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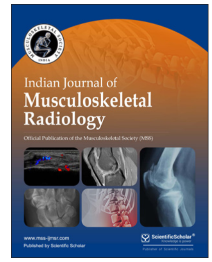

Pictorial Review

Multimodality imaging in shoulder arthroplasties Part 2: Immediate pre- and intra-operative imaging and imaging of early and late complications – A pictorial review

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ABSTRACT

Shoulder arthroplasty imaging requires a thorough understanding of surgical techniques, biomechanics involved during and after the joint replacement surgery and complications unique to shoulder arthroplasties. One may believe that imaging of complications requires excessive complex imaging modalities such as MRI or nuclear imaging. However, contrary to such beliefs, one can diagnose such complications mostly on radiographs. We will describe advances in immediate pre-operative imaging and utility of imaging to diagnose shoulder arthroplasty-related complications in part 2 of our two-part pictorial review series.

Keywords: Shoulder arthroplasty, Shoulder replacement, Osteoarthritis imaging, Glenohumeral osteoarthritis, Joint degeneration

INTRODUCTION

We have described indications for shoulder arthroplasties, enumerated their types, and illustrated pre-operative imaging pictorially in the part 1 of two-part article series. In the part 2, we narrate perioperative imaging and introduce concepts of pre- and intra-operative CT navigation. We shall also discuss shoulder arthroplasty contraindications [Table 1] as well as both, general and arthroplasty-specific complications.

SHOULDER SURGEON'S PERSPECTIVE

Use of CT in pre-operative planning, implant selection, and 3D printing

CT using bespoke Software protocols assists with preoperative planning and is powerful tools in the surgeon's armamentarium. It helps the surgeon to understand the altered anatomy, glenoid wear, and version when specialized surgical techniques (e.g. augmentation using bone or metal to recreate the glenoid in reverse TSR, or specialized polyethylene for anatomic TSR) are necessary. It further aids in using patient-specific instrumentation (PSI) and/or executing navigation for a correct implant placement, minimizing human error, and possibly improving

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the longevity of the implant. New artificial intelligence algorithms incorporated in the software can predict the best implant and procedure combination based on the CT [Figure 1]. 3D printing provides the surgeon a platform to rehearse the procedure in a safe environment to help minimize errors during surgery and makes the surgical procedure safer.

Intraoperative navigation

It helps the surgeon by providing real-time feedback, allowing the surgeon to make necessary adjustments when presented with altered anatomy, particularly in cases where there has been a delay between acquisition of the pre-operative imaging and the surgical procedure. It further aids the surgeon by determining the correct scapular and glenoid axis, glenoid version and depth of reaming for the glenoid, avoiding areas of potentially weak bone [Figure 2], and ensuring correct placement of screws, including their direction and length.[1]

Table 1: Contraindications for shoulder arthroplasties.

Absolute contraindications
Active infection
Charcot's neuroarthropathy following brachial plexus injury or other neuropathies
Ankylosed/arthrodesed shoulder following end-stage inflammatory or tubercular arthropathy which is functional and painless
Flail shoulder due to loss of axillary nerve function or stroke or poliomyelitis
Relative contraindications
Poor glenoid bone stock (very rare)

EARLY POST-OPERATIVE COMPLICATIONS

Despite advances in more sophisticated imaging modalities, imaging of shoulder arthroplasty complications is still heavily reliant on plain film radiography. Ultrasound may be helpful in some suspected rotator cuff tears, and CT may be necessary when fractures are radiographically occult and clinical suspicion is high.

Deep prosthetic joint infection is the most common complication in the first 2 years following total shoulder arthroplasty (TSA).[2] Its incidence can range up to 3.9% for anatomic TSA and up to 5% for reverse TSA. Diagnosis and management of prosthetic infections are evaluated using the Musculoskeletal Infection Society criteria. This advocates a multidisciplinary approach, predominantly based on clinical and biochemical parameters with minimal involvement of radiology. Treatment options include long-term antibiotic suppression, debridement, antibiotics, and implant retention, and two-stage revision (considered the gold standard, Figure 3b).

