Imaging of the operated shoulder: a pictorial review

Poster No.: C-2077
Congress: ECR 2017
Type: Educational Exhibit
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Keywords: Musculoskeletal joint, CT, MR, Ultrasound, Diagnostic procedure, Education and training, Prostheses
DOI: 10.1594/ecr2017/C-2077

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Learning objectives

The aims of this poster is to explain the normal and pathological post operative aspects of shoulder surgery, according to three steps:

I) Rotator cuff and biceps surgery

II) Instability surgery

III) Prosthetic surgery
**Background**

Before performing any radiological interpretation (MRI, CT-scan, ultrasound), it is mandatory for the radiologist to:

- have the surgical report of the patient.
- have standard x-rays
- perform an oral and physical examination

I) Rotator cuff and biceps surgery

A) Rotator cuff surgery

When surgeons put their arthroscope in a pathological shoulder, they can find what you see in figure 1, a large rotator cuff tear with a nuded footprint of the greater tuberosity in that case. Thanks to stitches mounted on anchors, they will be able to pull on tendons and to reattach them on the tuberosity (figures 2, 3 and 4). Overall, there are two main surgical techniques: the single row and the double row repair.

When performing a single row repair, the surgeon uses one or two anchors placed on the lateral cortex of the humerus. When performing a double row repair, the surgeon uses an other row of anchors, more medially, close to the cartilage (figure 5).

At the end of the procedure, the surgeon's goal is to obtain a complete coverage of the footprint (figure 6).

B) Biceps surgery

Biceps surgery is very often associated with rotator cuff surgery. In fact, some authors found that 95% of the long head of biceps tendons are pathological in case of transfixious rotator cuff injuries (Boileau et al., *RCO* 2007; Maynou et al., *RCO* 2007). Surgeons have two options:

- Biceps tenotomy, which consists in tendon sectioning at glenoidal enthesis.
- Biceps tenodesis: which consists in the attachment of the tendon in the bicipital, after tenotomy of the latter (figure 7).

II) Instability surgery

A) Bankart procedure

The glenoid labrum is a 4 mm thick fibrocartilaginous tissue, whose aim is to enlarge glenoid depth and surface.

It has two other roles:
- Viscoelastic plunger effect, intended to maintain a negative pressure
- Fibrous anchorage platform for capsular ligaments insertion

Labrum can be injured by humeral head in gleno-humeral luxations. The Bankart lesion is the typical pattern of injury in case of anterior shoulder dislocation.

Once again, thanks to stitches mounted on anchors, the surgeon will pull back on the glenoid rim the inferior and anterior labrum. Those anchors have to be inserted in the glenoid neck, close to the cartilage but not through it (figure 8).

B) Hill-Sachs Remplissage

Hill-Sachs lesion is a classical bony lesion secondary to a gleno-humeral dislocation. It can sometimes be very deep and engaging. Wolf described in 2004 an arthroscopic technique called Hill-Sachs remplissage (HSR). This procedure is in two parts:

- An anterior time, consisting of carrying out a bankart repair.

- A posterior time, consisting of bridging the notch by performing capsulodesis and tenodesis of the infra spinatus tendon (figure 9).

C) Coracoid Bone Block: the Latarjet procedure

This procedure consists of reinforcing the anterior glenoid bone using a bone graft taken from the coracoid process. After coracoid osteotomy, the scapular muscle is incised horizontally. The bone graft is then attached to the glenoid using either screws (figure 10) or endo-buttons (figure 11). This surgery is performed either conventionally or under arthroscopy.
A) D) Coracoid Bone Block: the Trillat procedure

This procedure consists of lowering and mediating the coracoid process (figure 12).

This allows the subscapularis to be lowered and create an extra-articular bone block. This produces a dynamic belt effect of the conjoint tendon (figure 13). This procedure is performed on young hyperlax patients with anterior instability and in older patients with inoperable rotator cuff tears associated with anterior instability. This surgery is performed either conventionally or under arthroscopy.

III) Prosthetic surgery

A) Hemi-arthroplasty

These prostheses include only a humeral implant (figure 14). The main indications are humeral fracture, osteonecrosis of the humeral head, centered osteoarthritis. They will also be used when a procedure cannot be performed on the glenoid: large dysplasia, low bone stock, young patient, osteoporosis. A certain type of humeral implant will be used in case of humeral fracture, allowing tuberosities synthesis.

In case of shoulder resurfacing arthroplasty, the humeral implant does not have diaphyseal stem (figure 15). The main indications are: focal chondral lesions of the humeral head, osteonecrosis of the humeral head, young patients’ osteoarthritis.

