

Reverse Shoulder Arthroplasty for Massive Rotator Cuff Tears

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ABSTRACT

The purpose of this review is to explore, the role of reverse shoulder arthroplasty (RSA) in substituting cuff dysfunction, indications, reported outcomes in the literature and surgical technique for treating patients with massive cuff tear (MCT) without gleno-humeral arthritis. Undoubtedly, the RSA is a well-accepted treatment for cuff tear arthropathy, but is there a place for a prosthesis to treat a tendinous disease? Moreover, if there is no debate to implant an RSA in an elderly, low-demand patient with a massive, retracted, irreparable cuff tear, what is the place of RSA in a young, active patient with an acceptable preoperative function when there is no other treatment? Young age and good preop function are debatable indications for RSA despite good and sustainable results at ten years of follow up. So, treatment of MCT must be adapted to each

situation. RSA is not for everybody and there is a place for other treatments. When the indication is well selected and the technique precise, RSA provides, in a large majority of patients, a pain-free, improved shoulder with durable results.

Key words: Cuff tear arthropathy; Massive rotator cuff tear; Reverse shoulder arthroplasty; Rotator cuff repair

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INTRODUCTION

The use of an RSA for massive cuff tear without degeneration of the glenohumeral joint is an extension of the indications of this prosthesis initially meant to treat cuff tears arthropathies (CTA)^[1,2]. CTA was firstly described by Neer *et al* in 1983^[3] as a complex condition of shoulder dysfunction characterized by mechanical factors associating MCT, glenohumeral joint degeneration, often accompanied by an antero-superior migration of the humeral head as well as nutritional factors including disuse osteopenia, effusion of synovial fluid and sometimes joint destruction.

Massive rotator cuff tears are very large tears that are difficult to repair and often associated with an uncertain prognosis^[4-8]. They are usually chronic lesions and associated with myotendinous retraction^[9], atrophy, and fatty infiltration of the muscles (Figure 2)^[10,11]. The clinical presentation typically includes a painful and pseudoparalytic shoulder, which is defined as a shoulder with active elevation of less than 90° in the presence of free passive anterior elevation^[12-15]. However, some patients with irreparable MCT are able to maintain elevation of more than 90° but have intractable pain.

The degenerative changes of the musculotendinous unit increase over time and are associated with loss of elasticity and poor biologic and mechanical tissue properties. These changes adversely affect and, in some cases, compromise the surgical reattachment and healing of the musculotendinous unit to the bone^[16-24].

The exact definition of MCT lesion still defies consensus^[25-27] and

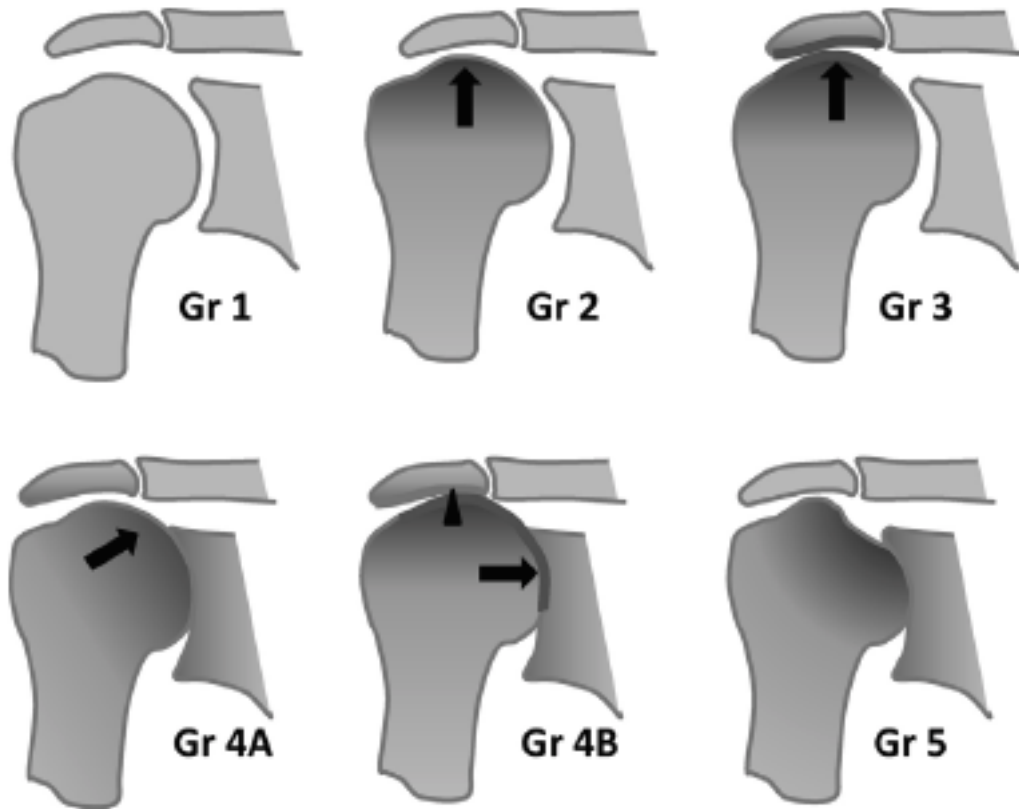


Figure 1 Hamada's classification of MCT arthritis.

the two most widely used systems are based on the dimension of *tendon retraction* (with a diameter > 5 cm)^[24] and on the number of tendons affected (with a minimum of 2 *complete tendon tears*)^[8,14,16]. According to these criteria, MCT have been reported as ranging from 10% to 40% of all rotator cuff tears and 80% of recurrent tears^[28-31].

Moreover, Hamada *et al*^[32,33] radiographically classified MCT by the acromio-humeral distance, degenerative changes of the acromion, and narrowing of the glenohumeral joint space. The 5-grade classification is supposed to reflect the temporal evolution of rotator cuff tears and is as on the figure 1.

Computed tomography scanning^[11] and magnetic resonance imaging^[10] are good tools to detect MCT and to grade the associated prognostic factors such as the tear size, tendon retraction and fatty infiltration. The information obtained can be used to estimate the quality and, consequently, the reparability of the torn musculotendinous unit^[35-38]. However, determining which rotator cuff tears constitute an irreparable MCT can be difficult and somewhat arbitrary^[37].

Nevertheless, in the presence of severe and fixed *retraction* of the musculotendinous unit (grade 3 on the classification system of Patte)^[9], severe cuff muscle *fatty infiltration* (grade 3 or 4 on the Goutallier classification for CT scan^[11] or Fuchs classification for MRI)^[10] or *proximal humeral migration* with narrowing of the acromiohumeral space (< 6 mm) on the anteroposterior view in neutral rotation, and/or *antero superior escape* clinically or radiologically observed^[39], the RCT can be considered chronic and irreparable.

Surgical treatment is advised in an irreparable MCT without arthritis (Hamada grade 1-3), associated with significant pain, and when non-operative treatment has failed to improve the symptoms after a minimal period of time, generally 6 months^[40]. Alternate treatment includes physical therapy to maximize range of motion and shoulder girdle strength, analgesics, intra articular corticosteroid and/

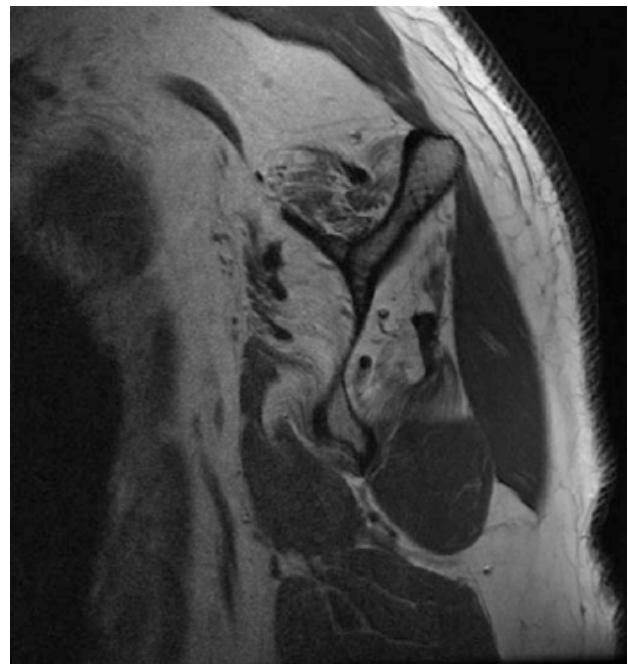


Figure 2 Sagittal T1 MRI: atrophy and fatty infiltration of all rotator cuff muscles except teres minor.

or hyaluronic acid injections, ...etc.