In early loosening, the role of radiological investigations could involve anteroposterior and lateral radiographs to look for prosthetic loosening [Figure 3a]. CT is very useful in assessing for implant loosening, bone stock on the glenoid and humeral side, as well as helping with pre-operative planning or customized computer-aided design/manufacture (CADCAM) prosthesis. Bone scans are unable to differentiate between aseptic and septic loosening.[3,4]

Periprosthetic fractures have 1.5–3% prevalence and can occur intraoperatively, secondary to trauma post-surgery, or following chronic stress shielding.[2] Stress shielding is the adaptation of periprosthetic bone to changes in stress forces distributed from the humeral stem [Figure 4]. It is seen in 9%

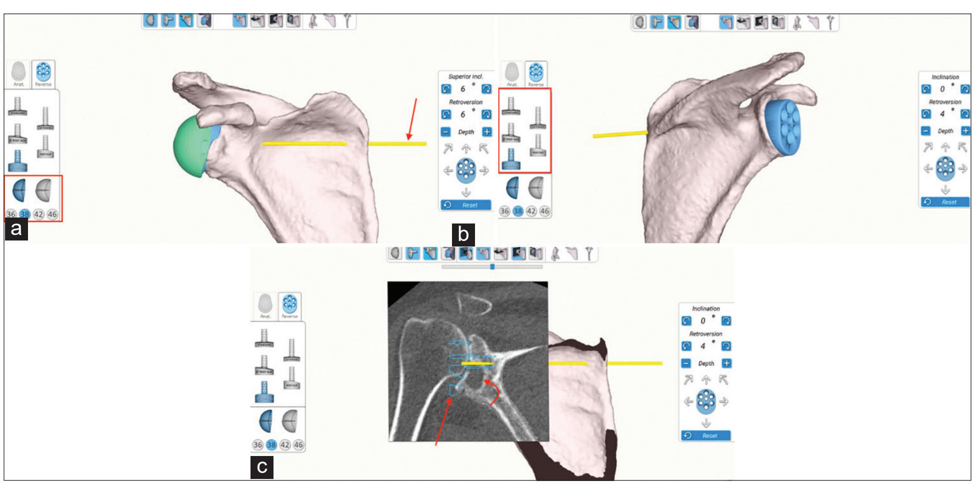

Figure 1: 3D reformats of the raw CT data by software before reverse total shoulder arthroplasty. Shoulder surgeons can rehearse by choosing different types of (a) glenospheres (red rectangle, red arrow depicts the scapular axis) and (b) glenoid baseplates for augmentation (red rectangle). (c) The software used in surgical planning can also provide the exact location of bone loss (curved red arrow) and its potential relation with surgical hardware (straight red arrow) and allows the shoulder surgeon to choose the best possible arthroplasty implant.

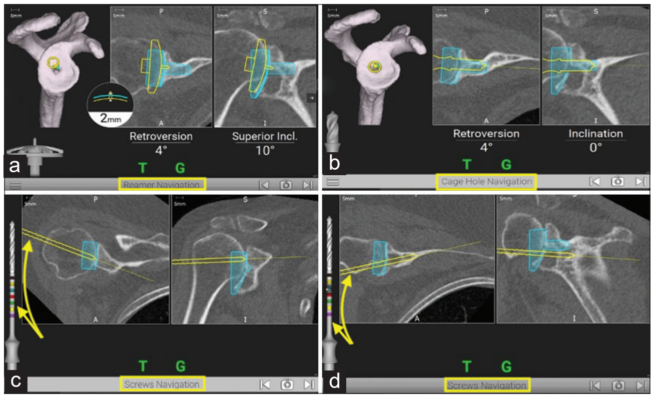

Figure 2: Intraoperative CT navigation in action during reverse total shoulder arthroplasty. The navigation system guided the shoulder surgeon during (a) reaming of the glenoid to achieve a good surface on which an appropriate baseplate can be fixed for augmentation of the insufficient bone stock. Another option is to place an autologous bone graft from the excised humeral head. (b) Following reaming and augmenting the glenoid, a cage hole is placed securing the glenosphere, fixed further with screws (yellow arrows on c and d), purchasing more bone. This technique ensures the complete stability of the glenoid component and reduces the chances of component loosening.

