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Surgical techniques

Reverse shoulder arthroplasty in recent proximal humerus fractures

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ABSTRACT

Reverse shoulder arthroplasty is now the standard treatment for displaced, three- or four-part, proximal humeral fractures in patients older than 70 years. Inadequate tuberosity repair or inappropriate humeral stem position are associated with poorer outcomes, notably regarding rotation and stability. Strict operative technique during prosthesis implantation is therefore crucial to obtain reliable and reproducible outcomes. The objective of this article is to describe the surgical technique for reverse shoulder arthroplasty used to treat recent proximal humerus fractures.

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1. Introduction

Changes in the treatment of proximal humerus fractures in recent years include both the growing popularity of internal fixation and the declining use of hemiarthroplasty due to a preference for reverse shoulder arthroplasty (RSA) for displaced, three- or four-part fractures in patients older than 70 years [1]. In these patients, hemiarthroplasty fails to produce reproducible and reliable outcomes in the event of tuberosity non-union or migration [2–5]. In contrast, RSA medialises the centre of rotation of the shoulder and lowers the humerus, thereby increasing the lever arm of the deltoid muscle, which then ensures good forward elevation, even when the rotator cuff is deficient [6]. Tuberosity non-union and/or migration are associated with poorer outcomes after RSA, notably regarding rotations [7–12] and stability [13–15]. One of the leading reasons for revision surgery after RSA is instability [10,16], which may be related to errors in height and/or version of the humeral stem [8,13,17]. Rigorous surgical technique must therefore be applied when implanting reverse shoulder prostheses in order to ensure reliable and reproducible outcomes.

2. Indications/contraindications

In recent proximal humerus fractures, the decision to perform RSA is based on patient age and comorbidities and on the characteristics of the fracture including tuberosity displacement and comminution, the condition of the cuff and calcar, the extent of the displacement, and the risk of avascular necrosis.

RSA is indicated in patients older than 70 years who have a three- or four-part displaced fracture with a high risk of avascular necrosis of the humeral head and/or poor-quality comminuted tuberosities and/or a pre-existing rotator cuff tear [5]. RSA should not be used as the first-line treatment in young active patients. Contraindications of RSA include pre-existing or concomitant axillary nerve injury, concomitant fracture of the scapular spine or acromion that might be displaced by increased tension of the deltoid muscle and concomitant glenoid fracture that might preclude the implantation of a glenoid baseplate.

3. Pre-operative work-up

This procedure is not urgent and should be carried out after proper planning. The imaging work-up consists of standard anteroposterior and lateral radiographs and of computed tomography (CT) with 3D reconstruction to provide an accurate analysis of the condition and displacement of the tuberosities [18] and of the characteristics of the glenoid (bone stock, version and glenoid type) [19]). Soft tissue windows supply information on pre-operative cuff trophicity and fatty degeneration. Metaphyseal bone loss should be assessed with care, and pre-operative planning of the humeral height to be restored is essential. In the event of substantial metaphyseal bone loss, a radiograph of the entire contralateral humerus can be obtained to accurately assess the height of the implant [20–22].

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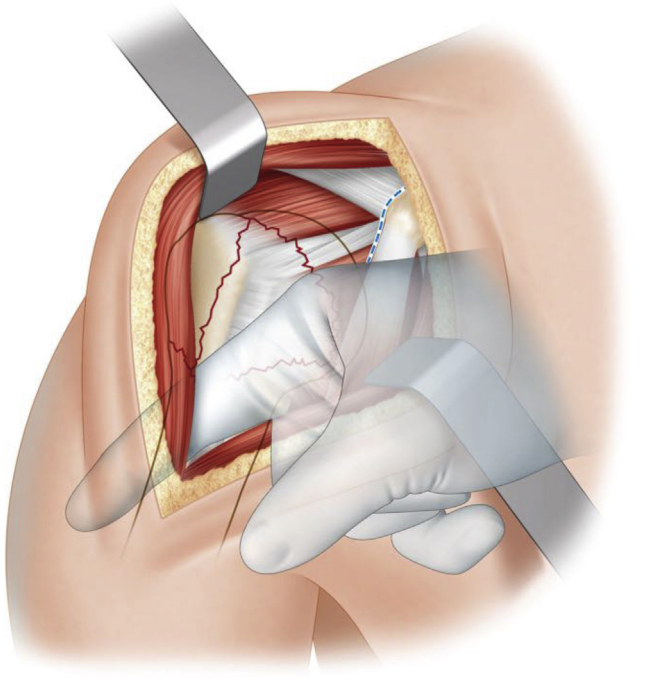

