

CMEARTICLE

Clinics in diagnostic imaging (167)

Tien Jin Tan¹, MBBS, FRCR, Ahmad Mohammad Aljefri¹, MBBS, SB-Rad, Marc Bruce Elliott¹, MD, FRCPC, Savvas Nicolaou¹, MD, FRCPC

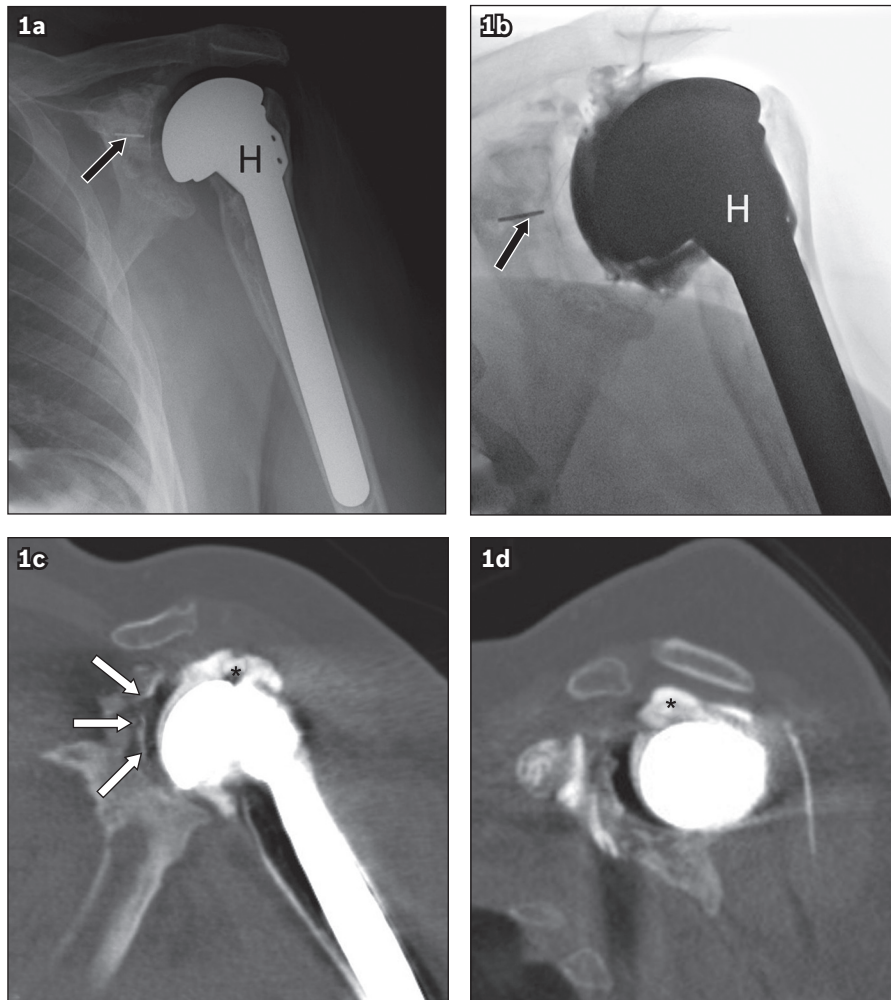


Fig. 1 Anteroposterior (a) radiograph and (b) fluoroscopic arthrogram image of the left shoulder. (c) Coronal and (d) sagittal monoenergetic 80 keV dual-energy computed tomography images of the left shoulder acquired immediately after the left shoulder arthrogram.

CASE PRESENTATION

A 59-year-old woman presented with left shoulder pain and stiffness of 12 months' duration. She had previously undergone an anatomic left total shoulder arthroplasty four years ago for avascular necrosis of the humeral head with advanced secondary glenohumeral osteoarthritis. The patient had actively participated in a postoperative rehabilitation programme, with good pain relief and restoration of function of the left shoulder. However, over a period of 12 months prior to the current clinical presentation, the patient began to experience increasing left shoulder pain and

stiffness, which limited her activities of daily living. A physical examination revealed significant reduction in motion of the left shoulder, which included limitation of active forward flexion of about 40°. There was also difficulty in initiating shoulder abduction. Radiographic (Fig. 1a) and arthrographic (Fig. 1b) assessments of the left shoulder were performed. These were followed by dual-energy computed tomography (DECT) of the left shoulder, which was performed without intravenous contrast immediately following the left shoulder arthrogram (Figs. 1c & d). What do these images demonstrate? What is the diagnosis?