B) Anatomic Total Shoulder Arthroplasty (TSA)

In case of TSA, there are humeral and glenoidal implants (figure 16). Anatomic total shoulder arthroplasty is most commonly performed for degenerative osteoarthritis in patients older than 60 years. Other indications for total shoulder arthroplasty include inflammatory arthritis, humeral head avascular necrosis with secondary glenohumeral arthritis, Charcot arthropathy, and postinfectious arthritis. Total shoulder arthroplasty requires an intact rotator cuff.

C) Reverse Shoulder Arthroplasty (RSA)
The humeral component consists of a proximal cup-shaped portion and metal stem. A radiolucent polyethylene insert sits in this cup portion and articulates with the glenosphere. The glenosphere is the rounded metal ball of the prosthesis that attaches to a baseplate (metaglene) secured to the native glenoid by bicortical screws (figure 16). The center of rotation is lowered and medialized relative to the anatomical center in order to increase the lever arm by the deltoid muscle. Reverse total shoulder arthroplasty is indicated for rotator cuff arthropathy, rotator cuff deficient shoulders with pseudoparalysis, tumor resection reconstruction, prior failed total shoulder arthroplasty with subsequent rotator cuff failure, and acute three- or four-part proximal humerus fracture. Reverse total shoulder arthroplasty requires an intact deltoid muscle.
Fig. 1: Arthroscopic view of a large rotator cuff tear

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Fig. 2: Example of stitches mounted on anchor

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Fig. 3: Example of surgical knot

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Fig. 4: Double Row Repair

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**Fig. 5:** Schematic representation of single row and double row rotator cuff repair

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**Fig. 6:** Arthroscopic view after rotator cuff surgery.

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**Fig. 7:** Biceps tenodesis, with an interferential screw

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Fig. 8: Schematic Bankart procedure

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Fig. 9: Schematic representation of an HSR procedure

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Fig. 10: X-Rays showing a coracoid bone block fixed with 2 screws after an « open » procedure

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Fig. 11: X-Rays showing a coracoid bone block fixed with 2 endo-buttons after an arthroscopic procedure

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Fig. 12: Schematic representation of Trillat procedure

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Fig. 13: Schematic representation of the dynamic belt effect obtain with the conjoint tendon

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**Fig. 14:** Example of a shoulder hemi-arthroplasty

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**Fig. 15:** Example of a shoulder resurfacing arthroplasty

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Fig. 16: Reverse Shoulder Arthroplasty

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Fig. 17: BIO-RSA

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Findings and procedure details

I) Rotator cuff and biceps surgery

A) Rotator cuff surgery

1) Anchors

Anchors used for rotator cuff surgery are nowadays bioabsorbable anchors. They don't generate too many artefacts and are clearly visible on T1 (figure 18), T2 or PD sequences (figure 19).

When anchors are metallic, some artefacts may be produced (figure 20). Tips can be used:

- avoid gradient echo sequences
- prefer STIR sequences than Fat Sat sequences
- use long echo train sequences (Fast Spin Echo sequences > Spin Echo sequences)

(McMenamin et al., Eur J Radiol 2008)

As they are bioabsorbable, the bone can react to these anchors. Thoses bone modifications were described and classified by Kim et al. (Kim et al, Am J Sports Med 2014). They graduated fluid signal around the anchor on T2-weighted MRI scan as follows:

- grade 0, no fluid signal around anchor
- grade 1, minimal fluid collection
- grade 2, local collection of fluid
- grade 3, fluid collection around the entire length of the anchor, with cyst diameter less than twice the anchor diameter
- grade 4, cyst diameter larger than grade 3 (figure 21)

In this study, the authors forementioned concluded that those modifications do not influence anatomical or clinical repair of the RCT.
2) How to evaluate the tendon healing?

Tendon evaluation should be performed at the end of the tendon healing period: at least 3 months, optimal at 6 months.

MRI is the best way to obtain a non-invasive, non-irradiating, reproducible tendon evaluation. The most common classification, used by both surgeons and radiologists, is the classification of Sugaya (Sugaya et al, *Arthroscopy* 2005; Sugaya et al, *JBJS* 2007).

It is divided in 5 stages:

- Stage I: tendon of normal thickness, homogeneous, hypointense (figure 22).
- Stage II: tendon of normal thickness, but with an heterogeneous signal (figure 23).
- Stage III: decreased tendon thickness but continuous (figure 24).
- Stage IV: moderate tendon discontinuity.
- Stage V: large rerupture (figure 25).

Ultrasounds (US) can also be used to assess tendon's healing. Sensitivity (85% to 100%) and specificity (90% to 100%) are quite good in the literature (Yoo et al, *J Ultrasound Med* 2015).

