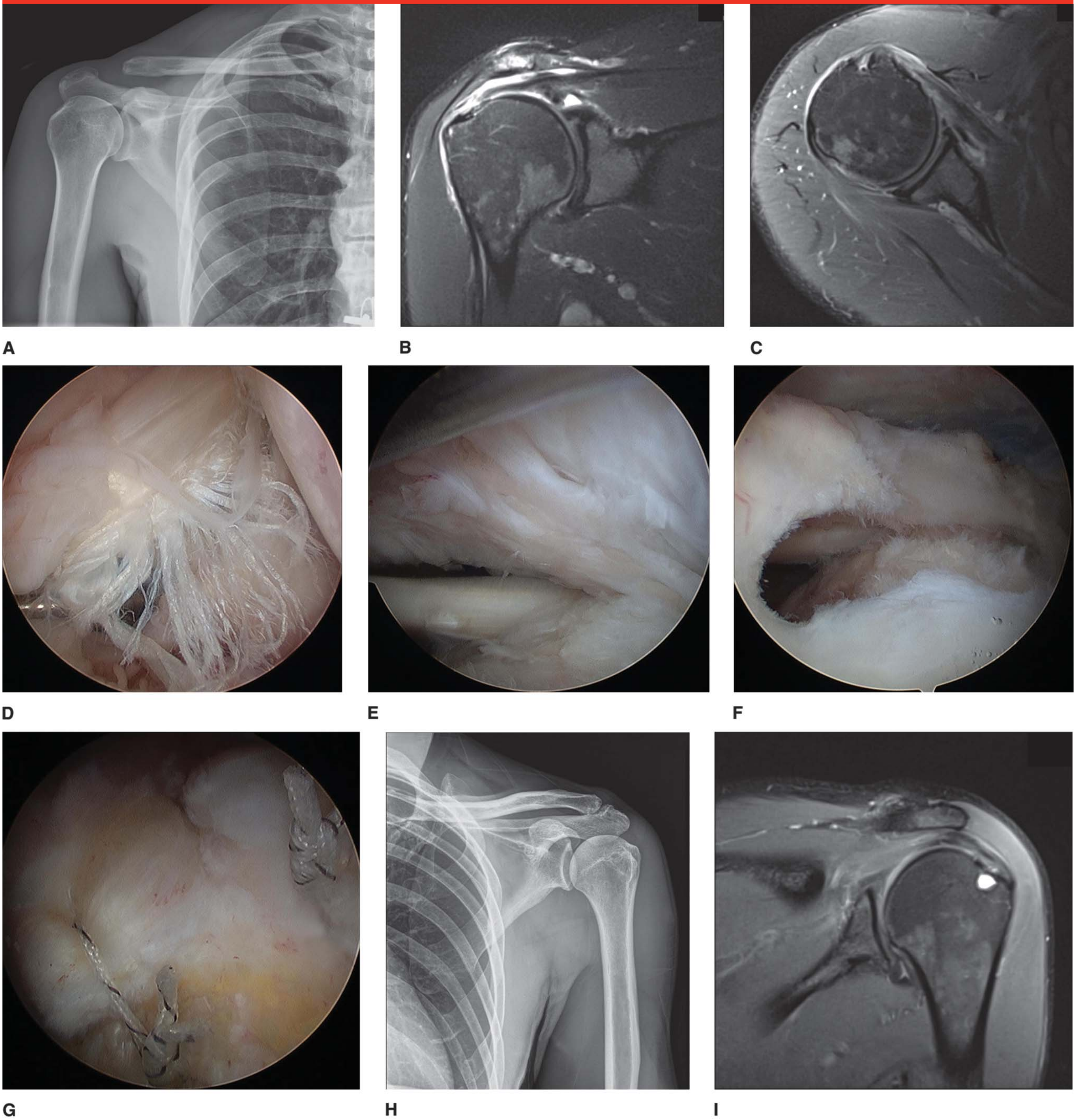
Limited data exist about the management of the long head of the biceps tendon. Fattal et al[14] mention arthroscopic tenodesis as their first-line treatment for proximal biceps tendon pathology. However, based on the senior author's (M.S.S.) experience, tenotomy may afford fewer postoperative restrictions than tenodesis (ie, protected open chain strengthening of elbow flexion and forearm supination). Because of the potential humeral head depressor function of the long head proximal biceps tendon, the senior author (M.S.S.) recommends retaining the tendon in situ unless distinct symptoms referable to biceps tendon pathology are present.