¹Department of Radiology, Vancouver General Hospital, Vancouver, British Columbia, Canada

Correspondence: Dr Tien Jin Tan, Consultant, Department of Radiology, Changi General Hospital, 2 Simei Street 3, Singapore 529889. tien_jin_tan@cgh.com.sg

IMAGE INTERPRETATION

Anteroposterior radiography (Fig. 1a) and the fluoroscopic arthrogram image (Fig. 1b) of the left shoulder demonstrate a cemented left anatomic total shoulder arthroplasty, which consists of the humeral component (H) and a radio-opaque marker (black arrows) on the central peg of the radiolucent glenoid component. No significant periprosthetic lucency suggesting loosening or a periprosthetic fracture is identified on the radiograph. There is no clear insinuation of contrast into the bone-cement or implant-cement interface in the fluoroscopic arthrogram image. Coronal (Fig. 1c) and sagittal (Fig. 1d) monoenergetic 80 kiloelectron-voltage (keV) DECT images of the left shoulder, obtained immediately following the arthrogram, reveal a dense sliver of intra-articular contrast insinuating into the implant-cement interface of the glenoid component (white arrows), as well as a large contrast-filled gap (*) at the expected location of the supraspinatus tendon; the latter is in keeping with a complete tendon tear.

DIAGNOSIS

Total shoulder arthroplasty glenoid component loosening with secondary rotator cuff failure.

CLINICAL COURSE

In view of the left shoulder DECT arthrography findings of glenoid periprosthetic loosening and secondary rotator cuff failure, the patient was counselled on the need for further surgery. She declined surgery at that point in time, but was agreeable to undergo aspiration of the left shoulder joint, which excluded an underlying infection as a potential cause for the patient's increasing shoulder pain. She has since been referred to a specialist pain management team for medical treatment of her left shoulder pain as a temporising measure.

DISCUSSION

Arthroses of the shoulder joint are common in ageing adults and can be debilitating due to the presence of significant pain and reduced range of motion of the shoulder joint, which results in an overall diminished quality of life.⁽¹⁾ Patients may be affected by primary osteoarthritis of the glenohumeral joint or have osteoarthritis secondary to preceding events such as trauma, avascular necrosis of the humeral head, inflammatory arthropathy, repetitive microtrauma in throwing athletes and joint instability. The exact incidence of glenohumeral osteoarthritis is not known, although Gartsman and Taverna found that approximately 13% of a total of 200 patients who underwent arthroscopy for full-thickness rotator cuff tears had coexisting chondral injuries.⁽²⁾

The majority of patients with glenohumeral osteoarthritis are treated with analgesics, which primarily consist of nonsteroidal anti-inflammatory drugs, with or without physical therapy. Intra-articular injections of steroids or viscosupplements such as hyaluronic acid have been found to provide temporary relief.⁽³⁾ Surgical treatment options for glenohumeral osteoarthritis include arthroscopic debridement for chondral injuries, microfracture and osteochondral grafts, capsular release, and shoulder arthroplasty. Subacromial decompression may be indicated in a subset of

