The implantation of a shoulder joint replacement implant is not a new procedure. Neer et al. pioneered this procedure as a hemi-arthroplasty in 1955; a glenoid component was added in 1972 [1]. These non-constrained implants were gradually modified to improve the fit. As typically happens, the expanded indications and the subsequent large number of implantation procedures has increased the number of complications and revisions. In France, hospitalization data (www.ath.sante.fr) indicates that the number of revisions for total shoulder arthroplasty (TSA) has increased 29% between 2006 and 2010; in the same period, the rate was only 10% for knee implants and 1% for hip implants.

The nature of these complications differs depending on the type of implant used, anatomical or reversed (Table 1).
In a review of 47 studies with non-constrained shoulder implants that were implanted for degenerative or inflammatory conditions and had at least two years follow-up, complications occurred in 906 out of 4010 shoulders, thus at a rate of 22.6% [2]. Surgical revision was needed in 11.2% of these cases, with at least one of the implant components being changed in 7.9% of cases. Most of the complications were on the glenoid side — either bone wear in cases of hemi-arthroplasty (20.6%) or loosening in cases of total arthroplasty (14.3%). Another meta-analysis summarized the results of the main published reverse shoulder arthroplasty (RSA) studies; 164 of the 782 implants (20%) had postoperative complications [3]. Twenty-six patients were re-operated without changing the implant (3.3%) and the implant was removed or changed in 79 cases (10.1%). It is evident from these findings that complications are currently a problem. Their management requires thorough analysis and careful planning that comprise three steps: initial assessment, choice of the treatment indication, and then preparing for and performing the surgical procedure.

### Table 1 Main complications associated with total shoulder arthroplasty.

<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Number of cases</td>
<td>4010</td>
<td>782</td>
</tr>
<tr>
<td>Number of complications (%)</td>
<td>1595 (39.8)</td>
<td>188 (24)</td>
</tr>
<tr>
<td>Number of revision procedures (%)</td>
<td>451 (11.2)</td>
<td>105 (13.4)</td>
</tr>
<tr>
<td>Number of component changes (%)</td>
<td>317 (7.9)</td>
<td>79 (10.1)</td>
</tr>
<tr>
<td>Glenoid loosening</td>
<td>14.3%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Humeral loosening</td>
<td>14%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.3%</td>
</tr>
<tr>
<td>Haematoma</td>
<td>—</td>
<td>2.6%</td>
</tr>
<tr>
<td>Instability</td>
<td>4.6%</td>
<td>4.7%</td>
</tr>
<tr>
<td>Infection</td>
<td>1.1%</td>
<td>3.8%</td>
</tr>
</tbody>
</table>

<sup>a</sup> 13% for cementless stems.

### Initial assessment

The initial assessment of a problematic shoulder implant involves clinical, laboratory and imaging evaluations. Five questions must be answered:

- Is it infected?
- Is it unstable, and if so, why?
- Is it worn, and if so, why?
- Is it loosened, and if so, why?
- How is the rotator cuff?

Detailed history-taking is required to trace the history of the implant. This is easy to do when the evaluator is the one who initially did the arthroplasty. But when it was done at another facility, some detective work is needed to find information on the initial aetiology, the patient’s preoperative status, the type of implant used, the conditions under which the surgery was performed and the postoperative recovery.

The questioning must also determine the patient’s complaint, which is typically pain, and uncover two important aspects: the symptom-free period and how the deterioration appeared. The physical examination will specifically evaluate the appearance of the scar and skin, the quality of the deltoid, the range of motion, and will test the rotator cuff, which can be challenging to carry out in a painful, stiff shoulder.

The basic laboratory work-up (complete blood count, erythrocyte sedimentation rate [ESR], C-reactive protein [CRP]) seeks to identify elements suggestive of an infection.

Radiographs under fluoroscopy control form the basis of the imaging evaluations, with AP views in neutral, external and internal rotation, along with a lateral axillary view being performed. These can be supplemented by a CT scan, as long as the artifacts caused by the implant can be eliminated (Fig. 1). The next step is to answer the initial five questions.