Arthroplasty is considered for management of severe osteoarthritis of the GH joint, rotator cuff arthropathy, and osteonecrosis in the able-bodied patient. Shoulder prostheses have advanced since the pioneering work of Neer, but these implants were designed for treating degenerative joint disease in an able-bodied patient. To our knowledge, the biomechanical load and kinematics of bearing weight on a shoulder prosthesis have not been studied.

The second important factor in determining whether to proceed with arthroplasty in MWUs is the prolonged postoperative recovery period, including ≥12 weeks of restricted activity to allow for soft-tissue healing. Total shoulder arthroplasty (TSA) or humeral head arthroplasty (hemiarthroplasty) are the two current options. Theoretically, reverse total shoulder arthroplasty (RTSA) would provide superior pain relief in patients with advanced rotator cuff disease. Despite expanding indications and improved implant designs, complication rates in able-bodied patients who have undergone RTSA have increased as well, with reported rates of 19% to 68%.[44] Current RTSA implants are not designed to accommodate weight-bearing loads from weight-relief transfer and propulsion activities, but they may be of use for those patients who have severe rotator cuff arthropathy and pain. Currently, no published literature exists on the use of RTSA in the weight-bearing shoulder population. The senior author (M.S.S.) recommends careful consideration and extensive discussion between the surgeon and the patient before proceeding with an RTSA in a patient who uses the upper extremities for weight bearing. In patients with advanced GH arthrosis and chronic rotator cuff deficiency, stemmed humeral head hemiarthroplasty that allows appropriate offset and lateralization is preferred to re-tension the remaining rotator cuff muscles.

Garreau De Loubresse et al[45] reported the first case series of paraplegic patients who underwent shoulder arthroplasty. Five female patients with a mean age of 70 years (range, 61 to 88 years) underwent four TSAs and one hemiarthroplasty. Three shoulders had full-thickness rotator cuff tears at the time of surgery, two of which were repaired. All humeral components were cemented; one of the four glenoid components was all-polyethylene with cementation, and the remaining three were metal-backed components with screw fixation. The mean Constant score improved from 30 preoperatively to 52 at a mean follow-up of 30 months (100-point scale). The mean American Shoulder and Elbow Surgeons function score improved from 28 preoperatively to 37 (55-point scale). The mean pain score improved from 5 preoperatively to 10 at follow-up (15-point scale), with one patient having complete pain relief (15 of 15). Two complications occurred—an early revision for a loose glenoid screw and the migration of a cemented glenoid implant at 30 months postoperatively. Given the high prevalence of rotator cuff tears in this subset of patients, the authors recommend TSA for patients aged ≥65 years without rotator cuff tears. Humeral head arthroplasty seems to be indicated for patients aged <65 years and for patients with full-thickness rotator cuff tears, regardless of patient age.

Figure 2



A, AP radiograph of the right shoulder demonstrating prior distal clavicle excision in a 45-year-old man with bilateral weight-bearing shoulders secondary to polio. He also has a chronic, large, painful rotator cuff tear of the right shoulder that developed subsequent to the distal clavicle excision that is unresponsive to nonsurgical treatment. He depends on his upper extremities for ambulation. **B,** Coronal T2-weighted MRI of the right shoulder demonstrating a full-thickness tear of the supraspinatus with retraction to the lateral humeral head articular cartilage and edema in the acromion. **C,** Axial T2-weighted MRI of the right shoulder showing subscapularis tendinopathy and partial tearing as well as biceps tendinopathy. **D,** Arthroscopic image of a posterior view of the right shoulder in a lateral position demonstrating biceps fraying. **E,** Arthroscopic image depicting a partial tear at the rotator interval in the right shoulder. **F,** Arthroscopic image showing a crescent-shaped full-thickness tear of the supraspinatus in the right shoulder. **G,** Arthroscopic image showing repair of the supraspinatus tear. **H,** AP radiograph of the left shoulder demonstrating acromioclavicular joint degeneration. **I,** Coronal T2-weighted MRI of the left shoulder demonstrating a cyst of the greater tuberosity consistent with chronic subacromial impingement.