However, surgical treatment remains a challenge due to technical difficulties and unpredictability of the results of the repair^[41,42], which led orthopedic surgeons to look for alternative options to treat MCT

Many palliative interventions have been proposed, including, tendon transfers^[17,37,38], long head of the biceps tenotomy or tenodesis^[43], subacromial decompression^[44], subacromial balloons,

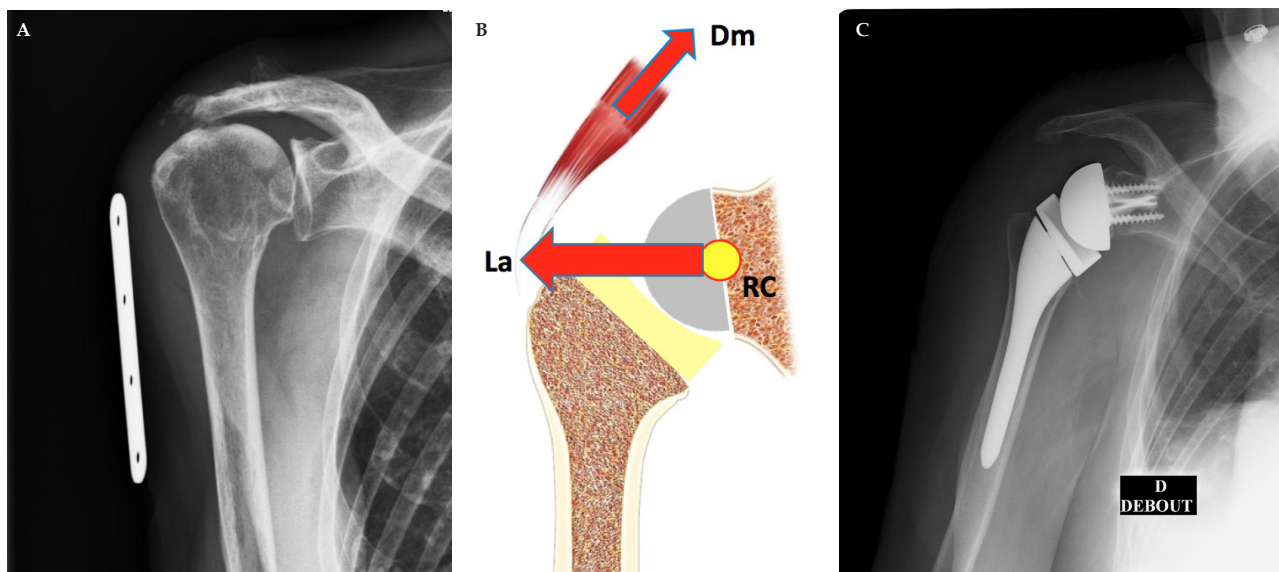


Figure 3 A: superior translation of the humeral head; B: Ball and socket system allows deltoid its normal function; C: Reverse ball and socket prosthesis.

partial rotator cuff repair^[45-47], superior capsular reconstruction^[51-54], hemiarthroplasty or total shoulder prosthesis constrained or not^[55-62] and reverse shoulder arthroplasty^[63-69].

Nevertheless, there is no consensus on an optimal surgical intervention for any one specific individual patient, and for that reason RSA is presented as an option that can provide a more predictable pain relief and function recovery^[70-77].

FUNCTION OF THE RSA IN MCT

The rotator cuff muscle-tendon unit serves as a critical dynamic stabilizer of the shoulder joint. The force couples of the rotator cuff in both the transverse and coronal planes provide a “concavity compression” effect, forcing the humeral head into the center of the glenoid^[78-80]. This compensates for the lack of inherent stability of the glenohumeral articulation and creates a stable fulcrum, allowing the more powerful deltoid muscle to elevate the arm and position the hand in space.

In the case of a massive rotator cuff tear, these force couples are disrupted, and the compressive stabilizing effect is lost. Without a stable pivot to resist translation of the humeral head, shoulder instability and dysfunction occurs. Clinically, this can manifest as pseudoparalysis, in which a patient is unable to actively abduct or elevate the arm despite full passive motion. When the force couples cannot be re-established by other surgical means, the Reverse ball and socket design of the RSA provides an inherently stable fulcrum at the shoulder joint *et allows* the deltoid to regain its normal function (Figure 3).

SURGICAL TECHNIQUE

In addition to a correct indication carefully applied to a deserving patient, a precise technique is essential to improve the long-term results of the RSA in MCT.

Pre Op imaging

Preoperative evaluation includes a CT scan or an MRI on all patients to better understand the version, inclination and morphology of the glenoid to assist in the planning of the glenoid preparation. Intra-operative evaluation of version and inclination, based on the appearance of the bone shape is misleading, and placement of the

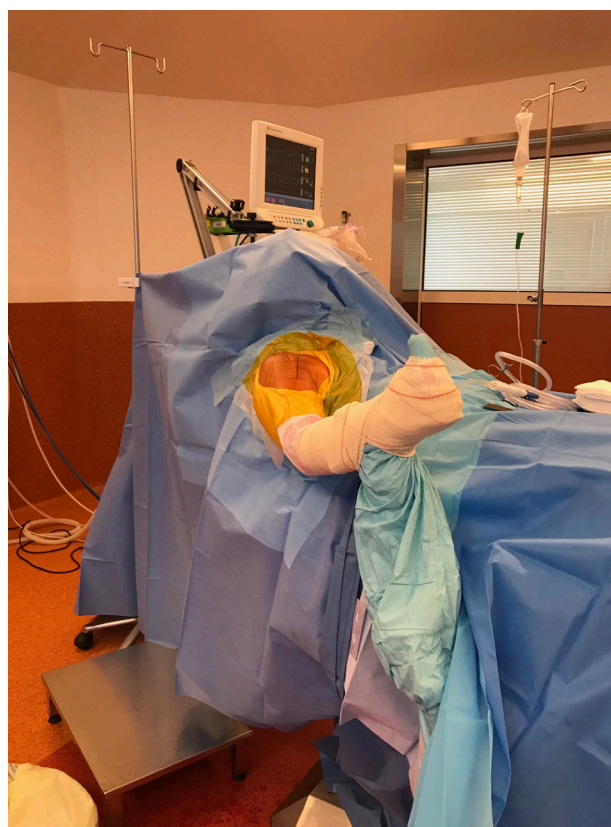


Figure 4 Patient positioned on the beach chair.

baseplate and the subsequent glenosphere is a key determinant of final motion, stability and durability of the prosthesis^[65,81-83].

Set up, positioning (Figure 4)

The patient is positioned in the beach chair with the hip semiflexed. An arm-positioning system can be utilized to take the place of an assistant holding the arm. The back of the table is adjusted so that the scapula is not in a protracted position. It is essential, prior to prepping and draping, to confirm that the arm can be placed in a maximally adducted and extended position to allow preparation of the humeral



Figure 5 (A) Trans deltoid splitting approach; (B) Saber cut incision; (C) Deltopectoral approach.

canal.

The shoulder and arm are then scrubbed prior to the prep with a chlorhexidine surgical scrub brush and then prepped along with the entire arm and hand with a chlorhexidine /alcoholprep. Some authors^[84-87] suggest to use benzoyl peroxide during the five days prior to surgery to have a better effect on *Cutibacterium acnes* involved in more than 40% of shoulder prosthesis infections^[88-90].

A stockinette is used to cover the hand and forearm to allow better fit of the arm-positioning system. Impregnated self-adhesive drapes may be placed over all the exposed skin after the planned incision and pertinent surface anatomy are marked (Figure 5). Preoperative antibiotics include classically a weight-based dose of a first-generation cephalosporin as well as vancomycin but recent studies suggest to use Clindamycin^[84].