### Is it infected?

Obvious signs are inflammatory changes in the wound, general signs of infection, and fistulation.

![CT scan showing loosening and significant bone loss. Right image: medialization of the glenosphere in the glenoid cavity; middle image: mixed bone loss (peripheral and central); left image: humeral loosening with bone loss in lateral cortex.](image-url)
In all other cases, an infection must be systematically identified, especially when the shoulder continues to be painful without a symptom-free period, if there is a history of confirmed infection, a history of radiation therapy, rheumatoid arthritis is present, the patient is diabetic or immunocompromised, if the loosening affects both components and if the laboratory findings (WBC, CRP, ESR) are abnormal.

If the slightest doubt exists, joint aspiration must be performed under fluoroscopy or CT scan guidance, or a biopsy specimen taken. Any antibiotics that may have been administered blindly in the previous days must be taken into consideration. The cultures should be kept for at least three weeks so that slow-growing micro-organisms can be identified, especially Propionibacterium acnes (PA), which is often the cause of shoulder infections.

Despite all these precautions, the rate of positive cultures in revisions that were presumed not to be infected is quite high. Kelly and Hobgood [4] found eight positive samples (six for PA) out of 27 revisions (29%). Two of these developed a secondary infection after the revision. Similarly, Topolski et al. [5] analysed samples from 439 revisions that had no abnormal laboratory or clinical findings. Seventy-five (17%) had at least one positive culture out of the six cultures performed; 45 were positive for PA. Ten developed an infection after the revision, with PA being implicated five times.

**Is it unstable, and if so, why?**

The instability is obvious when the patient presents at the emergency department with a dislocation. It is more insidious in the context of subluxation or gradually decentering of the humeral head forwards or backwards.

**Anatomical total shoulder arthroplasty**

The cause differs depending on if the instability is anterior or posterior.

When the instability is anterior (Fig. 2), the main reason is subscapularis insufficiency [6]. More rarely, the anterior instability can be related to problems in humeral version or to faulty positioning of the glenoid component [7]. When the instability is posterior, the main reason is poor implant positioning due to posterior wear of the glenoid that existed preoperatively, especially if it is associated with posterior translation of the humeral head.

**Reversed total shoulder arthroplasty**

Instability is usually the reason for revision. In men, it occurs most often with the deltopectoral approach when the subscapularis is deficient and small-diameter glenospheres are used [8,9]. When determining the cause of the instability, first make sure that there are no neurological problems. Then, verify the humeral length, which often is not properly restored [9]. It is important to measure humeral length during the preoperative assessment. When assessing the length, both sides should be compared, the humerus must be exactly parallel to the plate and a reliable length gauge must be included in the field.

**Is it loosened, and if so, why?**

Humeral loosening occurs in about 6% of cases [2]. Radiographs are used to confirm loosening in the presence of continuous radiolucent lines or implant migration. The bone stock must also be evaluated to determine the reconstruction method [10] (Fig. 3). The amount of cement in the diaphysis, presence of a plug, centering of the stem, thickness of the cortex must be evaluated, as they come into play when the stem and cement are removed (Fig. 4).

On the glenoid side, loosening is the main complication of anatomical shoulder implants. The average rate was 14.3% in Gonzalez et al.’s meta-analysis [2] and it greatly increased over time [11,12]. Diagnosis is made based on radiographs where implant migration and radiolucent lines greater than 2 mm wide over the entire bone-cement interface (which corresponds to a Mole score of ≥ 12 [13]) are significant findings. Glenoid component migration has been analysed by...
Revision of total shoulder arthroplasty

Is it worn, and if so, why?

The thin polyethylene (PE) liner on the glenoid component can be worn, especially in a non-cemented glenoid; this may result in metal-on-metal contact and wear of the metal shell (Fig. 7).