A modified Sugaya Score (mSS), adapted to US, was recently proposed by Barth et al (Barth et al, *Knee Surg Sports Traumatol Arthrosc.* 2015), with a classification also divided in 5 types:

- Type I indicated a repaired cuff that had sufficient thickness (>2 mm) with normal echostructure (hypechoic and brillar on each image) (figure 27).
- Type III indicated a repaired cuff that had insufficient thickness (<2 mm) without continuity;
- Type IV indicated the presence of a minor full-thickness discontinuity of whose border is well visible, suggesting a small tear (figure 29);
- Type V indicated the presence of a major discontinuity of whose medial border is not visible under the acromial arch, suggesting a medium or large tear.

3) What about the sub acromial bursa?
Fluid can be very often be visualized in the sub acromial bursa after a RCT surgery. Is it due to bursitis? Reclalm of a sub acromial impingement? Indirect sign of a retear? In the large majority of cases, none of those propositions. The presence of fluid may persist within the BSAD years after a cuff surgery, in around 10% of cases because of the absence of permeability of the rotator cuff interval (Zanetti et al, *Skeletal Radiol* 2000; Tudisco et al, *BMC* 2013).

A) Biceps surgery

1) Tenotomy

After a biceps tenotomy, an empty bicipital groove may be found. This may not be considered pathological but part of the surgery (figure 30 and 31).

2) Tenodesis

When you see on MRI an anchor placed into the bicipital groove, it is an interferential screw of a biceps tenodesis (figure 32. They can be seen as clearly as rotator cuff tendon anchors.

I) Instability surgery

A) The bankart procedure

Glenoid anchors can be seen as round bone defects on sagittal view on CT-scan (figure 33). On MRI, anchors are seen as small dots in asignal T1 and T2 (figure 34). Bioabsorbable anchors do not demonstrate much artefacts.

But the best imaging modality to assess a Bankart repair is arthro-MRI with a 100% of sensitivity and 82% of specificity (Sugimoto et al, *Radiology* 2002). Arthro-CT and arthro-MRI can clearly show a re-tear of the labrum, as well as the position of the labrum (figure 35). It should not be too medial with respect to the anterior glenoid rim. Finally, it is possible to appreciate the path of the anchors. When misplaced, there is a high risk of osteoarthritis (figure 36 and 37).

B) Hill-Sachs remplissage
The evaluation of a procedure of a Hill Sachs Remplissage is done through an arthro-CT or arthro-MRI. The filling assessment is done in percentage, in increments of 25% (figure 38 and 39). Of course, it will be necessary to evaluate the Bankart repair.

C) Coracoid Bone Block: the Latarjet procedure

The postoperative evaluation of a Latarjet bone block will be done in the best way using a CT-scan. First, the position of the bone block is evaluated in the sagittal plane: its position may be supra-equatorial, equatorial or infra-equatorial with respect of the middle of the glenoid. In supra-equatorial position, the bone block does not fulfill its role (figure 40).

Then the bone block position will be evaluated in the axial plane. Its position will be defined with respect to a line tangent to the articular surface of the glenoid (figure 41). 3 positions are possible:

- Overflowing the glenoid rim, with an increased risk of osteoarthritis because of a conflict between the humeral head and the bone block.
- Flush to the glenoid rim, which is the ideal position
- Medial to the glenoid rim, which will reduce the effectiveness of the procedure

At the end, the bone consolidation of the bone block should be evaluated (figure 42):

- partial or complete bone consolidation
- pseudarthrosis: This term should be used after 6 months, the frequency of which varies between 0 to 5% according to the series, uncorrelated to the clinical results. The bone block in the prone position appears to be a risk factor
- fracture of the bone block

D) Coracoid Bone Block: the Trillat procedure

After osteoclasis of the coracoid process, the latter is fixed with either a screw or endo-buttons (figure 43).

Two main complications have to be investigated by imaging:
- Antero-inferior impingement between the coracoid process and the subscapularis tendon.

- Fracture of the coracoid process

I) Prosthetic surgery

A) Hemi-arthroplasty

The two main complications of hemi-arthroplasty are glenoid bone erosion, which may be centered or excentered (figure 44).

Stress shielding is a more common complication of hemi-arthroplasty for fracture, causing an osteolysis of the greater tuberosity (figure 45).

A) Anatomic Total Shoulder Arthroplasty (TSA)

Considering that the humeral implant is more often metallic and the glenoid implant made of polyethylene (PE), the latter can wear more or less quickly. Wear of the upper part of the glenoidal PE with loss of the concavity of the latter can lead to an ascent of the humeral head (figure 46).

The consequence of the micro mobility induced by the bone lysis will create a "rocking horse effect" which will accelerate the lysis bone, until producing a dislocation of the PE (figure 48).