Approach, exposure, capsular and cuff management

A standard deltopectoral (DP) or a trans deltoid (TD) splitting approach may be used.

In the DP (Figure 5C), the incision begins at the tip of (or just proximal to) the coracoid process and extends distally and laterally along the anterior aspect of the deltoid to the deltoid insertion. Upon subcutaneous dissection to the deltopectoral interval, the cephalic vein is identified proximally and is taken, most of the time, laterally with the deltoid, taking care to cauterize all medial tributaries.

The medial border of the deltoid is elevated. It is essential to release all subdeltoid adhesions and debride the bursa from the subdeltoid and subacromial spaces with a gentle finger. After placing tagging sutures in the tendon, the subscapularis muscle is peeled off the bone from the medial border of the bicipital groove and from the lesser tuberosity with electrocautery. The subscapularis should be adequately mobilized to facilitate later repair by debriding capsular tissue from the anterior border of the glenoid and releasing adhesions deep to the muscle belly from the anterior wall of the scapula, as well as those from the subcoracoid space. Following this, the proximal humerus is dislocated anteriorly. In most cases, this will produce exposure of a “bald” humeral head free of any superior rotator cuff insertion. Sometimes, loose edges of irreparable rotator cuff should be debrided to prevent impingement with the humeral poly and glenosphere. The external rotators, if they are still present, must be preserved. The main advantage of the DP approach is the possibility to extend the incision distally to the humerus.

In the TD (Figure 5A) the incision starts proximal to the posterior border of the A-C joint, to the antero-lateral corner of the acromion and distally 4 to 5 cm from the acromion. With an electrocautery, staying in contact with the bone, the proximal insertion of the deltoid is released from the acromion in continuity with the coraco-acromial

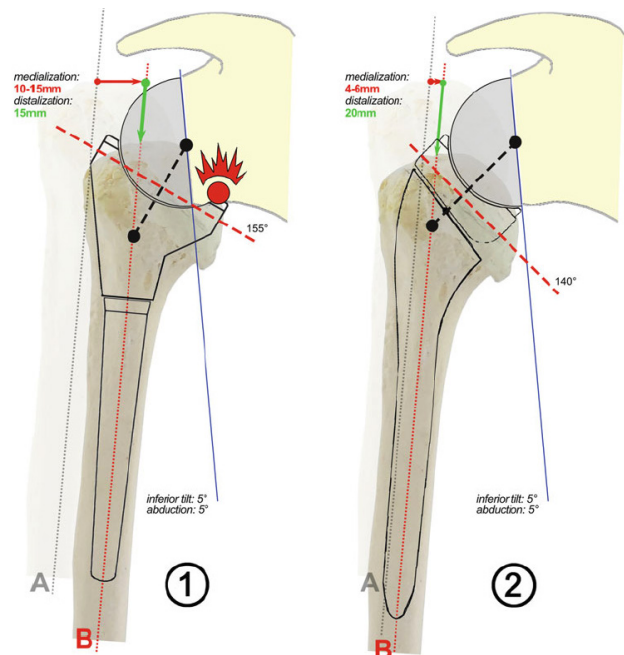


Figure 6 Humeral cut more vertical for notching prevention and better ROM.

ligament insertion to facilitate the final repair, medially to the A-C joint and distally in the raphe between anterior and medial parts of the deltoid. Distally, the incision is limited by the presence of the axillary nerve. A good landmark to preserve it is the inferior part of the recess of the subdeltoid bursa that one can check by inserting a smooth instrument inside. The nerve is always distal to this landmark. The main advantage of the TD approach is the possibility to keep the subscap tendon intact.

In both cases the anterior capsule has to be released from the anterior glenoid to mobilize the subscap and to improve external rotation and access.

Humeral cut

After exposing the humeral head, it is time to resect it. The angle will depend on the specific implant system being used. A more vertical resection (130-140°) decreases the risk of notching the scapula^[91] (Figure 6).

There are commercial resection jigs to assist with this cut, or it can be made utilizing a free-hand technique. The resection is taken through the proximal humerus metaphysis at a level depending on the implant and preferences of the surgeon. A minimum of bone

resection is necessary to have a good access to the glenoid especially in case of TD approach. The version of the cut is very controversial. It varies from 10° of ante to 40° of retroversion as per the authors, with respect to the forearm. There is no evidence in the literature of the influence of the version on final internal rotation^[92,93].

Humeral preparation

The proximal humerus is then prepared according to the implant selected. Most implants first require reaming to size the canal and then broaching to prepare the canal. The version has been determined previously, then the broaching should be performed with the same version that was established. Because of the potential risk of stress shielding, avoid a too large broach and a too tight press fit. A humeral protector plate is inserted to protect the head from iatrogenic damage by retractors while preparing the glenoid.

Glenoid exposure

A release of the capsule all around the glenoid is essential to improve range of motion and to expose the glenoid limits especially the inferior border which is critical to perfectly place the baseplate. In the *TD approach* (Figure 7C), the release is done after humeral head resection and placement of the inferior retractor. In the *DP approach*, it is easier to start the release before the head resection by placing a large retractor on the posterior wall of the glenoid using the strong support of the head retained in place.

Glenoid preparation

The glenoid has to be perfectly exposed by a humeral head retractor positioned posterior to the glenoid (Figure 7A) or inferior in TD approach (Figure 7B), and perimeter retractors. This step is dangerous for the nerves especially the axillary nerve that we can identify just inferior to the glenoid. We do not routinely tag the nerve but it is kept in mind always.

In MCT there will not be significant glenoid cartilage wear, it is helpful to remove the cartilage with a curette prior to placing a guide wire. The position of the guide wire is based on the preoperative CT scan or MRI planning. The axes of the glenoid in terms of length and width can be marked with electrocautery (Figure 7C) to also aid in the position of the guide wire. The guide wire is then placed so that the inferior part of the baseplate will be flushed with the inferior border of the glenoid *et also* with a 10° inferior tilt^[81,94] anyway never superior. As exposed before, do not trust the per operative appearance of the glenoid morphology. This step may be facilitated by placing an instrument parallel to the anterior wall of the glenoid giving the orientation or by different systems, digital with PSI or by glenoid clamps. The glenoid is then reamed, sparing the subchondral bone. Pulsatile lavage is used, and then, the sized baseplate is inserted, according to the patient's glenoid size. In the UNIC® system (Evolutis Company, Briennon, France)^[95], the common central peg is replaced by a helical blade which increases the bone-metal surface and spares the bone (Figure 8). We complete the fixation utilizing two to four holes with the inferior screw placed in an almost neutral direction in the coronal and axial planes, almost parallel to the blade to avoid an extra-articular placement and the proximal screw angled toward the base of the coracoid. Before implanting the sphere, it is essential to excise remnants of soft tissues or bone which may prevent a full impaction of the sphere on the baseplate. A glenosphere of appropriate size is then selected, implanted in place, and then tested to ensure that it is completely seated and secured by a safety screw. The glenosphere is also adapted to the patient, and for males is often of a large size, generally 38 to 42 mm. For smaller males