Fig. 1. Delto-pectoral approach: long (8–10 cm) and lateralised. The deep aspect of the deltoid muscle must be fully released to allow posterior mobilisation of the muscle.

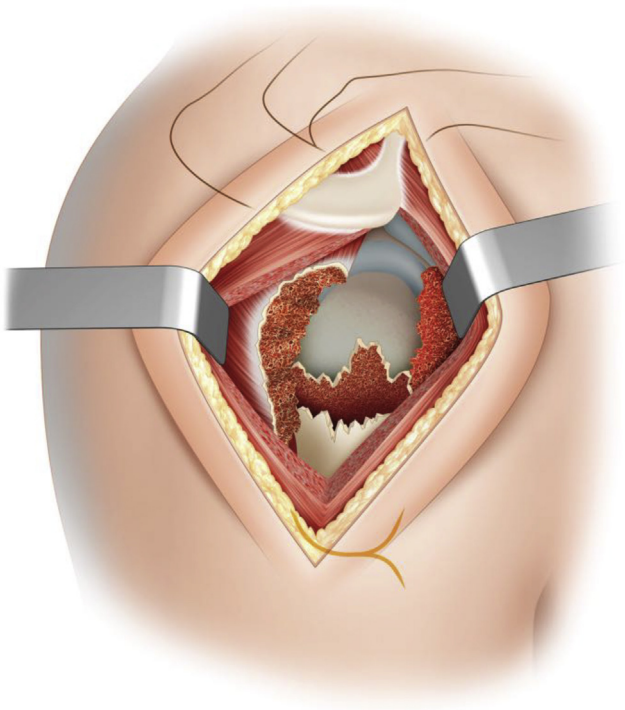

Fig. 2. Supero-lateral approach: incision along the anterior edge of the acromion without going beyond 38 mm under the lateral edge of the acromion to avoid injuring the axillary nerve.

4. Operative technique

4.1. Anaesthesia and installation

The procedure is performed under general anaesthesia with or without an interscalene block to ensure post-operative pain control.

The patient is in the beach-chair position tilted at 30– to 60–, on the edge of the table. The position should allow free anterior and posterior shoulder movements, as well as retropulsion of the humerus. The arm is placed on a rest.

4.2. Surgical approach

Either the delto-pectoral or the supero-lateral approach may be used. With the delto-pectoral approach, reduction of the greater tuberosity is more difficult to control and access to the glenoid is less direct. Nevertheless, this approach deserves preference in patients with a fracture-dislocation injury or a fracture line extending into the metaphysis. It also has the theoretical advantages of sparing the anterior deltoid and of avoiding axillary nerve exposure. When using the delto-pectoral approach, the upper edge of the pectoralis major tendon can serve as a landmark for the height of the prosthesis and the reduction of the tuberosities.

The delto-pectoral approach is a lateralised 8-to-10 cm approach that starts at the acromio-clavicular joint and extends to the tip of the deltoid V to ensure that access to the glenoid is as direct as possible. The deep surface of the deltoid must be fully released to allow posterior mobilisation of the muscle. The clavi-pectoral fascia is opened at the lateral edge of the conjoined tendon and the coraco-acromial and coraco-humeral ligaments are cut flush with the coracoid process (Fig. 1).

The incision is made along the anterior edge of the acromion, from the acromio-clavicular joint to 38 mm under the lateral edge of the acromion. This limit is important, as extending the incision further carries a risk of axillary nerve injury. The fibres of the anterior and middle deltoid are separated. A suture can be placed at the distal part of the separation between the two deltoid bundles to protect the axillary nerve. The anterior deltoid and coraco-acromial ligament are detached en-bloc, sub-periosteally, from the acromion. Acromioplasty can be performed to improve exposure (Fig. 2).