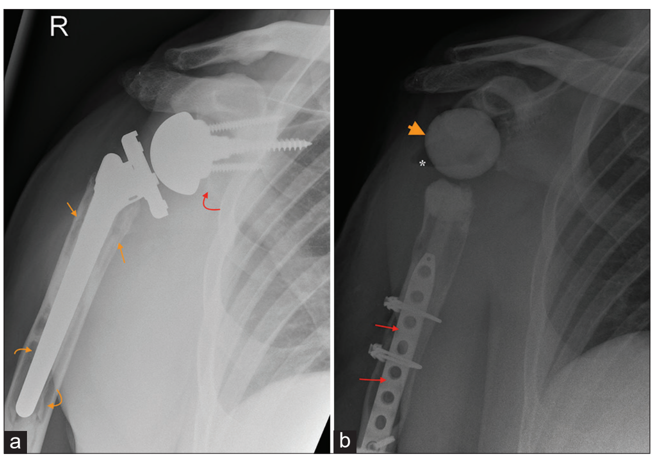

Figure 3: A 78-year-old male presented with restriction of shoulder movements, pain, fever, and raised C-reactive protein and white cell counts following reverse total shoulder arthroplasty of the right shoulder. (a) Complete resorption and non-visualization of the inferior glenoid (curved red arrow), irregular osteolysis around the humeral component and cement resorption (straight amber arrows), and the humeral stem with extension into the cement spacer underlying the tip of the humeral stem (curved amber arrows) suggesting infective prosthesis loosening. Imaging wise, it is incredibly challenging to differentiate infective and non-infective prosthesis loosening, and the diagnosis of infective loosening heavily relies on clinical and biochemical indicators. Two-step surgery, including infected implant removal and revision shoulder arthroplasty, is usually the surgery of choice. (b) The infected implant was removed, interval cement glenosphere (amber arrowhead) was placed, and the humeral shaft was strengthened (red arrows) with metalwork with high-dose antibiotic cover to eliminate an infection. Also, appreciate air-fluid level (asterisk) within the right shoulder joint.

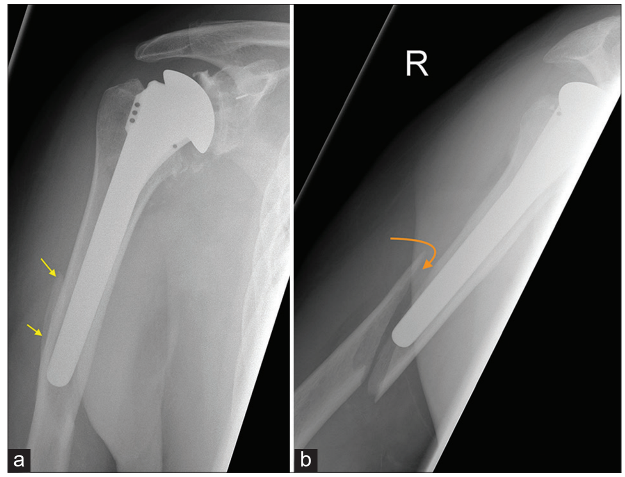

Figure 4: An 82-year-old female after sustaining fall over the right arm. (a) Anteroposterior and (b) lateral radiographs depict an oblique periprosthetic fracture (straight yellow arrows) at the humeral stem. The displacement of the fractured bone is better seen on the lateral radiograph (curved amber arrow).

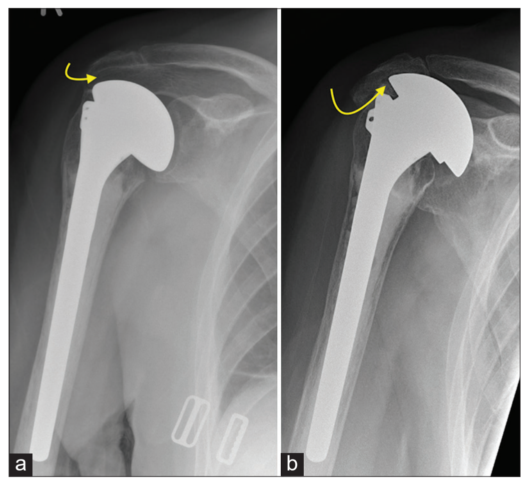

Figure 5: A 75-year-old male presented with a gradual reduction in shoulder strength and pain with overhead movements following right total shoulder arthroplasty (anatomical repair). An anteroposterior radiograph (a) in May 2019 demonstrates only a minimal reduction in the acromiohumeral distance, (b) compared to the radiograph on January 2021, which has progressed to complete loss of the acromiohumeral distance with bone-on-bone articulation and remodeling of the undersurface of the acromion process. This suggests a complete and irreversibly retracted rotator cuff tear.

of arthroplasty cases and is a risk factor for aseptic loosening and periprosthetic fracture. Stress shielding manifests radiologically as a central radiodensity and/or cortical thinning.[5]

Rotator cuff tears, particularly of the subscapularis, can be seen acutely (mean follow-up time – 1.9 years) following anatomical TSA. They become clinically evident soon after

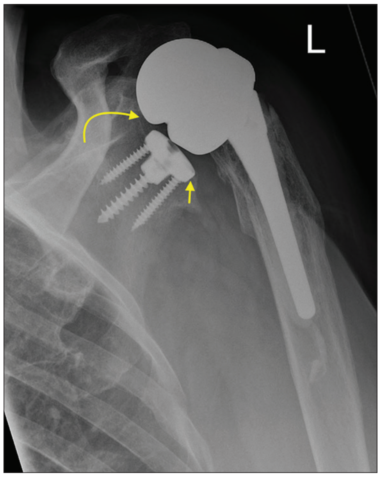

Figure 6: An 84-year-old male following fall over the left shoulder. Complete loss of congruence between superiorly placed humeral prosthesis (curved yellow arrow) compared to the glenoid base plate (straight yellow arrow), suggesting anterosuperior dislocation of the humeral component.