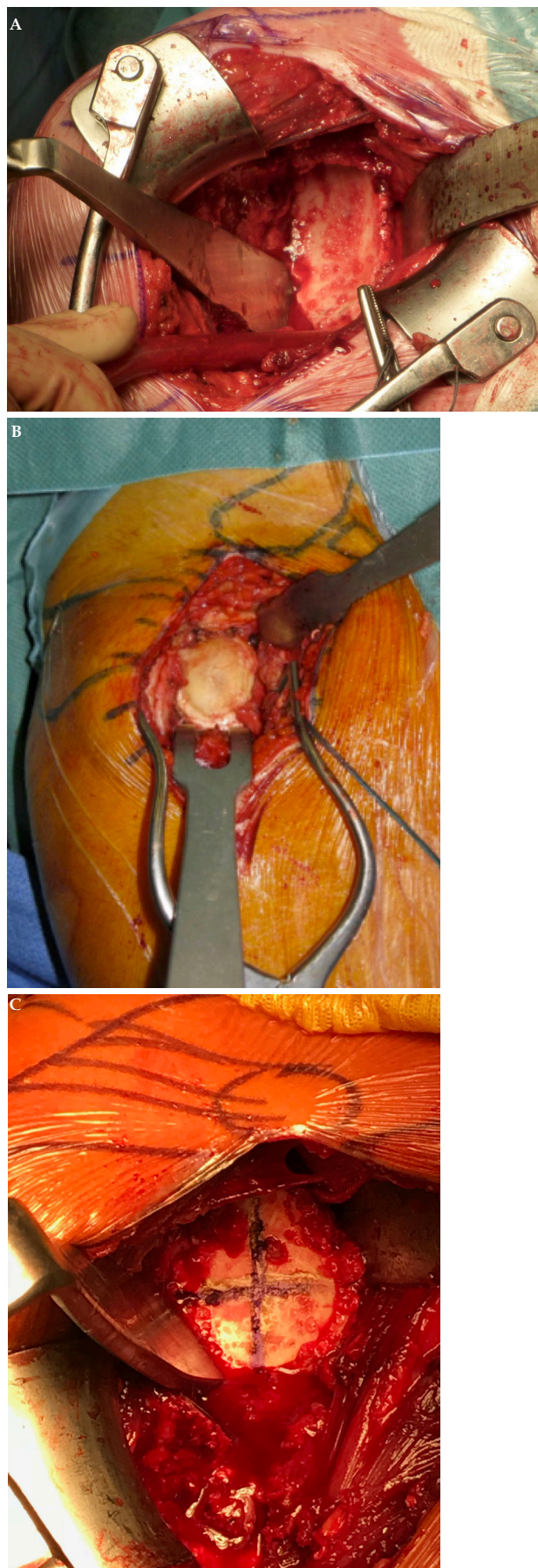


Figure 7 (A) Exposition of a right glenoid by a DP approach with posterior retractor; (B) Exposition by a TD approach with inferior retractor; (C) Axes marked with cautery.

and most females, however, a smaller glenosphere is implanted, sometimes in very small people, a 34 mm sphere is well fitted. Whatever the diameter it is essential to have a sphere overhanging the inferior border of the glenoid (Figure 9) to prevent notching^[81-83,96,97].

Humeral components

After placing baseplate and sphere, a trial stem is placed with a trial cup to check the possibility of reduction, tension of soft tissues, stability especially in full adduction-internal rotation (the most unstable position), range of motion particularly internal rotation, and if there are impingements between the sphere and the coracoid and between the greater tuberosity and the acromion especially in case of large and lateralized sphere. You may also adapt the thickness of PE to improve the stability. Some systems as the Unic® one are very helpful to select the ideal PE thickness (Figure 10).

Then the definitive stem is implanted, cemented or cementless, in the same position and at the same level as the broach and the cup and PE adapted.

Prior to placing the humeral implant, if the subscap has to be reinserted, trans osseous drill holes are created and strong sutures placed and wrapped around the neck, just before reduction. It is possible to medialize the sutures if necessary. It is preferable not to reinsert the subscap if it is too tight^[65,69-71,98-100].

Latissimus dorsi/Teres major transfer^[101-104]

Patients having an external rotation lag sign on physical examination, corresponding to an irreparable massive rotator cuff tear extending posteriorly, may be candidates for a transfer of the latissimus dorsi and teres major tendons. This is performed at the time of the reverse arthroplasty after completing the glenosphere placement and before placing the final humeral component. The latissimus dorsi is released from its insertion on the humerus and sutures are placed in a figure-of-eight fashion. The tendon is then released with sharp and blunt dissection until approximately 3 cm of excursion is achieved. The location of the radial nerve must be realized so that it can be protected. It lies on the latissimus dorsi tendon and then crosses in front of the teres major as it courses toward the proximal portion of the spiral groove. It has been shown to be an average of 2.9 cm medial to the superior aspect and 2.3 cm medial to the inferior aspect of the humeral insertion. The teres major is then identified and similarly released from the humerus with alternating figure-of-eight as well as Mason–Allen sutures placed. It is also mobilized to achieve 3cm excursion. At this point, an opening is created posterior to the shaft of the humerus to mobilize the triceps off the humeral shaft with a Cobb elevator. Blunt palpation can confirm that a large enough opening has been created. A suture passer is used to retrieve the sutures through the tendons, such that they are passed posteriorly and brought around to the lateral shaft of the humerus. The arm is internally rotated so that the soft tissue can be cleared off the lateral humeral shaft and the bone is abraded with a burr to create a surface receptive to healing. Holes are then drilled in the shaft, on either sides of the bicipital groove. Using a suture passer or suture loop, the sutures are then passed through the holes. After the final humeral component has been placed and the shoulder reduced, the sutures are then tied securely, completing the tendon transfer (Figure 11).

Post operative management

In our department, after a standard RSA, the superior limb is placed in a sling for 2 to 3 weeks. Patients are allowed immediate pendulum exercises and gentle activities of daily living. Passive motion is initiated immediately with limited external rotation depending on the



Figure 8 Baseplate of the UNIC® system with an helical Blade increasing the bone-metal surface.

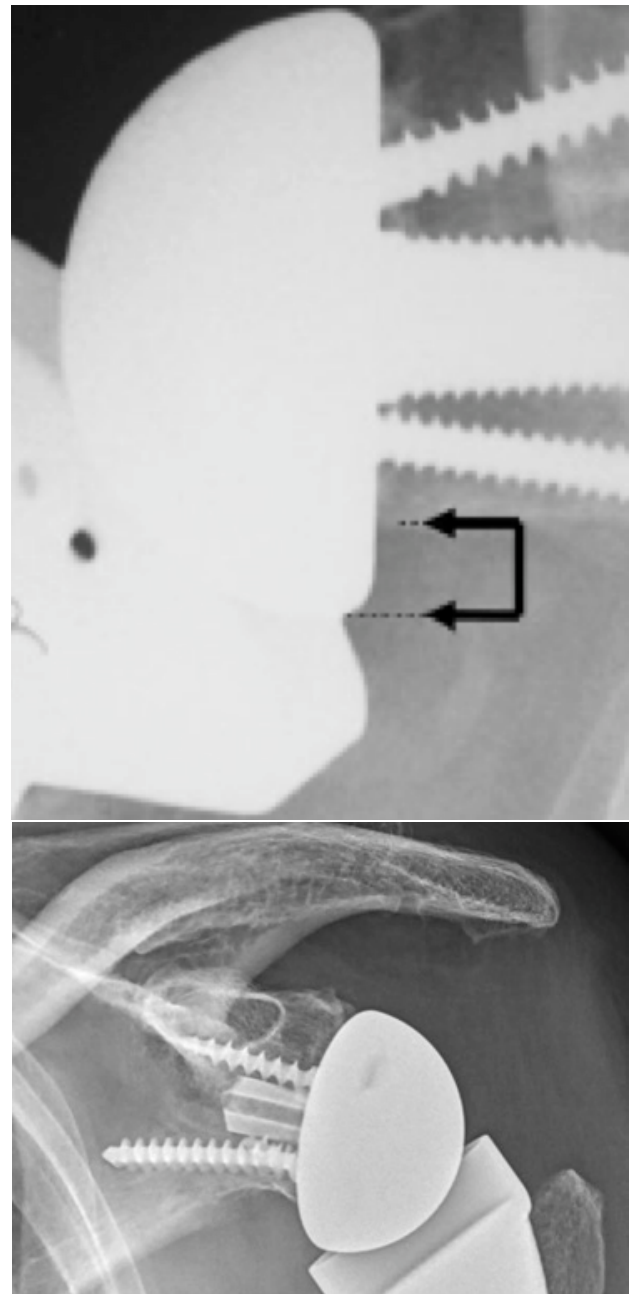


Figure 9 Glenosphere overhanging the inferior border of the glenoid.