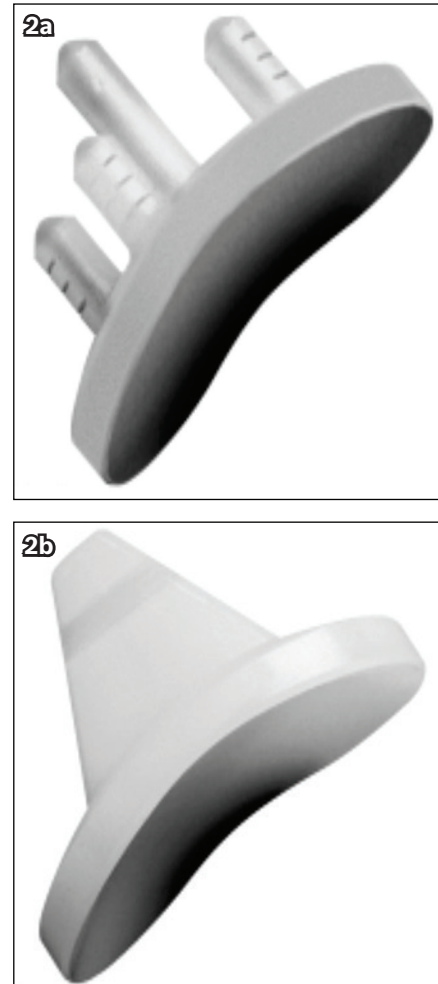


Fig. 2 Illustrations show the (a) pegged and (b) keeled glenoid components used in shoulder arthroplasty (reproduced with permission from Lazarus et al⁽⁴⁰⁾).

patients with mild to moderate arthroses and concomitant impingement symptoms.⁽³⁾

Anatomic total shoulder arthroplasty, reverse shoulder arthroplasty, hemiarthroplasty and humeral head resurfacing are becoming increasingly more common in current orthopaedic reconstructive surgery practice. Approximately 27,000 total shoulder arthroplasties and 20,000 hemiarthroplasties were performed in the United States in the year 2008 alone.⁽⁴⁾ Osteoarthritis was the primary indication in 77% of total shoulder arthroplasty cases and 43% of hemiarthroplasty cases. Proximal humeral fractures were the second most common indication for a hemiarthroplasty (33%).

Our case involved an anatomic total shoulder arthroplasty, which is most commonly performed for degenerative osteoarthritis in patients older than 60 years, and required an intact rotator cuff. The humeral component is a minimally constrained anatomic implant consisting of a hemispherical metal articular surface and a cemented or press-fit stem. This articulates with a radiolucent polyethylene glenoid component. The central peg of the glenoid component contains a radio-opaque marker.⁽⁵⁾ Pegged glenoid components (Fig. 2a) are now favoured over their keeled counterparts (Fig. 2b) due to the proposed benefits of more uniform stress distribution to the

Table I. Franklin classification of periprosthetic radiolucency for keeled glenoid components.⁽⁹⁾

Grade	Radiographic findings
0	No radiolucency
1	Radiolucency at the superior and/or inferior flange
2	Incomplete radiolucency at the keel
3	Complete radiolucency (≤ 2 mm wide) around the keel
4	Complete radiolucency (> 2 mm wide) around the keel
5	Gross loosening

Table II. Lazarus classification of periprosthetic radiolucency for pegged glenoid components.⁽¹⁰⁾

Grade	Radiographic findings
0	No radiolucency
1	Incomplete radiolucency around one or two pegs
2	Complete radiolucency (≤ 2 mm wide) around one peg only, with or without incomplete radiolucency around one other peg
3	Complete radiolucency (≤ 2 mm wide) around two or more pegs
4	Complete radiolucency (> 2 mm wide) around two or more pegs
5	Gross loosening

bone and minimal removal of the glenoid bone, thus facilitating future revision surgeries if so required.⁽⁶⁾

The most commonly encountered complication of anatomic total shoulder arthroplasty is loosening of the glenoid component, which occurs in up to 39% of patients following arthroplasty.⁽⁷⁾ Preliminary imaging evaluation of the painful shoulder following an arthroplasty is typically performed using plain radiographs, where glenoid component loosening manifests as glenoid component migration, tilt or periprosthetic radiolucency measuring more than 1.5 mm in thickness.^(7,8) The grading of periprosthetic radiolucency for keeled glenoid components was first described by Franklin et al (Table I),⁽⁹⁾ and subsequently modified by Lazarus et al to grade periprosthetic radiolucency for pegged glenoid components (Table II).⁽¹⁰⁾ Other previously described complications of anatomic total shoulder arthroplasty include loosening of the humeral component (Figs. 3 & 4), glenohumeral instability, periprosthetic fracture (Fig. 4), dislocation (Fig. 5), infection (Fig. 6), rotator cuff failure, neural injury and deltoid muscle dysfunction.⁽¹¹⁾