4.3. Identification of the tuberosities and rotator cuff

The haemorrhagic sub-acromial bursa is excised. The long head of biceps tendon is identified and the bicipital groove is opened. Tenotomy of the biceps tendon is performed routinely. Tenodesis at the distal part of the groove is an option, although no effect of this procedure has been demonstrated. The fracture is usually located immediately lateral to the groove. The tuberosities are separated at the fracture line. The rotator interval is identified and opened down to the glenoid. The supra-spinatus tendon is excised down to the glenoid. Although this tendon can be spared, it may then place excessive traction on the greater tuberosity after the reduction (Fig. 3). The greater tuberosity is identified and mobilised, taking care to preserve the periosteal attachments to the extent possible. Four suture loops are run through the postero-superior cuff (Fig. 3) flush with the tendon attachments on the greater tuberosity (two loops in the medial-to-lateral direction in the intra-spinatus and teres minor tendons, after which the needles are removed and two in the lateral-to-medial direction through the same tendons). The humeral head is released from its capsular adhesions and removed to expose the medial aspect of the lesser tuberosity. It is kept as a graft source during reconstruction. The lesser tuberosity is identified and reclined forwards with the sub-scapularis. Two tag sutures

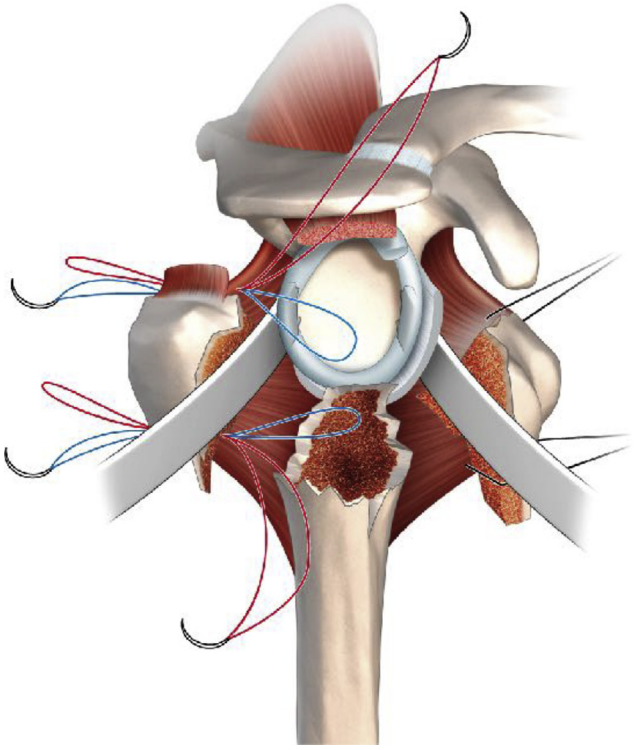

Fig. 3. Preparation of the tuberosities. The supra-spinatus tendon is excised down to the glenoid. Four suture loops are passed through the postero-superior cuff, flush with the tendon insertions onto the greater tuberosity; the needles are removed from two of the loops, which are passed from medial to lateral through the infra-spinatus and teres minor, respectively; and the other two loops are passed from lateral to medial through the same tendons. Traction sutures are used to pull the tuberosities apart. The anterior capsule is excised to expose the anterior glenoid rim. Two retractors are placed at the anterior and posterior borders of the glenoid, respectively.

are run through the sub-scapularis flush with its insertion on the lesser tuberosity to allow its mobilisation.