How is the rotator cuff?

The rotator cuff is difficult to assess once the implant is in place. Magnetic resonance imaging (MRI) cannot be interpreted. Ultrasonography does not provide any useful information. CT scan of the joint is possible, but artifacts will be troublesome. Also, the rotator cuff may be non-functional, even if it is not completely ruptured, as in rheumatoid arthritis. Indirect signs best reflect on the functional status of the cuff, notably the superior migration of the humeral head in the vertical plane (Fig. 8), which can be measured using the method described by Torchia et al. [12]. This abnormal finding has been reported in 46.5% of anatomical TSA cases (19.4% mild, 13.4% moderate, 13.8% severe superior migration) [11].

Negative findings

If the answers to all the previous questions are negative, other implant-independent diagnoses must be advanced, such as acromioclavicular problems, a long biceps tendon that has been left behind (0.3% of cases [2]), fatigue fracture of the spine of the scapula when a reversed implant is used [16], complex regional pain syndrome characterized by stiffness with no evident aetiology.

After this assessment, the treatment indication must be determined: is a surgical revision required? If yes, does part or all of the implant need to be changed?

Walch et al. [14]. Three loosening mechanisms have been described: superior tilting of the implant in 41% of cases, subsidence into the glenoid cavity in 32.5% of cases and posterior tilting in 26.5% of cases (Fig. 5). Loosening rarely occurs in isolation, thus other factors must be considered: horizontal off-center displacement of the head, rotator cuff rupture, wrong implant positioning, etc.

CT scan unquestionably helps in the analysis (Fig. 2). It can also help to assess bone loss around the implant (Fig. 6), which is typically labelled as central, peripheral or mixed [15].

Figure 4 Important aspects to evaluate on the humeral component.

Figure 5 Three types of glenoid component loosening according to Walch et al. [14].
Treatment indications

Revision without implant change

These are quite rare and are typically linked to accessory problems:

- after the procedure, this typically involves draining a haematoma, especially after RSA where this complication risk is higher because of the dead space created by the surgical technique [3];
- later on, tenotomy of a painful forgotten long head of biceps, resection of the distal end of the clavicle for symptomatic acromioclavicular osteoarthritis, internal fixation of a humeral shaft fracture without associated loosening, complications related to the approach especially in the case of a trans-acromial approach, which is no longer used;
- isolated procedures on the rotator cuff or capsule are rare, and often have disappointing results;
- in some cases, the instability and infection can be treated without changing the implant; this will be described further in the section on complications.

Revision with implant change or conversion to total arthroplasty

With glenoid loosening being the most common problem, two scenarios require specific treatment modalities: instability and infection.

Instability cases

Anatomical implant

With anterior instability, various surgical treatments such as secondary repair of the subscapularis, with or without reinforcement [17], or pectoralis major transfer, are often ineffective. With posterior instability, isolated procedures on the capsule or reorienting the implant components have led to inconsistent results [7]. And no matter if the instability is posterior or anterior, the risk of failure is above 50% [7] and the most effective treatment is RSA.
Reversed implant

If the instability occurs early on (within the first month), the joint should be reduced under general anaesthesia and then immobilized for 45 days [9]. If the instability occurs later on (after one month) or has recurred, conservative treatment brings about the risk of recurrence. If length is the problem, revision should be considered with implantation of a thicker liner or an extender for up to 20 mm of difference, and a stem change beyond that amount [9]. When there is no obvious cause, better stability can be obtained by using a larger glenosphere (42 mm instead of 36 mm) and potentially by adding a lateralization spacer.

Infection cases

The treatment choice depends on two aspects: the general and functional condition of the patient and the factors surrounding the infection (early after the surgery, blood-borne, or later on). This decision must always be made after multidisciplinary consultation with infectious disease specialists.

The patient’s general condition is crucial and if there are no signs of systemic infection, it is often preferable to keep a productive fistula and maintain good function in an elderly or at-risk patient.