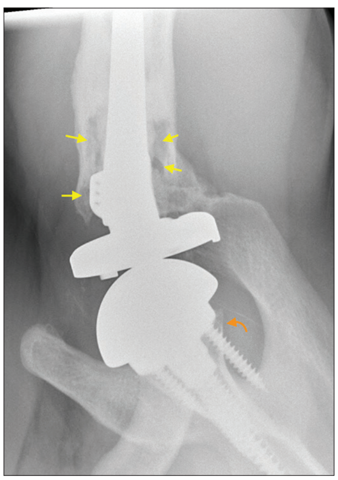

Figure 7: An 86-year-old female presented with a gradual decline of the implanted left shoulder, increasing pain during shoulder movements. The axillary radiograph demonstrates radiolucency indicating resorption of the posterior glenoid (amber curved arrow) and irregular radiolucent areas at the bone-cement junction along the humeral component neck. These findings are suggestive of glenoid as well as humeral component loosening.

arthroplasty as an intact rotator cuff is necessary for adequate function.[2] Plain film [Figure 5], ultrasound, and MRI with metal reduction sequences can be used to confirm the diagnosis. Revision to a reverse TSA can be performed in such cases. Rotator cuff tears can occur in either the early or late post-operative period.

A common complication following reverse TSA is anterior shoulder dislocation which can occur in up to 20% of patients

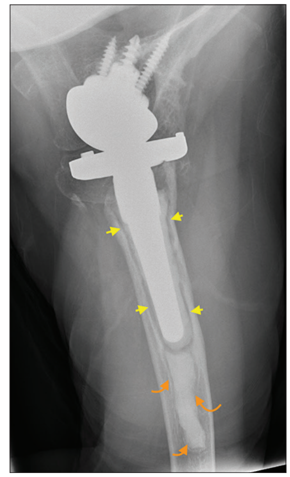

Figure 8: A 79-year-old male presented with pain and loss of function of the left shoulder after a decade following reverse total shoulder arthroplasty. Irregular radiolucency at the bone-cement junction in all periprosthetic zones (short yellow arrows) consistent with humeral component loosening. Also, appreciate the radiolucency around the cement spacer at the humeral stem tip (amber curved arrows), which necessitates the exclusion of underlying indolent infection and possible biofilm formation.

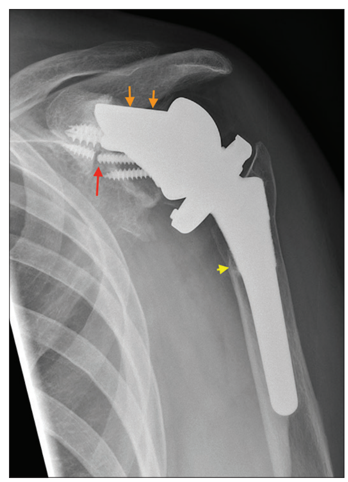

Figure 9: An 84-year-old male presented with pain in the left shoulder following reverse total shoulder arthroplasty. AP radiograph demonstrates broken glenoid screw (red arrow) indicating micromovement, leading to glenoid component loosening in the future. Also, note additional metallic material at the posterosuperior glenoid (amber arrows) suggesting augmented baseplate and mild sclerosis at the medial aspect of the humeral stem neck (yellow arrowhead) with radiolucency at the medial humeral margin just superior to it suggesting stress shielding.

[Figure 6]. It occurs in the anterosuperior direction rather than the usual anteroinferior direction, due to unopposed deltoid contraction.[6]

LATE POST-OPERATIVE COMPLICATIONS

Periprosthetic loosening occurs most frequently in anatomical total shoulder arthroplasties.[2] The glenoid component [Figure 7] is preferentially affected over the humeral stem component [Figure 8]. Typical radiographic findings are periprosthetic lucencies of more than 1.5 mm thickness[2] and progression overtime.[7] Loosening can progress to periprosthetic fracture. Periprosthetic movement can also manifest as metalwork fractures [Figure 9] or inferior glenoid resorption [Figure 10], characteristically seen in reverse TSA with medialized placement or when a smaller sized glenosphere is used.