4.4. Preparation of the glenoid

The tuberosities are pulled apart using traction sutures and the anterior capsule is excised to release the anterior edge of the glenoid. Two retractors are placed at the anterior and posterior edges of the glenoid, respectively (Fig. 3). The labrum is excised and the capsule released circumferentially. The arm is positioned in adduction-external rotation to place the axillary nerve at a distance when releasing the inferior capsule [23–25]. The foot of the coracoid process and scapular pillar are identified. Electrocautery is used to trace the long vertical and horizontal axes of the glenoid, which serve as landmarks. The glenoid is then prepared using the dedicated tools. To optimise the functional outcomes and limit the risk of notching and/or loosening, the following recommendations must be followed: the glenoid implant should have 0° of tilt or 10° of inferior tilt but should never be tilted superiorly [26–28]; the glenoid implant should be flush with the lower rim of the glenoid [26]; implant retroversion must be less than 10° and can be assessed intra-operatively by palpating the central aiming point of the glenoid at the anterior part of the scapular neck [29]; reaming must preserve the sub-chondral bone stock; the superior screw must be inserted into the foot of the coracoid process and the inferior screw must be perpendicular to the baseplate [30] (Fig. 4). Once the glenoid implant is press-fit and screwed in place with sufficient stability, the glenosphere is fixed. Although

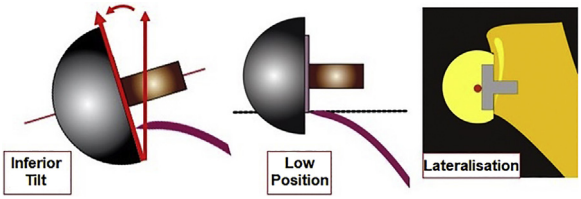

Fig. 4. Recommendations about positioning the glenoid component. The glenoid component should be positioned with less than 10° of tilt, flush with the inferior glenoid rim, using an implant that is lateralised using a bone or metal component.

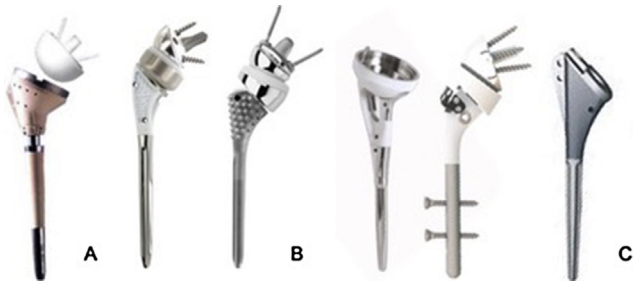

Fig. 5. A. Types of humeral stems. Standard filling stem. B. Fracture-specific filling stem. C. Fracture-specific non-filling stem.

the optimal glenosphere diameter remains unclear, a larger diameter may provide greater range of motion, provided the sphere is not too bulky [31–33]. Lateralisation of the glenoid (achieved using bone or metal) significantly diminishes the risk of scapular notching.

4.5. Selecting the humeral stem

Available humeral stems fall into three categories:

- standard filling stems (Grammont type);
- filling fracture-specific stems (i.e., bearing holes to facilitate re-attachment of the tuberosities);
- non-filling fracture-specific stems.

Non-filling stems require the addition of bone grafts taken from the head and placed at the level of the tuberosities to improve their union (Fig. 5).

4.6. Implantation of the stem

The humerus is prepared using increasingly large broaches until rotational stability is satisfactory, without seeking to achieve cortical contact, which carries a long-term risk of cortical thinning due to stress-shielding [34]. The broaches are introduced with 20° of retroversion. This angle can be assessed relative to the axis of the forearm, bearing in mind that this axis forms a 10° angle with the bi-epicondylar line. Another option consists in alignment on metaphyseal retroversion at the fracture line, which predicts ipsilateral humeral retroversion [35] (Fig. 6). A 1.5-mm bit is used to drill two holes in the lateral cortex of the proximal humerus, 2 cm from the fracture line. Two vertical suture loops are threaded through the holes, one from the posterior hole to the anterior hole and the other from the anterior hole to the posterior hole, taking care to create two loops in the humeral shaft (Fig. 7). Humeral height should be painstakingly adjusted, as errors may result in instability. Several methods are available for positioning the humeral stem at the correct height. The height can be determined pre-operatively based on standard radiographs, by comparison with the contra-lateral humerus [22].