If the infection occurs early (< 3 weeks) after the surgery or is blood-borne, lavage with debridement and changing of the bearing components (PE liner, potentially glenosphere) leads to good functional results, but more random healing of the infection [18].

If the infection is found later on, removal of the implant, the cement and any foreign body that could host the infection should be considered. Then the choice must be made between one-stage or two-stage replacement, permanent removal of the implant or fusion in specific cases where the deltoit is not functional.

The functional results after implant removal are poor [19]. The results of two-stage revisions are poor, except if a cement spacer is used; one-stage revision provides better results [18]. Thus, a one-stage revision is preferable whenever possible: known micro-organism that is sensitive to conventional antibiotics, manageable bone stock, satisfactory patient general condition.

Glenoid complication cases

When determining the course of action relative to the glenoid, remember that working on this component is more complicated with the humeral component present (Fig. 9). Appropriate planning requires information about the modularity of the current implant and an evaluation of the possibility of extraction, if this becomes necessary. Many scenarios are possible.

Loosened glenoid component

Anatomical glenoid component

With an anatomical glenoid implant, published data provide some guidance.

![Glenoid complication cases diagram](image)
Results are better when a new glenoid component is implanted than when only a bone graft is used. Neyton et al. [20] showed that results were best when a glenoid component was reimplanted (Constant score of 58 versus 47.5 with a graft only). However, Cheung et al. [21] could not confirm the superiority of glenoid reimplantation relative to a graft alone in terms of pain or range of motion, only for active elevation.

If only a graft is used, cortical-cancellous bone grafts are preferable to cancellous bone grafts. In Neyton et al.’s study [22], the results were better and there was less secondary medialization when a tricortical graft was used.

Over the long-term, the hold of cemented glenoid components is poor. Bonnevie et al. [23] reported on a 42 patient series in which revision was performed with a cemented glenoid component in every case and with a bone graft also added in 10 cases. After six years, the complication rate was 45%, including seven cases of glenoid component migration. The revision rate was 21%. Radiographs revealed loosening of the new glenoid implant in 67% of cases. This complication was not reported as often in Cheung et al.’s study, but the average follow-up was only 3.8 years [21].

In summary, the type of reconstruction must be planned based on the following criteria (Fig. 9):

- young patient, intact rotator cuff, centered humeral head: an anatomical TSA can be used either by cementing a new anatomical glenoid component if there is minimal bone loss or by reconstructing the glenoid with a tricortical graft (without a glenoid implant) if the bone loss does not allow for reliable fixation of an anatomical glenoid component;
- older patient, rotator cuff deficiency, humeral head off-center either vertically or horizontally: consider using a RSA implant and reconstructing the glenoid if necessary. This reconstruction can either be done in a single procedure or in two stages if major reconstruction is needed and the glenoid component cannot be immediately subjected to loading. In every case, the patient’s general condition and the amount of his/her disability must be factored into the decision. Sometimes, nothing can be done and the shoulder must be left dangling or only hemi-arthroplasty performed to provide an interposition.

Reversed glenoid component

With a reversed glenoid, published data provide some guidance.

Revision with a new RSA leads to better results than conversion to hemi-arthroplasty. Molé et al. [13] reported 33 cases of glenoid component loosening in RSA. When another RSA was implanted, the postoperative Constant score was 48.7 versus 31 with hemi-arthroplasty; active forward flexion was 109° versus 70° after hemi-arthroplasty. These acceptable results after implantation of a new RSA implant have been confirmed by Holcomb et al. [24].

The main complications during revision with a new RSA implant are instability and repeated loosening [3,24].

In summary, the type of reconstruction must be planned based on the amount of remaining bone, with the goal being to put in a new RSA implant whenever possible. In fact, the factors that were at the cause of the initial indication still exist and a priori no other option can be as effective:

- bone stock suitable for reconstruction: placement of a new glenoid base plate with a graft and peg that is long enough to gain purchase in native healthy bone. The choice between a one-stage or two-stage procedure depends on the quality of the reconstruction performed;
- bone stock not suitable for reconstruction: transform the stem to a hemi-arthroplasty and reduce the functional expectations.