In another case series, Hattrup and Cofield[46] reported on the results of six female patients who underwent five TSAs and one humeral head arthroplasty. The mean patient age was 68.7 years (range, 54 to 87 years), and the average follow-up was 84 months (range, 24 to 200 months). All shoulders had evidence of rotator cuff damage, including one massive rotator cuff tear that was the sole irreparable full-thickness tear. All glenoid components were cemented (5 of 5). Five of the humeral components were press-fit and one was cemented, although one noncemented humeral component was revised to a cemented implant. Pain improved postoperatively in five of six patients; one patient continued to have severe pain. Mean active flexion improved from 92° to 122°, and mean active external rotation improved from 27° to 48°. The results were excellent in one shoulder, satisfactory in four, and unsatisfactory in one. Five of six patients had a medical or surgical postoperative complication. One patient required an early revision from a noncemented stem to a cemented stem because of an unrecognized intraoperative greater tuberosity fracture. In one patient with chronic upper extremity neuropathy, brachial plexopathy developed, and three patients experienced medical complications related to immobility, including pneumonia, ileus, and a stage II ischial pressure sore. No failure from radiographic loosening was seen on postoperative radiographs. However, all patients demonstrated anterior GH subluxation, superior subluxation, or both, consistent with rotator cuff damage and subsequent radiographic instability. The rotator cuff repairs and arthrotomy were protected for 8 to 10 weeks postoperatively, but because of the postoperative subluxation, a longer period of protection may be necessary. Like Garreau De Loubresse et al,[45] Hattrup and Cofield[46] recommend TSA if the rotator cuff is intact or reparable because of the potential for improved pain relief, functional scores, and ROM.

Postoperative Rehabilitation

The postoperative rehabilitation program must be closely supervised and customized to the patient, the level of independence, the support system, and the type of surgery. Rehabilitation typically is aggressive to allow the patient to return to ADLs as early and safely as possible. In the initial postoperative period, a stay at an inpatient rehabilitation or skilled nursing facility may be necessary until it is safe for the patient to return home. Typically, supervised passive ROM exercises, such as Codman pendulum exercises, can begin immediately after surgery. It is critically important to use the previously described weight-relieving strategies during the postoperative period, including hydraulic lifts, weight-relief shifts, and leans. Manual wheelchairs should be replaced with motorized wheelchairs or modified by adding motorized wheels to reduce shoulder use.[2,14] For nonreparative surgeries, active-assisted ROM and active ROM exercises also can begin immediately. Gentle resistance exercises, manual wheelchair use, and limited transfers can be initiated 3 to 4 weeks after surgery as ROM returns and pain improves. By the eighth week postoperatively, patients can expect to be able to propel a wheelchair on level surfaces, perform independent weight-relief maneuvers, assist with transfers, and perform ADLs, such as grooming and feeding.

If the rotator cuff is repaired, passive and active-assisted ROM exercises are initially permitted, but active ROM is delayed until the fourth week postoperatively. Wheelchair use, limited transfers, and gentle progressive resistance exercises are restricted, at least until the sixth postoperative week. Typically, independence in ADLs is achieved by the ninth postoperative week, whereas premorbid levels of strength in transfer and in manual propulsion return by 4 months postoperatively.

After arthroplasty, Hattrup and Cofield[46] recommend 6 weeks in a sling with only passive ROM exercises permitted. Active-assisted ROM exercises can begin during the sixth postoperative week, along with isometric strengthening. Based on their experience, the authors of the study recommended restricting the use of the surgical extremity for transfers and ambulation until 12 weeks postoperatively.

Summary

People who use the upper extremities for weight-bearing purposes put a substantial load on the shoulders during ADLs. The associated high incidence of symptomatic shoulder pathology in this population challenges surgeons to be less conservative than they would be in treating comparable able-bodied patients in order to preserve the joint, and ultimately, the function of the patient. Patients may benefit from a multidisciplinary consultation before deciding whether to proceed with surgical intervention. As the population of MWUs and orthotic-assisted ambulators increases, orthopaedic surgeons will be called on increasingly to manage the weight-bearing shoulder. Prospective data collection and collaboration between care centers will be necessary for effective treatment of this patient population.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, reference 24 is a level I study. References 7, 23, and 39 are level II studies. References 1, 10, 12, 13, 19, 21, 25-27, 29, 31, 33, 40, and 41 are level III studies. References 2, 8, 14, 34, 36, 38, 42, 45, and 46 are level IV studies. Reference 35 is level V expert opinion.

References printed in **bold type** are those published within the past 5 years.

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