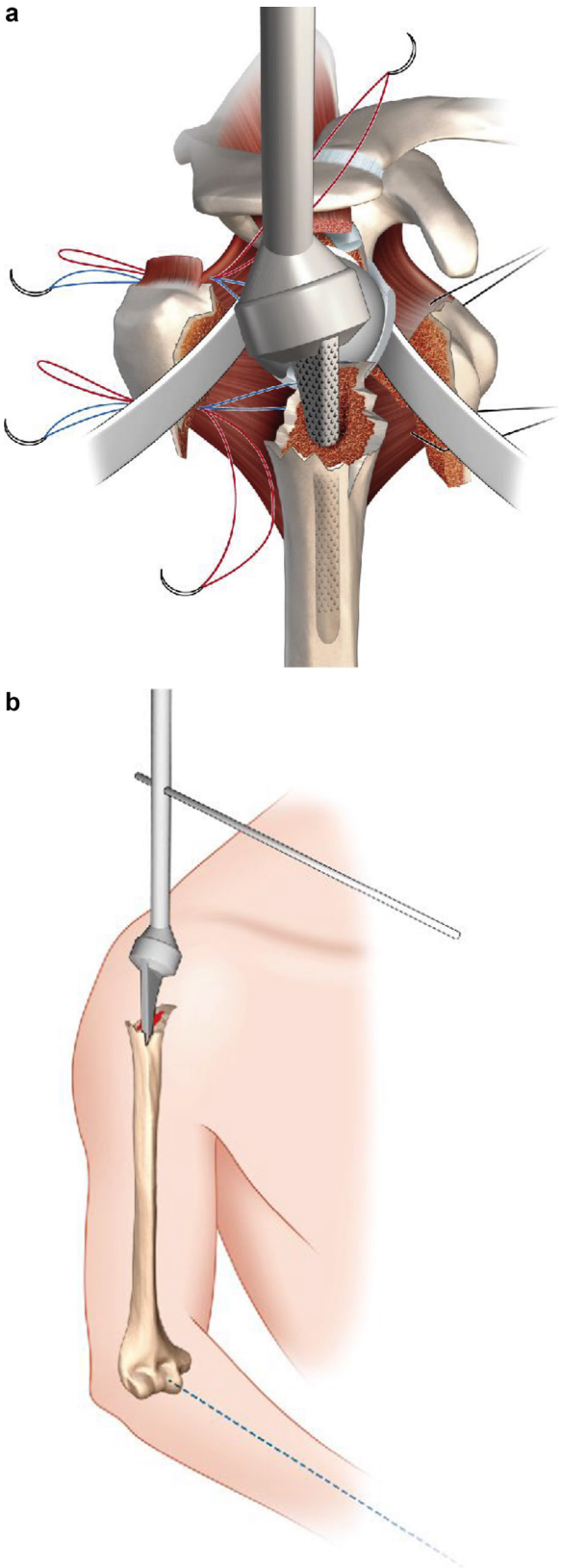

Fig. 6. The rasps are introduced with 20° of retroversion. The amount of retroversion can be determined relative to the axis of the forearm. Another option is to align on the metaphyseal retroversion at the level of the fracture line, which predicts retroversion of the ipsilateral humerus.