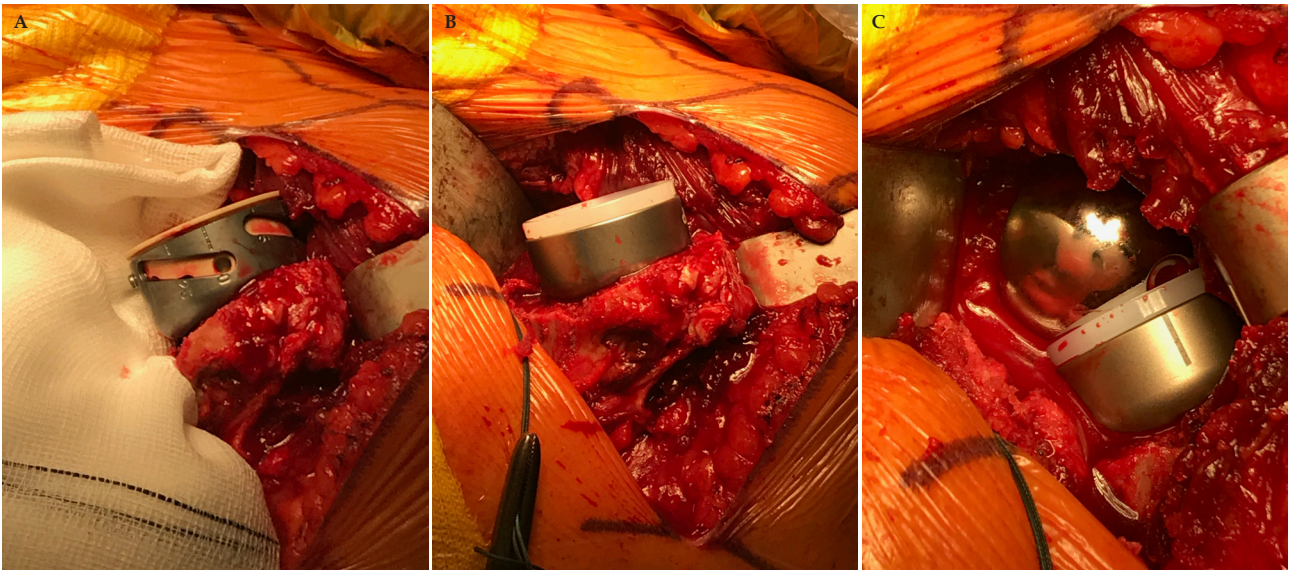


Figure 10 (A) UNIC® trial cup; (B) UNIC® cup before... (C) and after reduction.

peroperative data and the approach. At four weeks post op, external rotation in abduction and hand behind the back are permitted.

After a RSA associated with a LD/TM transfer, the arm is immobilized in external rotation for 6 weeks with motion of elbow and hand. During shower, the arm must be in external rotation. After six weeks, the immobilizer is removed and active and passive range of motion is allowed.

INDICATIONS OF RSA IN MCT WITHOUT GLENOHUMERAL ARTHRITIS

CTA is a clear and well accepted indication of RSA because with other treatments, medical, conventional shoulder prosthesis^[105], repair^[106], results are disappointing^[2,5,14,15,18,25,35,47,51,106]. The advent of RSA was revolutionary in the treatment of this condition^[2,63,66,70,107-109].

But in patients with MCT and absence of arthritis, the optimal treatment is less obvious and still controversial. The treatment has to be adapted to each patient according to the age, general status, pre-operative function especially pseudo paralysis or antero superior escape. Of course, characteristics of the tendon tear are also very important: chronicity, retraction, quality of muscle, fatty degeneration. Finally that means: is the tendon reparable or not?

If the tendon seems being irreparable, surgical options are limited: partial tendon repair particularly external rotators to rebalance the shoulder^[110], allografts or superior capsular reconstruction but the experience is short and data limited^[51-54] and in pseudo paralytic shoulders, results are unpredictable. Transfers or palliative options (tenotomy or tenodesis of a long head of biceps still present)^[43] could be discussed but have the same limitations. RSA, in these difficult situations, is a reasonable option to relieve pain and restore function^[111-113].

A patient being considered for RSA should have a painful, irreparable rotator cuff tear and evidence of pseudoparalysis with active forward elevation less than 90°^[37,39]. One should look closely at the patient's age, health status, and comorbid conditions.

Some specific factors may play a role in the indications and results: age, prior surgery, active range of motion, instability and cuff status.

Age

While multiple reports have shown RSA to be a reliable procedure

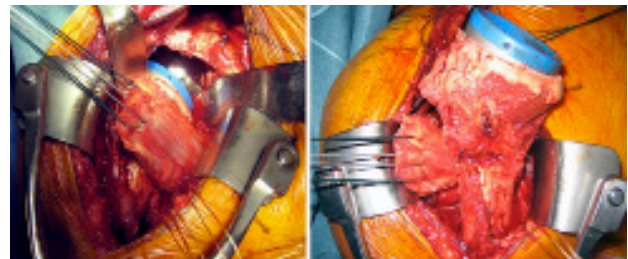


Figure 11 LD and TM transfer before and after passing back of the humerus Coll P. Boileau.

with good outcomes in patients less than 65 years of age^[65,111,112], Muh *et al* reported that patient satisfaction was lower for younger patients^[111]. Hartzler *et al*^[69] recently found younger age to be a risk factor for poor functional improvement after RSA in the specific setting of MCT without arthritis. Accordingly, the Frankle team rarely considers performing RSA as an index procedure for MCT without arthritis in patients < 65, and one should exercise caution in this population. However, the elderly patient, particularly if they have poor prognostic indicators for rotator cuff healing such as smoking or diabetes, may be ideally served with RSA^[22,39].

Prior surgery

Careful consideration should be given to a patient's prior history of shoulder surgery, particularly a previously failed attempt at RCR. Denard *et al* previously found that revision RCR was able to reverse pseudoparalysis in only 43% of patients with MCT^[15]. Moreover, Shamshudin *et al* reported that revision cuff repair was associated with declining functional outcomes after 6 months, more re-tears, more pain with activities of daily living, lower activity level, and decrease overall satisfaction at 2 years post-operatively compared with primary cuff repair^[114]. Thus, RSA is an excellent salvage operation in these patients and may be more prudent than a repeated attempt at repair. Importantly, Sadoghi *et al*, Frankle *et al* found that previously failed arthroscopic rotator cuff surgery did not have a negative impact on outcomes and survival rate after reverse shoulder arthroplasty^[115,116]. In contrast, the improvement is slightly less for Boileau *et al* and Werner *et al*^[14,53] and for Mulieri who directly compares RSA for MCT without arthritis with or without prior surgery, no significant differences was observed^[37].

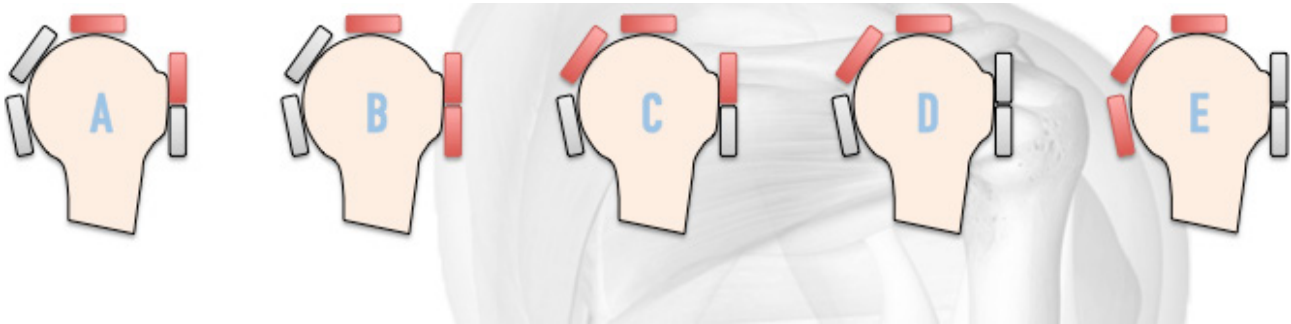


Figure 12 Collin P *et al*. Classification of cuff lesions: A: subscap sup+supraspinatus; B: Whole subscap+supraspinatus; C: Subscap sup+supra+infraspinatus; D: Supra+infraspinatus; E: supra+infra+teres minor.