Non-loosened glenoid component (metal shell, reversed, cemented without loosening)

Consider revision in cases of instability, infection, wear, etc:

- for a non-cemented glenoid component that does not absolutely need to be changed out (no infection, positioning is acceptable, etc.), consider simply changing the PE liner or using an appropriate conversion module or custom-made module if possible. Otherwise, removing the metal glenoid shell can be challenging and the remaining bone stock must be evaluated once the implant has been removed;
- for a cemented glenoid component, removal is usually easy, even if it is not loosened.

Problems with the humeral component

Loosened stem

This is a rare problem (Fig. 10). Since it has to be changed out, the best extraction method must be chosen while taking into account the bone damage and anticipating that the humerus or tuberosity might fracture. Reconstruction will depend on the remaining bone stock.

![Decision tree for the management of the humeral component](image_url)

Figure 10  Decision tree for the management of the humeral component; RC: rotator cuff.
**Non-loosened stem**

This occurs when the humeral stem is well cemented or has excellent bone integration, but its presence makes it more difficult to work on the glenoid side, or when it must be removed to change to a different implant type (anatomical to reverse arthroplasty), or even when there is an infection or instability present. In determining if the stem can be retained, the modularity of the stem must be known. If it must be removed, certain technical problems are likely. Once the treatment indication has been made, the next step is to prepare for and perform the surgical procedure.

**Preparing for and performing the procedure**

Before the procedure, the surgeon must determine the model of the current implant, its modularity, the available extraction instrumentation specific to this implant, decide which type of bone will be used (autograft or allograft) for the humerus and glenoid reconstruction, and have the instruments needed to extract the implant and cement. The patient is placed in the typical position, but will be less seated, as access to the iliac crest is often required. The preferred approach is the deltopectoral route, which allows for easy extension to the humerus in case a humeral window is needed or in case of an intra-operative fracture.

**Humerus**

**Extraction of humeral stem**

Other than in cases of loosening where extraction is fairly easy to perform, extraction of a non-loosened humeral component is difficult, risky and prone to complications, especially humerus fracture (12% in anatomical stem revisions and 30% in reversed stem revisions [25]).

Generally, the following steps are performed:

- removal of the humeral head cap when a modular stem is present;
- resection of tissues around the metaphyseal part of the implant and of cement from the upper part (for a cemented prosthesis);
- first attempt at extraction, either using appropriate flyweight-type instrumentation, or using a bone tamp that is placed inside the stem and perfectly aligned with the humeral axis; this avoids a wedging effect, which could result in fracture;
- if the extraction is not successful, a longitudinal osteotomy at the metaphysis and diaphysis junction (Fig. 11) is made with an oscillating saw outside the bicipital groove [25,26]. The length of the osteotomy must have been previously determined during preoperative measurements. This slot in the shaft is gradually widened to detach the implant from the cement or the cortex, and then the extraction is attempted again;
- if this fails, a cortical window on both sides of the distal end of the implant can be made if the cement is being preserved or a humeral window can be made if all the cement must be removed. The distal window, cut with an oscillating saw, provides the option to remove the distal cement plug and to push the implant up and out.

At this stage, while the humerus is stiffened by the remaining cement, work can be performed on the glenoid,
since the humerus can be reflected backwards without much risk of breaking it.

**Cement removal**

With a loosened stem, the loosening often occurs between the cement and bone, making it easy to remove the cement as it will come out with the stem. With a non-loosened stem, once the stem is extracted, the cement may or may not need to be removed. Other than in infection cases, it is not always necessary to remove the cement, especially if the bone cortex is thin and fragile. Just remove enough cement so that another implant can be added.