Implant loosening may also be evaluated using CT, although image degradation caused by significant metal artefacts may prevent reliable analysis of implant fixation.^(12,13) New CT protocols and image reconstruction techniques have been developed in an attempt to reduce these artefacts,^(14,15) although further studies are required to evaluate the true efficacy of these techniques in the context of shoulder arthroplasty. Insinuation of intra-articular contrast medium into the bone-cement or implant-cement interface is also diagnostic of loosening of the glenoid component. While Mallo et al concluded from their study of 14 patients that CT arthrography (CTA) had a high positive predictive value of 87.5% in the diagnosis of glenoid component

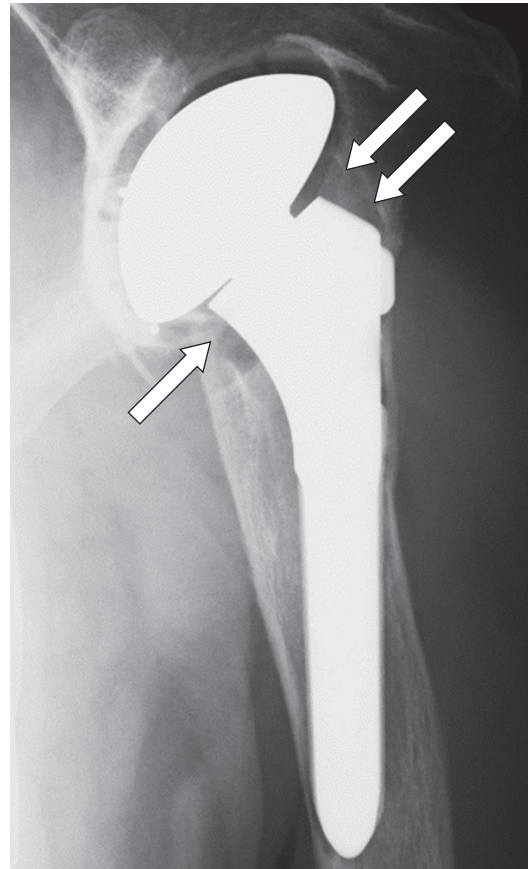


Fig. 3 A 79-year-old man with prior anatomic total shoulder arthroplasty. Left shoulder radiograph shows periprosthetic lucency (arrows) related to the humeral component, which is in keeping with loosening.



Fig. 4 An 81-year-old man with acute chronic left shoulder pain following arthroplasty. Lateral radiograph of the proximal left humerus shows periprosthetic lucency (black arrows), which is in keeping with loosening of the humeral component, and a cortical break close to the distal tip of the stem (white arrow), which is compatible with a periprosthetic fracture.

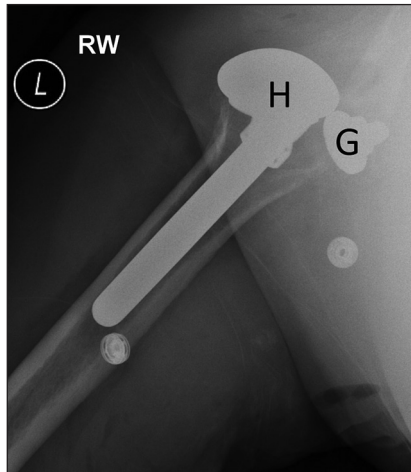


Fig. 5 A 53-year-old man with previous arthroplasty who presented with acute left shoulder pain and restricted range of motion following a fall. Axial left shoulder radiograph shows loss of congruency between the articular surfaces of the glenoid (G) and humeral (H) components secondary to acute posterior dislocation.