Figure 13 Antero superior escape of the humeral head.

ROM and instability

As we noted before, pseudoparalysis which failed to recover with physiotherapy well observed during 6 months is a good indication for RSA, especially in type B (large antero superior ruptures)^[117] with 80% of pseudo paralysis never recovering with physiotherapy. At the opposite, Type A never presents paralysis and type D recovers well (Figure 12)^[25]. The absence of teres minor is always bad prognostic indicator whatever the treatment^[110,117].

Then it is necessary to carefully assess the patient’s shoulder stability. On physical exam, anterosuperior escape of the humeral head can be observed with attempted abduction of the arm, indicating dynamic instability^[39]. These patients may or may not have a narrowed acromiohumeral interval on radiographic imaging, indicating more chronic instability and subluxation. Patients with a painful MCT, obvious instability, and moderate to severe anterosuperior escape are appropriate candidates for RSA (Figures 13-14).

CONTRA INDICATIONS?

Except for Läderman^[118], the non-functional deltoid is the only true contra indication of RSA, in case of radiculopathy, axillary nerve injury, or deltoid injury from prior open surgery. A careful physical and, potentially, electromyographic examination may differentiate deltoid and cuff weakness. The other contra indications are, in fact, non-indications: possible reparable cuff tear in a young patient with massive but recent traumatic cuff rupture is an indication of cuff repair.

Are there patients with a risk of having poor outcomes with RSA implanted for MCT with no arthritis? Hartzler *et al*^[69] found three risk factors of poor improvement: age < 60, pre operative SST > 7,

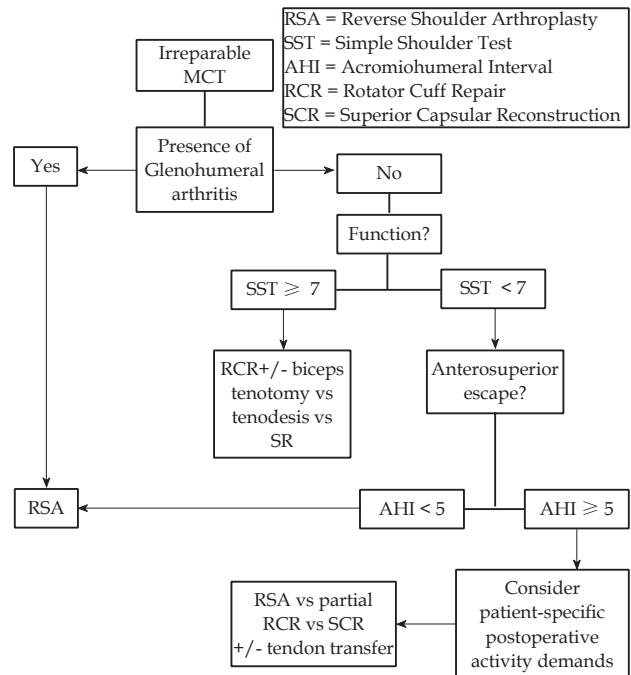


Figure 14 Algorithm of treatment proposed by Sellers, Frankle *et al*^[77].

neurologic dysfunction. Werner *et al*^[13] found that good pre operative ASES score is correlated with poor post op improvement. Mulieri^[37], Boileau^[63,66] observed that a pre operative forward elevation > 90° is associated with a less improved result and a higher risk of complication. But, at the opposite, Hartzler^[69] did not find any negative influence of a good pre operative elevation.

If a good elevation is not a contra indication for an RSA, it is a factor to take into account. Another one is the loss of active external rotation which means a combined atrophy of infra spinatus and teres minor, which badly influences the result^[69] and indicates latissimus dorsi transfer associated with the RSA. This transfer includes approximately 13% to 17% of patients and gives good results^[48,49,102].

OUTCOMES

We can evaluate the outcomes regarding pain and function, the radiological evolution, the survival rates of the RSA in MCT.

Function

Publications are numerous in the literature and unanimous on the good or excellent results obtained by the RSA in this specific indication or combined with RSA in CTA. All items are improved:

Sirveaux *et al* in 2004^[97] published a series of 80 replacements,

with a follow-up of 24 to 97 months, with an increased Constant score from 23 to 66, AAE from 73° to 138°, and 96% of patients having no or minimal pain, but with 15% of complications. They noted the importance of teres minor for a good functional result and the frequency of notching affecting the Constant score when it was a grade 4.

Frankle *et al* in 2005^[115] published one of the first studies on RSA in MCT but with arthritis on 60 replacements with a follow up of a minimum of 24 months, they also noted the good results on pain (VAS 6.3 to 2.2), ASES score from 34 to 68, AAE 41° to 101°. 93% of patients were satisfied. There were 17% of complications.

Mole *et al* in 2006^[73] published probably the first series of results from a multicenter study presented at the Nice Shoulder Course of patients having an RSA for MCT without arthritis. 48 replacements were followed for a minimum of 30 months. Constant score improved from 28 to 63, AAE improved from 80° to 133°, ER from 10° to 13°. 93% of patients were satisfied. There were 17% of complications.

Boileau *et al* in 2007^[109] participated in a large, french multicentric study of 484 replacements including 206 MCT, with a follow-up of 24 to 135 months, the Constant score increased from 24 to 62, AAE from 70° to 130°, Pain from 4 to 13, and 90% of patients were satisfied. They noted a minimal gain on external rotation, a risk of loss of internal rotation in 22% of cases, and a negative influence of a young age, a deficient teres minor and prior operation.

Wall *et al* in 2007^[68] noted on a series of 111 patients with 17% of MCT with a follow-up of 34 months that the Constant score increased from 23 to 63, AAE from 94° to 143°, pain decreased by 56%. But the external rotation decreased by 6° and there was 19% of complications not separately studied for MCT.

Boileau *et al* in 2009^[66] published a study of RSA after failed rotator cuff surgery including 15.7% without arthritis. They studied 42 RSA in 40 patients (mean age 71 years), with a follow up of 50 months. These patients improved their pain rating of 49% and their Constant score of 40.9%. They noted that the results were much better in pseudo paralytic shoulders than in shoulders with maintained preoperative elevation. Moreover, in the last group, 23% of patients were dissatisfied.

Mulieri *et al* in 2010^[37] specifically studied a group of 72 replacements on MCT without arthritis with a follow up of 24 to 101 months. ASES score improved from 33 to 75, SST 1.6 to 6.5, VAS for pain from 6.3 to 1.9, AAE from 53° to 134°, ER1 from 27° to 51° and internal rotation from S1 to L2. There was 20% of complications. At 52 months, the survival rate was 91%. These differences could be due to the non-Grammont style prosthesis utilized in this series.

Valenti *et al* in 2011^[120] retrospectively reviewed 76 patients with less medialized RSA in pseudo paralytic shoulders, the follow up was from 24 to 60 months, the Constant score increased from 24 to 59, EAA increased from 65 to 126°, external rotation from 15 to 30° and pain Constant score improved from 4 to 14. With a relatively short follow up there was no notching or glenoid loosening.

Hartzler *et al* in 2015^[69] specifically studied the risk factors of poor functional improvement in a series of 74 patients followed for a minimum of 2 years (average 43 months), VAS pain improved from 5.5 to 2, SST score from 2.2 to 7.6, ASE from 41.6 to 74, AAE from 60 to 121° and external rotation from 20° to 28°. They identified that young age < 60, good preoperative function (SST > 7) and neurological dysfunction are associated with poor functional improvement. It has been partially confirmed by...

Werner *et al* in 2016^[13] who did not find a correlation with the age, but a high pre operative ASES score and an intact cuff at the surgery.

Petrillo *et al*^[121] in 2016 did a meta analysis based on a systematic

review of the literature. Seven articles including the previous one were selected. A statistically significant improvement in all clinical scores was found. 408 replacements were analyzed with a follow-up of 12 to 101 months. Constant score improved from 31 to 60, SST from 2 to 7.5, AAE from 50° to 125°, ER1 from 17 to 28 and ER2 from 8 to 47, SSV from 27 to 77. There was 17% of complications but there was no mention of data on internal rotation.