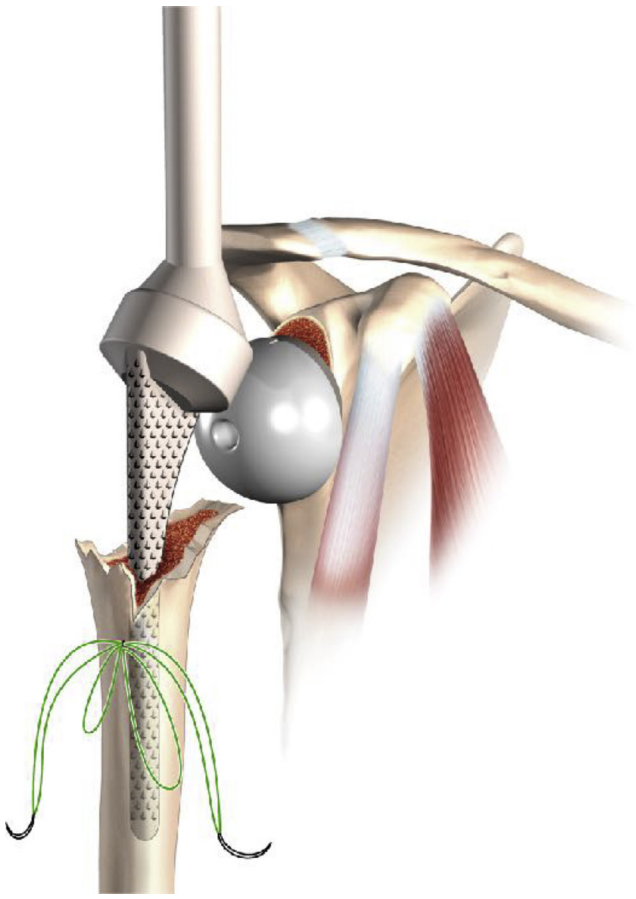

Fig. 7. Two holes are drilled using a 1.5-mm bit in the lateral cortex of the proximal humerus, 2 cm from the fracture line. Two vertical suture loops are threaded through the holes, one from the posterior hole to the anterior hole and the other from the anterior hole to the posterior hole, taking care to create two loops in the humeral shaft.

Intra-operatively, the options include using specific tools, positioning the lateral edge of the humeral stem 5.6 cm proximal to the pectoralis major tendon [36,37], or positioning this lateral edge flush with the apex of the anatomically reduced greater tuberosity. Fluoroscopy can be used intra-operatively to check that humeral height and the Gothic arch are restored [21] (Fig. 8). The trial prosthesis can be left in place and reduction performed to test stability. The prosthesis must be stable before fixation of the tuberosities can be performed. When reduction is difficult or impossible, a narrower stem should be used and not placed in a proud position. If the prosthesis is unstable, either a larger trial polyethylene component should be used or the stem repositioned in a somewhat proud position. A long stem is preferable if the fracture line extends to the metaphysis or diaphysis. When too much metaphyseal bone has been lost to ensure sufficient rotational stability during testing after reduction, the height landmarks described above can be used: alignment on the calcar, alignment on the apex of the reduced greater tuberosity, pre-operative planning based on radiographs of the entire humerus, or positioning of the greater tuberosity apex 5.6 cm away from the pectoralis major tendon.

To enhance union of the tuberosities, a prosthesis with an epiphyseal and metaphyseal coating that promotes osseo-integration should be used and cement should be avoided in this area.

After insertion of a distal plug, the humeral canal is rinsed and dried and cement of near-liquid consistency is introduced in

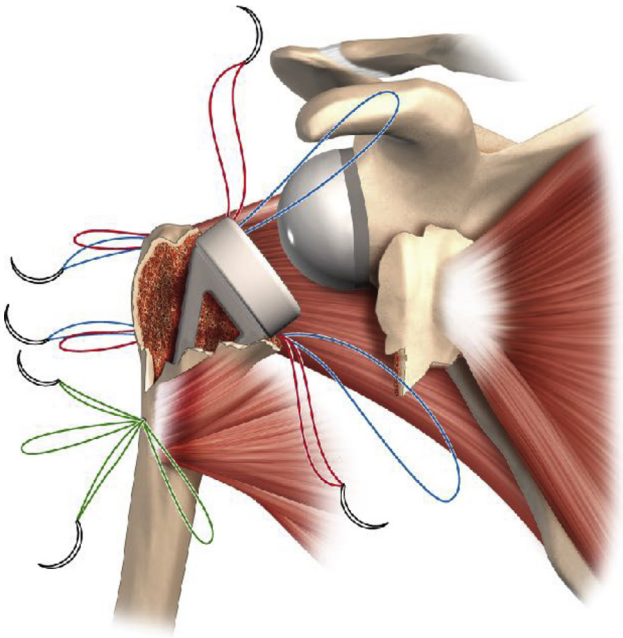

Fig. 8. Humeral height should be adjusted with great care as errors may result in instability. Intra-operatively, to ensure that the humeral stem is at the proper height, the lateral edge of the stem can be positioned 5.6 cm away from the pectoralis major tendon or flush with the apex of the anatomically reduced greater tuberosity.