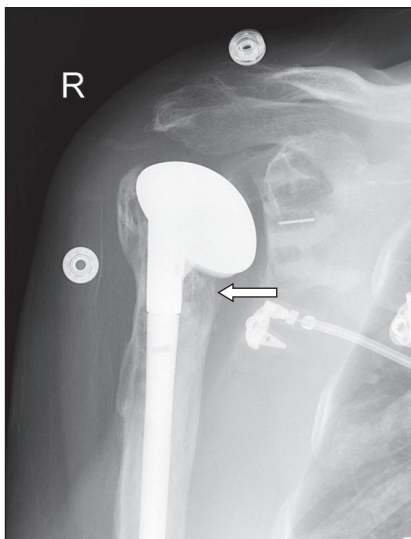


Fig. 6 A 79-year-old woman with increasing shoulder pain following shoulder arthroplasty. Anteroposterior radiograph shows increased lucency and early erosion inferior to the prosthetic humeral head (arrow). US-guided aspiration of the shoulder joint was performed and cultures of the aspirated joint fluid were positive for infection.

loosening, they also urged caution in predicting component stability based solely on a negative CTA study, particularly in view of the low negative predictive value of 50%.⁽¹⁶⁾

Utilisation of the monoenergetic spectrum of DECT to minimise beam hardening artefacts associated with implanted metal orthopaedic devices is an important application in musculoskeletal imaging.⁽¹⁷⁾ The image quality and diagnostic value of DECT imaging of orthopaedic hardware were found to be significantly improved, with minimal artefacts, at a high-energy monoenergetic 130 keV setting.^(18,19) This was seen in our case, where monoenergetic 130 keV images were superior to average weighted 120 keV images in minimising beam hardening artefacts (not shown). Of note, the monoenergetic 80 keV images better demonstrated contrast insinuation into the implant-cement interface (which confirmed the presence of glenoid component loosening) compared to the monoenergetic 130 keV images

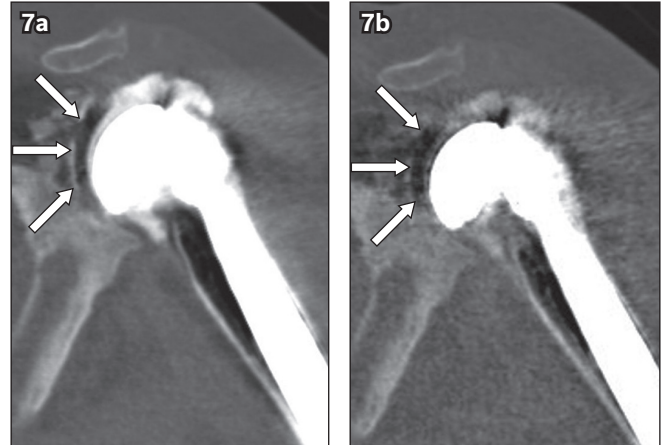


Fig. 7 Coronal monoenergetic (a) 80 keV and (b) 130 keV DECT images of the left shoulder. The sliver of contrast insinuating into the implant-cement interface of the glenoid component (arrows) is better demonstrated in the 80 keV than the 130 keV DECT image.

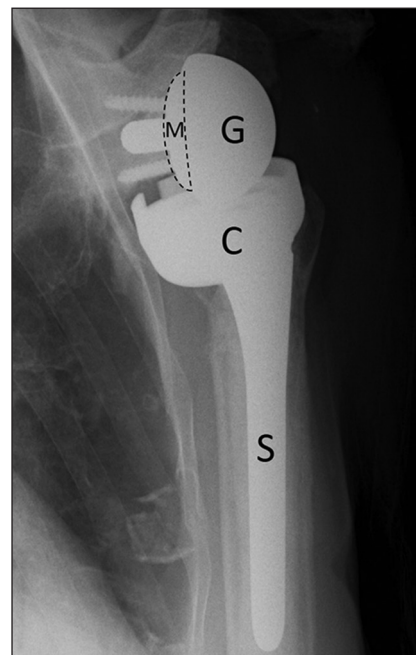


Fig. 8 Reverse total shoulder arthroplasty in a 76-year-old woman. Anteroposterior radiograph of the right shoulder shows the humeral component, which consists of a stem (S) and cup-shaped proximal portion (C). The glenosphere (G) is a hemispheric metal component that articulates with the humeral cup via a radiolucent polyethylene insert. The glenosphere is attached to a baseplate known as metaglene (area marked with broken lines; M), which is fixed on the native glenoid using screws.