Gonzalez *et al*^[71] in 2016 were in charge of analyzing the special chapter of RSA on MCT without arthritis for the Nice shoulder course 2016. 114 patients were followed for 60 to 246 months. The Constant score improved from 27 to 61 stable in time, AAE from 71 to 136°, ER1 from 14 to 19°, but internal rotation did not improve. There was 19% of complications. This study highlighted the role of teres minor to obtain a good functional result and an active external rotation. In case of bad teres minor, a transfer of latissimus dorsi may be indicated increasing active external rotation (+26°). At more than 8 years of follow up there was 77% of notching with no glenoid loosening and no negative effect on the Constant score. A pre operative stiff shoulder has a negative effect on the Constant score and final ROM, indicating a physiotherapy before the surgery.

Sevivas *et al*^[112] in 2017 performed a comprehensive search on the databases. 6 studies including 266 shoulders were included with a follow up from 34 to 61 months. This study confirmed the conclusions of the previous publications.

Oudet *et al*^[122] in 2017 participated in a multicenter study proposed by the Arthroscopic French Society. 218 patients were enrolled in this prospective, non randomized study comparing different treatments including patients presenting a MCT (2 tendons minimum with a fatty degeneration > 2): medical, partial cuff repair, isolated tenotomy of the biceps, latissimus dorsi transfer and RSA (36 patients).

Despite a worse pre-operative situation in the group of RSA, at one year of follow-up, the results are better for pain: 5 to 14, SSV: 33 to 84 and Constant score: 31 to 74 (Figure 15) but less good for AAE: 79 to 147 and internal rotation: 4.3 to 4.5 decreasing in 1/3 of cases and the patients have to be informed. We concluded that the RSA is a reliable treatment for patients up to 65, especially in case of pseudo paralytic shoulder.

In summary, RSA is a good treatment when medical treatment fails. It improves functional scores (Constant, ASES, SST, SSV...), pain scores with 48% of improvement, ROM especially the anterior active elevation with a gain from 50 to 75°, patient's satisfaction rates ranging from 65 to 95% of good and excellent results. We have to keep in mind the risk of less good results in young patients and if the preoperative functional score is still good or if the active elevation is > 90°. In addition, it is necessary to inform the patient that there is a risk of loss of internal rotation.

Long-term evolution

One concern regarding the routine use of RSA, particularly in younger patients, has been that of the longevity of the implant^[111]. This is of critical importance given the known high complication rate and technical difficulty of revising RSA^[123-128]. Two early reports of the long-term survivorship of RSA both demonstrated a survival rate of 95% at 120 and 97 months, respectively, when performed specifically for MCT with arthropathy^[97,129]. More recently, Bacle *et al*^[130] observed an implant survival rate of 93% at a minimum of 10 years after RSA performed for multiple indications. Cuff recently reviewed 10 years follow-up data and found implant survivorship of 91%^[70].

While post-operative complications and long-term implant survival appear to be reasonable, there is the additional concern of potentially

decreasing functional outcomes over time with RSA. Both Guery *et al* and Sirveaux *et al* noted deterioration in functional scores after 6 years^[97,129]. As part of a multicenter study, Favard *et al*^[131] reviewed a large number of RSAs performed by multiple surgeons using different approaches and implants and found a decrease in Constant-Murley scores after 8 years. Most recently, Bacle *et al*^[130] found a similar decrease in Constant-Murley scores at a long-term follow-up (average 150 months) when compared to the scores at mid-term follow-up (average 39 months). It is worth noting that RSAs performed for the indications of CTA and MCT were associated with less functional decline. In a review of the most recent follow-up data of the Frankle team, the authors found that their patients maintained their improvements in ASES, SST, and pain scores at 10 years^[70]. They observed a small decrease in range of motion in all directions between the 5-year and 10-year studies, which they attribute to the advanced age of the cohort (average age of 78 years at last follow-up). It has been observed in most series that RSA performed for MCT and CTA give better results in the short and long-term when compared to RSA performed for other indications^[97,117,129-131].

Beside these uncertainties about long-term results and survival of RSA in MCT, a lot of publications noted the high risk of complications: Zumstein *et al*^[128] published in 2011 a meta analysis on 782 RSA: the most common post operative complications of RSA are: instability (4.1 %), Infections (3.8%), fractures of the spine

(1.5%) but these percentages are less prevalent in the publication of Groh^[100].

G. Walch reported in September 2016, during the MASES meeting^[117], the results of the multicenter study on Grammont style RSA presented at the Nice Shoulder Course 2016. It was a very large series of 1035 RSA with a follow up of 5 to 20 years (average FU: 8.2 Y)! This study analyzed complications, survival rates and results according to the etiologies. As noted by Groh, complications are less frequent than reported by Zumstein: infection: 2.6%, instability 2.3%, humeral complications 1.7%, scapula fracture 0.8%. More interestingly, the average Constant score of RSA for MCT (63 pts) was, with CTA, failed cuff surgery and primary osteoarthritis (OA), the best of the series with stable results at ten years, refuting the conclusions of the previous series. The survival rate at 10 years was 95.3% for MCT, 94.7% for CTA and 90% for OA. G. Walch pointed out the risk of loss of internal rotation and the necessity to evaluate the teres minor which is essential to have a good functional result depending on the activity of the last external rotator. Another important conclusion of this presentation was the high percentage of nothing (52%).

The notching

Notching is a problem specific to the RSA and notching is a post op problem before potentially becoming a complication (Figure 16C). Its frequency varies from 44 to 96%!^[81,83,97,117]. It is an osseous defect in the scapular neck resulting from a mechanical contact between the PE cup and the inferior or posterior pillar of the scapula and an osteolytic reaction due to PE wear (Figure 16B).

Described for the first time by F. Sirveaux in 1997 in his medical thesis in 4 stages (Figure 16A), it seems to evolve over time with controversial functional consequences depending on the series published^[13,83,97,117,124]. Factors influencing the notching frequency are^[117] pre operatively: BMI, Etiology (MCT, CTA) and vertical erosion and inclination of the glenoid, per operatively: the baseplate positioning which has to be as inferior as possible and inferiorly tilted, the lateralization and diameter of the sphere and the cut of the humerus more vertical (140°). In preventing notching, the rules of implantation are important as well as the design of the prosthesis. Because of the higher frequency of notching in RSA for MCT, these rules have to be strictly respected.

Personal experience and evolutions

My first RSA Grammont style has been implanted in 1994. I followed the technical evolutions of this prosthesis and participated

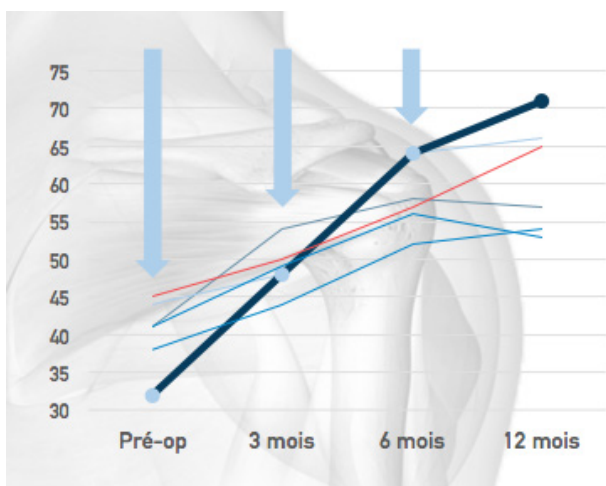


Figure 15 SFA series, evolution of the Constant score, comparing from final top to bottom: RSA, partial RCR, LD transfer, medical treatment, tenotomy of the LB, pre operatively and at 3, 6, 12 months.