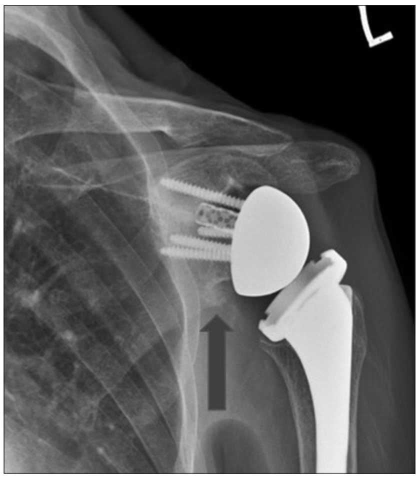

Figure 10: Inferior glenoid resorption indicated by gray arrow suggesting medially placed glenosphere and repetitive contact of the medial margin of the humeral component to the inferomedial glenoid during the shoulder abduction.

Acromion and scapular spine fractures are exclusively seen in reverse total shoulder arthroplasties[8] and are essential review areas for the radiologist. Early plain film changes are sclerosis and periosteal reaction at the site of pathology. Occasionally, plain films are unremarkable despite a strong clinical concern for stress fractures of the acromion or spine of the scapula, with the patient experiencing focal tenderness in these regions [Figure 11]. CT or bone scintigraphy is more sensitive subsequent investigations and may reveal abnormalities occult on plain film radiography.[9]

EFFECTS OF IMAGING FINDINGS ON SURGICAL DECISIONS DURING SHOULDER ARTHROPLASTIES

A strategic use of imaging helps to plan an appropriate surgical procedure. Specifically, it helps while selecting specialist instrumentation and kit design (using CADCAM). 3D printing can help counsel patients and allow simulation of the surgical procedure if necessary. Aforementioned technical factors along with patient and surgeon-related human factors allow fully informed and optimal decision making. Patient motivation, realistic expectations, and the likelihood of adhering to post-operative rehabilitation including physiotherapy support are critical non-imaging considerations for prognostic assessment.

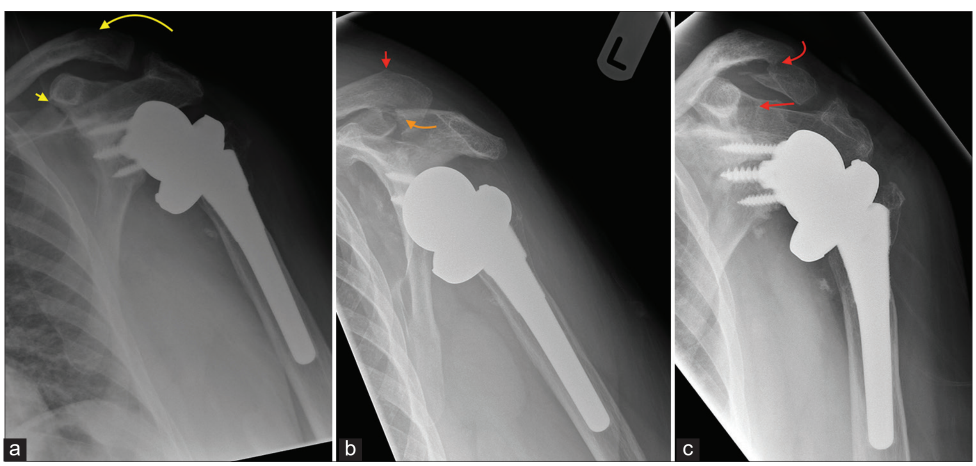

Figure 11: A 78-year-old male presented with loss of shoulder movement following fall. Anteroposterior (a) and scapular Y-view (b) radiographs demonstrating acromion and scapular spine fractures. Please note subtlety of acromion fracture (depicted by the curved yellow arrow in Figure 11a and corresponding red arrow in Figure 11b) and scapular spine fracture (yellow arrow in Figure 11a) seen as a cortical breach and increased sclerosis of the medial scapula, which is more conspicuously seen in Figure 11b (curved amber arrow). A follow-up radiograph after 3 months (Figure 11c) demonstrates a progression of the acromion process fracture (curved red arrow), which is now completely displaced, whereas the scapular spine fracture shows some healing changes (straight red arrow).

CONCLUSION

Pre-operative planning using CT helps foster better understanding and execution of shoulder replacements, especially in challenging scenarios. It has led to incremental use of either navigation-based operative procedures or custom-designed PSI for shoulder arthroplasties.

Complications are infrequent if meticulous attention is paid to correct patient selection, pre-operative optimization, managing patient expectations, and ensuring correct planning and appropriate execution.

Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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