MINI-SYMPOSIUM: SHOULDER RECONSTRUCTION

(ii) Rotator cuff arthropathy

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Summary
Rotator cuff arthropathy is a specific and uncommon disease entity. It affects mainly elderly, but often active people. The exact causes are not known, but there is evidence of genetic predisposition, crystal disease and mechanical factors. There are numerous treatment options for both the pain and dysfunction. Generally, non-operative measures are successful, if used appropriately and timely. Arthroscopic debridement and washout alone has only short-term benefit, but arthroscopic biceps tenotomy or tenodesis is effective in eliminating pain caused by long head of biceps tendon pathology. Anatomical hemi-arthroplasty, whether stemmed or surface replacement, primarily improves pain. However, modern designs specifically for cuff tear arthropathy have shown improved functional results. Surface replacement implants also confer the benefits of being less invasive and of preserving bone. Reverse total shoulder arthroplasty is a powerful tool for the elderly patient with unresponsive painful pseudoparalysis. However, it has a high complication rate and should be used with care.

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Introduction
Rotator cuff arthropathy is characterised by rotator cuff insufficiency, diminished acromiohumeral distance and arthritic changes of the glenohumeral joint.

The first descriptions of rotator cuff arthropathy date back to 1853, when Professor Adams at the University of Dublin described chronic rotator cuff tears leading to localised destructive arthritis. The term Milwaukee shoulder was introduced in 1981 to describe the condition in four elderly women who had recurrent bilateral shoulder effusions, severe radiographic destructive changes of the glenohumeral joints and massive tears of the rotator cuff.

Charles Neer coined the term “cuff tear arthropathy” in 1977 and published his classic article in 1983. Neer described the pathoanatomical changes associated with massive, chronic full-thickness rotator cuff tears, which include erosions of the osseous structures, humeral osteopaenia, and restricted shoulder motion. The massive tears allow superior displacement of the humerus resulting in “femoralisation” of the humeral head (erosion of the greater tuberosity) and “acetabularisation” of the coracoacromial arch (reshaping of the arch so that it creates a socket for the proximal aspect of the humerus).

Pathomechanics
The exact cause of cuff arthropathy is not known. Although the progression of rotator cuff tears seems to play a role in

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the development of cuff tear arthropathy, it appears to be a separate pathological entity and not simply the end stage of chronic cuff tears. Neer and co-workers estimated that cuff tear arthropathy would develop in only 4% of patients with a complete rotator cuff tear.

Rotator cuff arthropathy differs from other causes of glenohumeral arthritis and should be recognised as a distinct clinical entity. In glenohumeral osteoarthritis, all the usual sequelae of osteoarthritis are present and the rotator cuff is typically intact. Any associated rotator cuff tear is usually traumatic or attritional in nature and repair is typically possible. Rheumatoid arthritis, when associated with massive cuff deficiency, can present in a similar fashion to rotator cuff arthropathy. However, in rheumatoid arthritis there is the added presence of destructive pannus, multiple joints are often involved and patients typically have systemic symptoms at some point in the disease process.

Three main theories have been proposed for the development of cuff arthropathy.

**Crystal Mediated Theory**

Halverson, in 1981, proposed that the calcium-phosphate crystals in synovial fluid induce an immunologic cascade and the release of collagenase. These activated products cause destruction of the periartricular and articular structures. In response to calcium-containing crystals in the synovial tissue, a low-grade inflammatory response initiates cellular and fibroblast proliferation. Human fibroblasts may then secrete proteolytic enzymes that are responsible for the rapid degradation of cartilage matrix components, as seen in cuff tear arthropathy.

There may be a genetic predisposition to crystal mediated cuff arthropathy. Peach et al. showed that cuff tear arthropathy is associated with variants in ANKH and TNAP that alter extracellular inorganic pyrophosphate concentrations causing calcium crystal deposition. This supports a theory that genetic variants predispose patients to primary crystal deposition which, when combined with a massive rotator cuff tear, leads to the development of arthritis.

**Cuff Tear Theory**

In 1983, Neer et al. postulated that massive rotator cuff tears lead to degeneration of the shoulder joint in a percentage of shoulders. Two mechanisms contribute to the destruction of shoulder joint and articular cartilage: mechanical and nutritional pathways. Neer et al. based this concept on clinicopathological observations made at the time of surgery and upon a review of histological samples (Fig. 1).