If the cement must absolutely be removed, this can be done gradually with various instruments, but the safest method is to go through an anterior window [27] or even better, a trans-humeral route [10]. The first osteotomy is performed in the humerus and the second one is performed inside the groove, which results in a vascularized bone window over the pectoralis major, turned inside-out and providing access to the entire cement mantle (Fig. 11).

**Reimplantation of a humeral stem**

The degree of bone loss determines how the stem is reimplanted. A cementless implant can rarely be used. Once the windows have been surrounded by wire cerclage and the radial nerve is safe, a leak-proof bone cylinder exists. A new implant can be cemented as long as its lower end spans that of the window by at least two shaft diameters.

If the bone defect involves the entire humeral metaphysis or more, a reversed implant must be used with an allograft combined with iliac cancellous bone. Chacon et al. [28] proposed using a structural proximal humeral allograft fixed to the native humerus in combination with a humeral implant having a long stem. If the bone loss goes beyond the diaphysis, during tumour excision surgery for example, a massive allograft of the proximal humerus can be combined with a long-stem implant that is cemented at the diaphysis and stabilized with an external plate with at least three screws in each fragment. The major challenge is choosing the correct implant height, which contributes to the risk of postoperative instability.

The occurrence of a fracture during the humeral phase requires the use of a long-stem humeral component to bridge the fracture site. During cementing, verify that no cement is extruded as this could cause thermal injuries or radial nerve compression.

**Glenoid**

**Extraction of glenoid component**

This is easy to accomplish when the glenoid is loosened, but is more complicated when the glenoid component is still attached. With a cemented component, the PE liner and then the cement can be removed easily. With a non-cemented component, this is harder to do. Carefully and gradually detach the bone from the glenoid base plate and try to limit the amount of bone lost during the removal.

**Figure 12** Glenoid reconstruction technique used by Norris et al. [29] for reverse shoulder arthroplasty.

**Reconstruction**

If the bone is not damaged, a new glenoid component can be implanted. If the glenoid must be reconstructed, the bone loss, evaluated after the implant is removed, and the patient’s condition must be taken into account. If a bone graft will be used without implanting a new glenoid component, the preferred approach is to impact a tricortical autograft or to use screw fixation if the graft is unstable. In this case, use of resorbable screws is preferable. If a decision has been made to proceed with reimplantation, a cementless component is preferred as the graft can be fixed at the same time. When a reversed implant is indicated, Norris et al.’s technique is most practical [29]. The iliac crest is opened, then dedicated instrumentation is used to harvest a cortical-cancellous bone graft; this graft is used to fill the bone defect and is placed on the base plate using a hole in the middle of the graft (Fig. 12). The central peg must have purchase in native healthy bone over a length equal to at least twice the diameter of the peg.

After the surgery, immobilisation for 45 days is recommended for any extensive or fragile reconstruction cases.

**Conclusion**

Revision of shoulder arthroplasty has three possible pitfalls:

- diagnosis error: many abnormal findings on radiographs are not necessarily symptomatic, especially radiolucent lines on the glenoid side. There must be complete agreement between the clinical and radiography findings for the revision indication to be made;
- underestimating the risk of a latent infection: even when the clinical and laboratory findings are not supportive, potential for aseptic loosening exists in 17 to 29% of cases, with PA being present in 50% of these cases;
- poor preparation for the surgical procedure: all the factors associated with instability, wear or loosening must be analysed (implant positioning, rotator cuff intact, patient’s condition). The risks and benefits of the chosen indication must be weighed carefully. Every aspect of the procedure must have been planned for, including the possible occurrence of complications and how they will be resolved.
Finally, do not forget that the patient is a party in this matter and needs to be duly informed and involved in the decision-making process.

Disclosure of interest

The author declares the following conflicts of interest: symposiums (invited as a contributor by Tornier), receipt of royalties (from Tornier).

Acknowledgements

The author would like to thank the SOFEC (French Shoulder and Elbow Society), Cécile Nérot and all the members who participated in the symposium on shoulder arthroplasty revisions.

References