the distal-to-proximal direction using a syringe [38]. Antibiotic-loaded cement (gentamicin, tobramycin, or vancomycin) is used to minimise the risk of post-operative infection [39]. The definitive stem is positioned at the previously defined height and retroversion. Once the cement is dry, trial humeral inserts are used and the prosthesis is reduced. Criteria for determining the optimal thickness of the humeral insert include the degree of difficulty in achieving reduction, whether a piston movement is present, passive motion ranges, stability and tension of the conjoined tendon [6]. However, these criteria allow only for a subjective assessment and vary with the degree of muscle relaxation [22]. The definitive humeral insert is then press-fit in place.

4.7. Fixation of the tuberosities

The two suture loops whose needles have been removed are passed under the neck of the prosthesis.

The suture loop with its needle coming from the infra-spinatus is passed from medial-to-lateral through the upper part of the sub-scapularis tendon, flush with the lesser tuberosity, skirting the medial edge of the prosthesis. The suture from the teres minor is passed from medial to lateral through the lower part of the sub-scapularis tendon in the same way (Fig. 9A). The prosthesis is then reduced. Cancellous bone fragments taken from the humeral head are impacted around the metaphyseal portion of the humeral stem (Fig. 9B). Reduction of the tuberosities is the next step. Forceps are used to place traction on the greater tuberosity and the two suture loops whose needles have been removed are knotted using the Nice Knot technique [40], while maintaining the arm in external rotation to facilitate the reduction (Fig. 9C). The lesser tuberosity is then reduced with a Museux forceps and the remaining suture loops are knotted in the same way (Fig. 9D). The vertical suture passed from posterior to anterior through the humeral shaft is passed through the upper part of the sub-scapularis, flush with the lesser tuberosity, and the anterior-to-posterior suture is passed through the upper portion of the infra-spinatus, flush with the greater tuberosity. The vertical sutures are then knotted according to the Nice Knot technique. The shoulder is manipulated to look for mechanical impingement or a cam effect. Forwards elevation is scored, as it predicts post-operative mobility [41].

The sub-acromial space is irrigated liberally to remove any particles of bone or cement. The shoulder is closed in layers. With the supero-lateral approach, the anterior deltoid is secured to the acromion using trans-osseous non-absorbable sutures, taking care to catch both the superficial and the deep deltoid fasciae in the sutures. With the delto-pectoral approach, the delto-pectoral interval is closed with loose stitches.

4.8. Immobilisation and post-operative care

The arm is placed in a splint for 45 days. Neutral rotation or abduction-neutral rotation is preferable over internal rotation to avoid placing tension on the greater tuberosity repair.

Pendulum exercises can be started rapidly after the procedure. In contrast, rehabilitation is best delayed rather than started immediately. The rehabilitation modalities in these elderly patients should be tailored to the abilities of each individual patient.

5. Conclusion

RSA is indicated in patients older than 70 years who have a displaced three- or four-part proximal humeral fracture. The anatomic union of the greater tuberosity provides satisfactory outcomes that are sustained over time. It is achieved by applying a rigorous surgical technique combining a specific non-filling stem with bone grafts and robust tuberosity repair.

Disclosure of interest

Jean-David Werthel receives royalties for shoulder prosthesis design from FH Orthopedics.

Francois Sirveaux is a consultant for Tornier-Wright.

The author Damien Block declares that he has no competing interest.

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Contributions of each author

David Werthel wrote the article.

François Siveaux was the supervisor and primary investigator.

Damien Block collected the data.