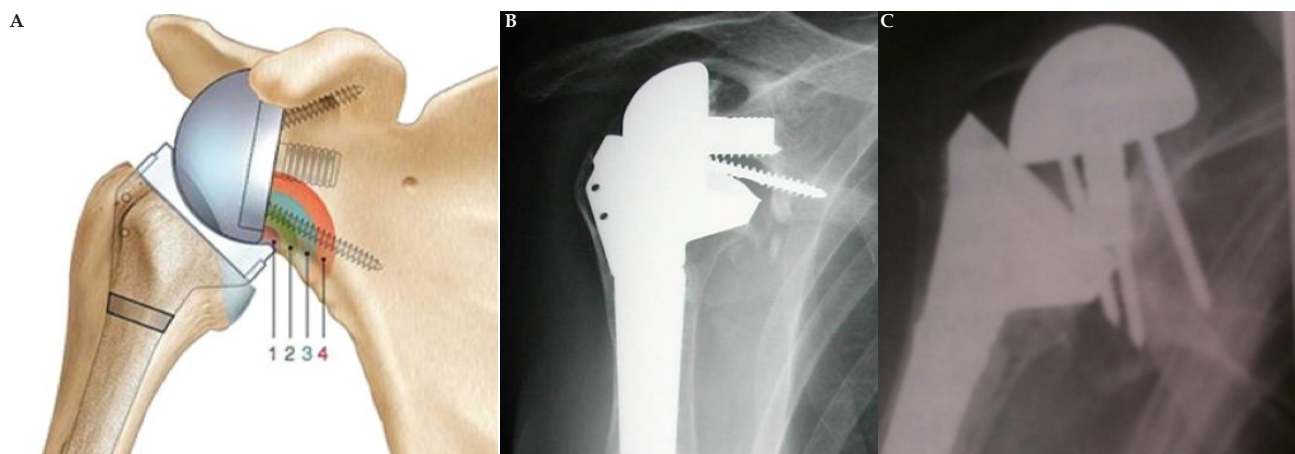


Figure 16 A-B-C (A)4 stages described by F Sirveaux; (B): Notching stage 4; (C): Complete loosening of the baseplate

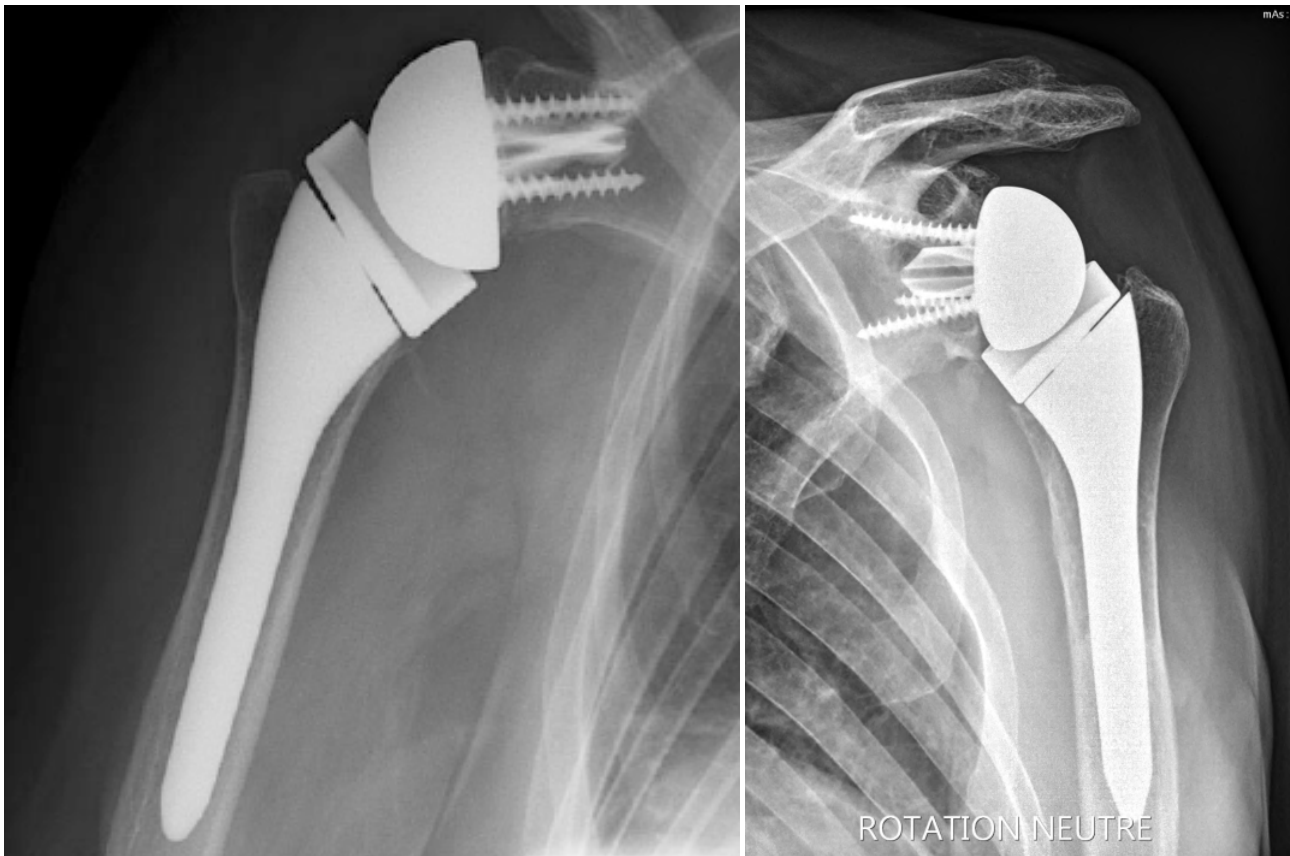


Figure 17 (A) UNIC® RSA at 5 years; (B) UNIC®RSA at 10 years.

in the follow up of the first cases. In 2007, we developed with a group of colleagues^[95] and the Evolutis Company (Briennon, France) the UNIC® RSA. At this time, original ideas concerning diameter of the sphere, fixation of the baseplate, humerus component design, fine tuning of the soft tissue tensioning, original system of connection between the stem and the cup, platform system, ...etc were analyzed. After 10 years and 302 RSA personally implanted, our complications rate is very low with functional results comparable to the other systems: 2 disassembling stem-cup, 1 dislocation, 0 nerve injury, 1.5% of infections, 2 late glenoid loosening in patients with long-term treatment by cortisone. Moreover, we observed a really low frequency of notching, less than 10%, not exceeding grade 2 (Figure 17).

We developed specific extra small sizes for the Asian market, dedicated stems for fractures and revision system including stems and glenoid baseplates because of the constantly rising number of RSA implanted particularly in younger people with a higher risk of revision. We are working to improve the baseplate positioning by an easy-to-use system of clamp and, simultaneously, Evolutis with the Moveo Foundation and Thomas Gregory, implanted recently a UNIC® RSA assisted by Hololens® glasses in virtual and augmented reality.

CONCLUSION

There is probably no other domain in orthopedic surgery where a prosthesis is indicated in the absence of any cartilaginous lesion of arthritic origin. RSA has shown excellent results for the treatment of MCT with no glenohumeral arthritis, with nearly a 50% reduction or more in patients' pain and 135° of elevation. Of course, CTA remains the classic indication of RSA. Several recent publications reported

good results with more than 10 years of follow up. These results concern prosthesis implanted years ago, with an "old" design, with imprecise rules of implantation especially regarding the positioning of the sphere. We can reasonably hope that the results of "new" RSA will be better and more sustainable. If the RSA may be a reasonable option for certain patients with a massive cuff tear, we have to keep in mind that the treatment must be tailored to each patient. The ideal candidate for RSA is an elderly, lower-demand individual with chronic, non-repairable cuff deficiency, pseudo paralysis, with or without antero-superior escape. In younger patients, all other possibilities should be evaluated and discussed, recent developments of superior capsular reconstructions may be helpful. In some cases, RSA is indicated, even in a young patient, especially in case of large irreparable antero-superior cuff rupture because there is no palliative or reconstructive option, or in case of prior failed rotator cuff repair because of the high risk of failure of a re-repair. There are risk factors of poor outcome of RSA for MCT: young age, better pre-operative function, neurologic dysfunction. The patient must be informed before the operation that he has a risk of loss of ROM, particularly in internal rotation. If the option of RSA is selected, care must be taken to prevent any infection and to perfectly implant the prosthesis to prevent the occurrence of notching, initially only a post op problem but which may become a true and severe complication.

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