**Mechanical factors**

The mechanical factors associated with massive rotator cuff tears lead to unbalanced muscle forces. These factors are anteroposterior instability of the humeral head, resulting from a massive tear of the rotator cuff and rupture or dislocation of the long head of the biceps, leading to proximal migration of the humeral head and acromial impingement. Glenohumeral articular wear occurs as a result of repetitive trauma from the altered biomechanics associated with the loss of primary and secondary stabilisers of the glenohumeral joint. The wear on the glenoid is often eccentric, involving the anterior superior part. This leads to an accelerated process of further cuff destruction and arthropathy.

**Nutritional factors**

The nutritional factors associated with massive full-thickness tears are related to loss of motion and periartricular damage due to loss of a normal joint milieu. The loss of fluid pressure and the accompanying reduction in the quality of the chemical content of synovial fluid leads to cartilage and bone atrophy. Recurrent bloody effusions and loss of glycosaminoglycan content of the cartilage further accelerate the destruction of both bone and soft tissue.

**Force Couple Theory**

Burkhart analysed fluoroscopic comparisons of the kinematic patterns of functional and non-functional rotator cuff tears. He showed that the loss of the coronal and sagittal force couples lead to accelerated wear and further disruption of transverse and coronal plane force couples (Fig. 2).

**Diagnosis**

Rotator cuff arthropathy usually presents in the seventh decade. Patients are typically elderly females with long-standing symptoms. Bilateral involvement is present in 60% of cases.

The presenting symptoms include:

1. Pain—can range from mild ache, sharp pains with movement to constant and night pain
2. Weakness—with overhead activities, mainly
3. Pseudoparalysis—complete inability to actively move the shoulder, due to cuff deficiency
4. Recurrent swellings—as a result of large synovial effusions
5. Instability—deficient cuff leads to anterosuperior escape of the humeral head with attempted elevation of the arm.

A patient may present with some or all of the above symptoms, which can be extremely disabling.

Clinical examination usually reveals swelling of the glenohumeral and subacromial joint (which is one articulation) (Fig. 3) and atrophy of supraspinatus and infraspinatus muscles. Active and passive range of motion can be limited because of fixed glenohumeral subluxation. Active glenohumeral motion may be accompanied by palpable or audible crepitus and usually is painful. Weakness of the external rotators may be profound. If the long head of biceps tendon is ruptured, a “popeye” biceps sign will be present, with a bunched up and flaccid biceps muscle. If the long head is intact, it is usually subluxed medially and a source of pain.

It is essential to assess the function of the deltoid muscle, as this is the only remaining elevator of the arm in a cuff deficient shoulder. Anterosuperior subluxation (known as “escape”) may be seen with resisted attempted active abduction, due to loss of the anterosuperior cuff and biceps tendon (Fig. 4). Acromioclavicular joint arthritis may also be present.

Figure 2 Transverse and coronal force couples. The loss of balance between each force couple leads to cuff tear arthropathy. (Blue circle indicates the centre of rotation of the glenohumeral joint.) (Adapted from: Burkhart.

Figure 3 Anterior synovial swelling of the left shoulder.

Figure 4 Pseudoparalysis with anterosuperior subluxation of the humeral head with attempted abduction.

Investigations

Plain radiography is the most useful investigation for diagnosing and assessing the severity of rotator cuff arthropathy.

The typical and characteristic findings are:

1. Superior migration of the humeral head, articulating with the overlying acromion
2. Narrowing of the glenohumeral joint space
3. Osteophytes
4. Rounding off of the greater tuberosity
5. Periarticular soft-tissue calcifications

Occasionally, in severely affected shoulders, erosive changes are seen both in the glenohumeral joint and in adjacent structures such as the base of the coracoid process, the lateral end of the clavicle and the anterior aspect of the acromion. Advanced superior migration and medialisation can become marked, producing “acetabularisation” of the coracoacromial arch and “femoralisation” of the humeral head. However, if the arm is relaxed and
dependent during radiographic examination the true extent of subacromial narrowing may not be appreciated. Any anterior or posterior instability of the glenohumeral joint is usually apparent from the axillary radiographs. This instability may become fixed and in these cases computerised tomography can be helpful to determine the degree of glenoid erosion (Fig. 5).

Treatment

Patients presenting with a cuff arthropathy, present with pain, disability or both. Numerous treatment options are available. The choice of treatment varies according to the patient’s circumstances, surgeon’s preferences and resources. “No operation” does not mean “no treatment”.