(Fig. 7). This is due to the greater photoelectric absorption of X-rays at a lower tube voltage value by materials with large atomic numbers such as iodine, which is found in contrast medium, resulting in a greater degree of beam attenuation and increased conspicuity of contrast.⁽²⁰⁾

The integrity of the rotator cuff is typically evaluated using ultrasonography, which has been found to be a highly accurate imaging modality for evaluating the integrity of the rotator cuff following shoulder arthroplasty.^(21,22) Prickett et al found that ultrasonography had a sensitivity of 91%, specificity of 86% and accuracy of 89% for identifying rotator cuff integrity postoperatively.⁽²²⁾ In our case, the DECT shoulder arthrogram was

also useful in determining the presence of a full-thickness rotator cuff tendon tear (a known complication of anatomic total shoulder arthroplasty), in addition to the finding of glenoid component loosening. The finding of a full-thickness rotator cuff tendon tear is important, as it influences further surgical management of the patient; a reverse total shoulder arthroplasty was one of the options considered as a salvage procedure, rather than a simple revision of the loosened glenoid component, given the presence of secondary rotator cuff failure.⁽¹¹⁾ A reverse total shoulder arthroplasty differs from an anatomic total shoulder arthroplasty in that the humeral component consists of a proximal cup-shaped portion (with radiolucent polyethylene insert) and metal stem, while the 'glenoid' component consists of a hemispheric metal component (glenosphere) that attaches to a baseplate (metaglene), which is itself secured to the native glenoid using screws (Fig. 8). Other indications for a reverse total shoulder arthroplasty, apart from it being a salvage procedure for a failed anatomic total shoulder arthroplasty secondary to rotator cuff dysfunction, include treatment of rotator cuff arthropathy, severe proximal humeral fractures with greater tuberosity malposition or non-union, and a massive rotator cuff tear.⁽⁷⁾

In scenarios where plain radiography, ultrasonography or CT fail to identify the underlying cause of the patient's symptoms, magnetic resonance (MR) imaging may be performed to further evaluate for potential pathology or address a specific clinical question.⁽²³⁾ Compared to plain radiography or CT, MR imaging is able to provide a superior assessment of the soft tissue structures surrounding the shoulder joint, which include the rotator cuff, deltoid muscle, neural structures, joint capsule and synovium.⁽²³⁾ Osteolysis, implant loosening and wear-induced synovitis may also now be evaluated using MR imaging due to advances in metal artefact suppression imaging techniques.⁽²³⁾

Notwithstanding the availability of different imaging modalities that have been shown to be useful in the evaluation of a patient with symptoms following total shoulder arthroplasty, the case we have presented illustrates how a DECT arthrogram may be used to identify glenoid component loosening, the most commonly encountered postoperative complication, particularly when preliminary plain radiographic findings are not conclusive.

ABSTRACT A 59-year-old woman who had previously undergone an anatomic left total shoulder arthroplasty presented with increasing left shoulder pain and significant reduction in motion of the left shoulder joint. No evidence of prosthetic loosening or periprosthetic fracture was detected on the radiographs or fluoroscopic arthrogram images. Dual-energy computed tomography (DECT) images revealed evidence of loosening of the glenoid component and secondary rotator cuff failure. This case illustrates how a combination of detailed clinical history, careful physical examination and DECT arthrogram evaluation may be used to identify complications of an anatomic total shoulder arthroplasty.

Keywords: dual-energy computed tomography, prosthesis loosening, rotator cuff failure, shoulder arthroplasty

Knowledge of the other potential complications of a total shoulder arthroplasty, as described in this article, will also greatly aid the managing clinician and reporting radiologist in the postoperative imaging evaluation of an anatomic total shoulder arthroplasty.