Aseptic humeral loosening will be evaluated using the Gruen classification (figure 49). We will speak of loosening in case of radioluescent border greater than 3mm on 3 zones or more.

A secondary lesion of the rotator cuff may be suspected on standard radiographs in the event of an ascent of more than 5 mm from the center of the humeral head relative to the center of the glenoid (figure 50).

Prosthetic instability is a classic complication (figure 51). The anterior luxation or subluxation will occur in case of lesion of the scapular tendon. Humeral (> 50 °) or glenoid (> 20 °) retroversion are favorable factors. Ultrasound has a well-defined interest in evaluating the scapular tendon in operated patients. However, some authors find lesions in 50% of asymptomatic patients (Yves et al, J Clin Ultrasound 2012).
Infection is a feared complication, although rare (estimated at 2% depending on the series). 2 forms have been described: immediate postoperative with an evocative clinical context; Chronic, torpid form, where signs of loosening and peri-prosthetic bone reactions (ossifications, periosteal apposition) will be found (figure 52).

A) Reverse Shoulder Arthroplasty

The main questions to be asked after the introduction of an RSA are:

- Is the humeral implant and the glenosphere aligned? Instability is one of the most common complications after RSA (figure 53).

- Are the screws of the metaglene in the scapula?

- Is the metaglene attached to the glenoid?

- Is there a prosthetic radioclar border? Two hypotheses to be posed in this case: infection? "Stress shielding"?

Humeral loosening can lead to humeral fracture (figure 54).

- Are the components of the prosthesis intact?

- Is the lower edge of the scapula eroded by the humeral implant? Scapular notching occurs because of repetitive contact of the medial aspect of the humeral cup with the inferior border of the scapula. Scapular notching has been reported in 50-96% of reverse total shoulder arthroplasties. The presence of scapular notching can be graded according to the classification of Sirveaux (figure 55).
Fig. 18: Proximal anchor of a double row repair: Axial T1.

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**Fig. 19:** Lateral anchor of a single row repair (Coronal DP)

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Fig. 20: Artefacts generated by a metal anchor

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Fig. 21: Grade 4 cyst

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Fig. 22: Sugaya Stage I

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Fig. 23: Sugaya Stage II

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Fig. 24: Sugaya Stage III

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Fig. 25: Sugaya Stage V

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**Fig. 26:** Cortical irregularity due to the presence of a medial anchor.

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Fig. 27: mSS type I

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Fig. 28: mSS type II
**Fig. 29**: mSS type IV

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**Fig. 30**: Empty bicipital groove after biceps tenotomy, ultrasound

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Fig. 31: Empty bicipital groove after biceps tenotomy, MRI

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**Fig. 32:** Coronal T1 MRI showing biceps tenodesis. Medial anchor of a double row repair is also visible.

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Fig. 33: CT scan of glenoid after a Bankart procedure

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Fig. 34: Sagittal view showing bankart repair anchors' path, T1 sequence

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Fig. 35: Arthro-CT showing a re-tear after a Bankart procedure

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**Fig. 36:** Arthro-CT showing an anchor placed through the glenoid cartilage

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**Fig. 37:** Arthro-CT showing iatrogenous chondral cartilage ulceration

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Fig. 38: Complete filling of a Hill-Sachs notch

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Fig. 39: Insufficient filling of a hill-sachs notch, less than 25%

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**Fig. 40:** Different sagittal positions of a coracoïd bone block: infra-equatorial, equatorial or supra equatorial

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**Fig. 41:** Different axial positions of a coracoid bone block: flush to the glenoid rim and overflowing it.

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**Fig. 42:** Bone block consolidation: complete consolidation, pseudarthrosis, fracture, lysis.

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**Fig. 43:** Normal post operative CT-Scan after a Trillat procedure, arthroscopic technique with endo-buttons, open technique with screw.

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Fig. 44: Centered and excentered glenoid erosion.

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Fig. 45: Stress shielding complicating a hemi-arthroplasty for fracture

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Fig. 46: PE wear leading to an ascent of the humeral head

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Fig. 47: Aseptic loosening of the glenoid implant

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Fig. 48: The « rocking horse effect »

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Fig. 49: Aseptic humeral loosening.

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Fig. 50: Secondary lesion of the rotator cuff.

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Fig. 51: Anatomic TSA dislocation.

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**Fig. 52:** Chronic post operative infection

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Fig. 53: Post-RSA instability

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Fig. 54: Humeral fracture after RSA.

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**Fig. 55:** Scapular notching

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Conclusion

Knowledge of main surgical techniques and modifications induced on control imaging will allow radiologists to better diagnose pathological situations to appropriately guide patients.
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