Treatment options for pain relief

1. Anti-inflammatory and analgesic drugs
2. Intra-articular injections of steroid
3. Intra-articular injections of hyaluronans
4. Physiotherapy techniques, including local therapy and acupuncture
5. Re-education and limitation of use
6. Modifying lifestyle
7. Surgical options

Treatment options for disability

1. Physiotherapy—Deltoid Rehabilitation Programs
2. Occupational therapy—use of aids (and home modifications)
3. Surgical options

Intra-articular injections

Repeated intra-articular injections of corticosteroids are discouraged, as they have been shown to be largely ineffective. They also only have short-term benefit. Hyaluronan injections are safer and may be repeated as necessary. They have been shown to be of benefit for early and late osteoarthritis of the shoulder, but have not been investigated for cuff arthropathy yet. Hyaluronans act by blocking pain receptors, stimulating endogenous hyaluronan production and have a direct anti-inflammatory effect by inhibiting leukocyte action.

Deltoid Rehabilitation Program

In the absence of a rotator cuff overhead movements are almost impossible without “trick” movements and assistance from the opposite arm. A well-structured program of retraining the anterior and middle deltoid muscles has been shown to be effective in restoring active arm elevation. This is mainly effective where pain is not a predominant feature or can be controlled adequately.

Arthroscopic surgical procedures

Arthroscopic irrigation to remove activated enzymes and crystals offers only limited, short-term relief. Arthroscopic acromioplasty and tendon debridement is commonly used for cuff arthropathy, but there is little supportive data. Release of the coracoacromial ligament and excessive bone should be avoided, as it could lead to anterosuperior escape of the humeral head. Tubroplasty or reversed acromioplasty, arthroscopic debridement of the greater tuberosity, has been shown to be effective in some situations if the tuberosity is not already smoothed down.

The biceps tendon, if intact, has been thought to be the main source of shoulder pain in patients with large cuff tears and cuff arthropathy. This has been recently published. Arthroscopic biceps tenotomy and arthroscopic biceps tenodesis have been shown to treat the severe pain or dysfunction caused by an irreparable rotator cuff tear associated with a biceps lesion. However, the presence of pseudoparalysis is a contraindication to this procedure.

Shoulder arthroplasty

The main indication for arthroplasty in cuff arthropathy is uncontrolled pain affecting the patient’s quality of life. It is contraindicated in the absence of confirmed arthritis of the glenohumeral joint.

The current replacement options include (in order of increasing complexity):

1. Anatomical prostheses:
   - Surface replacement
   - Stemmed hemi-arthroplasty
2. Reverse geometry prosthesis

Surface replacement arthroplasty

Surface replacement has the advantages of being a less invasive and quicker procedure, for the typically elderly and frail group of patients with cuff arthropathy. It also preserves bone, thus simplifying future possible revision procedures.

The modern surface replacement prosthesis has been popularised by Copeland, who has reported good results in pain relief, but not in range of motion.
Copeland Extended Articular Surface (EAS) prosthesis offers theoretical advantages in improving the lever arm of the deltoid and therefore allowing for some improvement of active function post-operatively. It is not indicated when there is dislocation or escape as this could lead to a painful escaped prosthesis.

**Stemmed hemi-arthroplasty**

Hemi-arthroplasty is preferred to total shoulder replacement for cuff arthropathy at the moment, as glenoid loosening is much more common. This is due to the loss of normal shoulder kinematics and abnormal glenoid forces causing a ‘rocking-horse’ glenoid loosening. The humeral component articulates on the edges of the glenoid component, causing it to rock loose.

Numerous stemmed prostheses have been used for cuff arthropathy. It has been common practice to oversize the humeral head in order to avoid further superomedial erosion and improve the lever arm of the deltoid. Bipolar designs have been developed, which have good functional results in the short term. However, later revision is difficult and radiographs of the shoulder in varying degrees of abduction revealed no motion at the glenoid–prosthesis interface or at the bipolar polyethylene liner-humeral head articulation. Concerns that have been raised regarding the modified bipolar prosthesis include potential overstuffing of the shoulder joint, rupture of the subscapularis tendon due to the vertical orientation of the component, and the effect of polyethylene wear.

More recent head designs have been developed specifically for cuff arthropathy (Fig. 6). These designs, such as the CTA Head (DePuy), have the same theoretical advantages as the Copeland EAS. Early 2-year results seem promising in terms of range of motion and pain relief, with an average doubling of active flexion post-operatively. As with the surface replacement, it is not indicated when there is dislocation or anterosuperior escape.