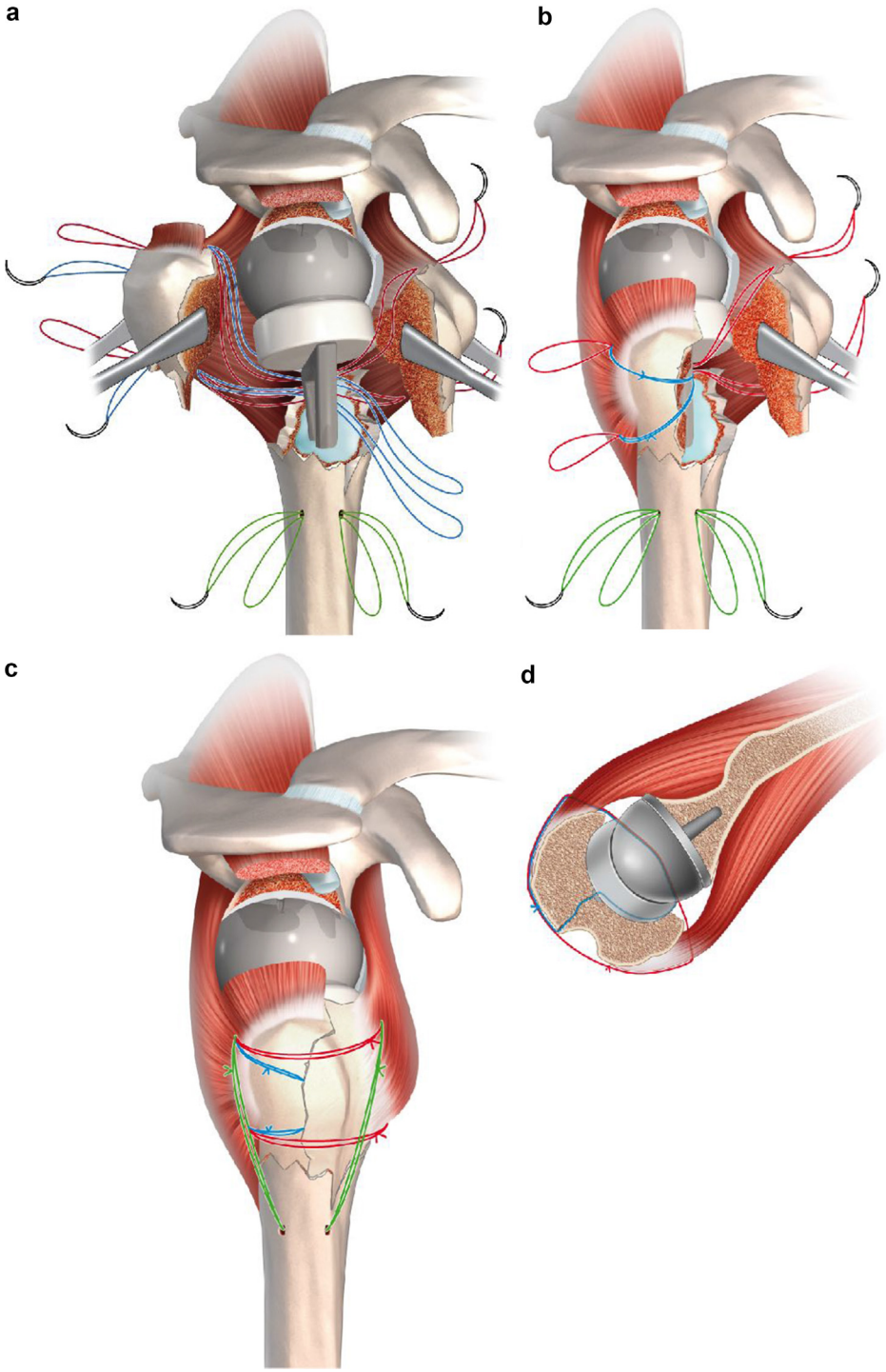

Fig. 9. Detailed surgical technique for tuberosity repair. A. Four suture loops are passed through the greater tuberosity (two in the infra-spinatus and two in the teres minor at the bone-tendon junction). B. The greater tuberosity is thus tied around the humeral stem and to the sub-scapularis. Two vertical suture loops are passed through the humeral shaft before the stem is cemented in place. C, D. The vertical sutures are passed through the upper part of the sub-scapularis and infra-spinatus then knotted.

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