**Reverse geometry arthroplasty**

Interest in the reverse geometry arthroplasty (RGA) has increased in Europe over the past 12 years, popularised by Grammont in France. He established the basic principle for the modern prosthesis, which includes medialisation and lowering of the centre of rotation of the joint, thereby increasing the lever arm and improving deltoid muscle efficiency. The semiconstrained design of the prosthesis ensures stability, even in the presence of anterosuperior escape. Until Grammont’s device, all reverse designs had a lateral offset of the glenoid component relative to the glenoid surface. This attachment site proved to be the site of failure, as the lateral offset increased the moment arm of the resultant joint reactive force, which further stressed the glenoid–prosthetic bone attachment. On the other hand, the medialisation of the Grammont design diminishes the moment arm on the joint reactive force (Fig. 7a and b).

The RGA has been used successfully for over 10 years now with excellent medium term results in the elderly cuff arthropathy patient and for complex revision surgery, where the cuff is deficient. It has been shown to both significantly improve pain, as well as improve motion and function of the shoulder. It has been able to restore useful function to extremely disabled patients (Figs. 8 and 9).

However, complication rates are significantly higher than anatomical prostheses and further revision options are difficult, therefore less invasive options must be exhausted first.

The main indication for the RGA is a pseudoparalytic cuff arthropathy in an elderly patient. It is also indicated where there is escape and revision situations with dislocation. A functional deltoid must be present in all cases. As mentioned above, RGA is considered when rehabilitation has failed, and conventional surgical reconstruction methods cannot satisfactorily manage shoulder pain and loss of function. Because of the magnitude of the intervention and potential risks of RGA, non-operative means of improving the patient’s quality of life merit a dedicated trial prior to surgery.

The RGA is contraindicated in patients with

1. Nonfunctional deltoid muscle
2. Active infection
3. Insufficient bone to seat the implant components
4. Muscular, neurologic, or vascular deficiencies that compromise the affected extremity
5. High levels of physical activity (e.g., competitive sports, manual labour)

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Figure 6  Anatomical arthroplasty designs for cuff tear arthropathy. From left to right: Copeland surface replacement (Biomet), Copeland EAS (Biomet), bipolar hemi-arthroplasty (Biomet), CTA Head (DePuy).
As one would expect with a prosthesis that is large and complex inserted into more challenging elderly and revision cases the complication rates are higher than with other implants. These are more frequent still when RGA is used to revise a failed prior arthroplasty.

**Figure 7** (a) Grammont principles of medialising the centre of rotation with the reverse geometry prosthesis and increasing the deltoid lever arm. (b) The deltoid is detensioned and shortened, due to superior subluxation of cuff arthropathy (left). The RGA increases the lever arm of deltoid, with lowering and tensioning of deltoid (right). (Adapted from: Matsen et al. 20)

**Figure 8** Post-operative radiograph of a reverse geometry arthroplasty.

**Figure 9** Treatment algorithm for managing cuff arthropathy.

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Intra-operative complications include humeral cortical perforations, shaft fractures or glenoid fractures. Prevention requires respect for the osteopaenic bone of older patients and gentle reaming by hand. Pre-operative planning is essential to ensure that there is sufficient glenoid bone to accept the glenoid component. CT scans are often required to assess the glenoid bone stock pre-operatively.

Post-operative haematomas are common, facilitated by the large dead space that occurs after surgery with an absent cuff. Humeral shaft fracture is another relatively common post-operative complication. These fractures usually are due to a fall or to abrupt passive elevation or rotation of the arm. They often occur at the tip of the prosthesis. Loosening of the humeral component is uncommon and usually is associated with a fracture or infection.

Infection is more common with RGA. Contributing causes include haematoma formation, revision of a previous arthroplasty, the magnitude of the surgery, and the compromised general health of some patients.

Other complications include unscrewing of the junction between the metaphyseal and diaphyseal portions of the humeral component and loosening of the glenoid component. Glenoid erosion by impingement of humeral component on the inferior glenoid is often seen. It usually is not progressive but needs to be observed and revised if severe. These complications are lessening due to improvements in prosthetic design.

Dislocation is a relatively common complication, especially after the revision of a previous arthroplasty, when the osseous and soft-tissue anatomy has been distorted by prior trauma, when components are malpositioned, or when the humeral component lever against glenoid bone.

Fractures of the acromion occur commonly as a result of a pre-existing acromial lesion, overextension of the deltoid, or osseous fatigue from loading of an osteopenic acromion.

Neurological injuries include axillary nerve damage from surgical dissection or traction injuries from excessive tension resulting from lengthening of the arm. These injuries are most common in revisions with difficult surgical exposures.

Conclusions

Rotator cuff arthropathy is an uncommon, challenging disease. Elderly people are, in general, more active nowadays and have an increasing demand for continued useful function into old age. Increased understanding of cuff arthropathy and improving technology gives us more knowledge and tools to skillfully manage this condition (Fig. 9).

References