REFERENCES

- Petscavage JM, Ha AS, Chew FS. Current concepts of shoulder arthroplasty for radiologists: Part 1--Epidemiology, history, preoperative imaging, and hemiarthroplasty. *AJR Am J Roentgenol* 2012; 199:757-67.
- Gartsman GM, Taverna E. The incidence of glenohumeral joint abnormalities associated with full-thickness, repairable rotator cuff tears. *Arthroscopy* 1997; 13:450-5.
- Boselli KJ, Ahmad CS, Levine WN. Treatment of glenohumeral arthrosis. *Am J Sports Med* 2010; 38:2558-72.
- Kim SH, Wise BL, Zhang Y, Szabo RM. Increasing incidence of shoulder arthroplasty in the United States. *J Bone Joint Surg Am* 2011; 93:2249-54.
- Merolla G, Di Pietto F, Romano S, et al. Radiographic analysis of shoulder anatomical arthroplasty. *Eur J Radiol* 2008; 68:159-69.
- Boileau P, Sinnerton RJ, Chuinard C, Walch G. Arthroplasty of the shoulder. *J Bone Joint Surg Br* 2006; 88:562-75.
- Ha AS, Petscavage JM, Chew FS. Current concepts of shoulder arthroplasty for radiologists: Part 2--Anatomic and reverse total shoulder replacement and nonprosthetic resurfacing. *AJR Am J Roentgenol* 2012; 199:768-76.
- Sheridan BD, Ahearn N, Tasker A, Wakeley C, Sarangi P. Shoulder arthroplasty. Part 2: normal and abnormal radiographic findings. *Clin Radiol* 2012; 67:716-21.
- Franklin JL, Barrett WP, Jackins SE, Matsen FA 3rd. Glenoid loosening in total shoulder arthroplasty. Association with rotator cuff deficiency. *J Arthroplasty* 1988; 3:39-46.
- Lazarus MD, Jensen KL, Southworth C, Matsen FA 3rd. The radiographic evaluation of keeled and pegged glenoid component insertion. *J Bone Joint Surg Am* 2002; 84-A:1174-82.
- Bohsali KI, Wirth MA, Rockwood CA Jr. Complications of total shoulder arthroplasty. *J Bone Joint Surg Am* 2006; 88:2279-92.
- Yian EH, Werner CM, Nyffeler RW, et al. Radiographic and computed tomography analysis of cemented pegged polyethylene glenoid components in total shoulder replacement. *J Bone Joint Surg Am* 2005; 87:1928-36.
- Arnold RM, High RR, Grosshans KT, Walker CW, Fehringer EV. Bone presence between the central peg's radial fins of a partially cemented pegged all poly glenoid component suggest few radiolucencies. *J Shoulder Elbow Surg* 2011; 20:315-21.
- Gregory T, Hansen U, Khanna M, et al. A CT scan protocol for the detection of radiographic loosening of the glenoid component after total shoulder arthroplasty. *Acta Orthop* 2014; 85:91-6.
- Subhas N, Primak AN, Obuchowski NA, et al. Iterative metal artifact reduction: evaluation and optimization of technique. *Skeletal Radiol* 2014; 43:1729-35.
- Mallo GC, Burton L, Coats-Thomas M, et al. Assessment of painful total shoulder arthroplasty using computed tomography arthrography. *J Shoulder Elbow Surg* 2015; 24:1507-11.
- Nicolaou S, Liang T, Murphy DT, et al. Dual-energy CT: a promising new technique for assessment of the musculoskeletal system. *AJR Am J Roentgenol* 2012; 199(5 Suppl):S78-86.
- Zhou C, Zhao YE, Luo S, et al. Monoenergetic imaging of dual-energy CT reduces artifacts from implanted metal orthopedic devices in patients with fractures. *Acad Radiol* 2011; 18:1252-7.
- Bamberg F, Dierks A, Nikolaou K, et al. Metal artifact reduction by dual energy computed tomography using monoenergetic extrapolation. *Eur Radiol* 2011; 21:1424-9.
- Kalva SP, Sahani DV, Hahn PF, Saini S. Using the K-edge to improve contrast conspicuity and to lower radiation dose with a 16-MDCT: a phantom and human study. *J Comput Assist Tomogr* 2006; 30:391-7.
- Armstrong A, Lashgari C, Teefey S, et al. Ultrasound evaluation and clinical correlation of subscapularis repair after total shoulder arthroplasty. *J Shoulder Elbow Surg* 2006; 15:541-8.
- Prickett WD, Teefey SA, Galatz LM, et al. Accuracy of ultrasound imaging of the rotator cuff in shoulders that are painful postoperatively. *J Bone Joint Surg Am* 2003; 85-A:1084-9.
- Beltran LS, Bencardino JT, Steinbach LS. Postoperative MRI of the shoulder. *J Magn Reson Imaging* 2014; 40:1280-97.

SINGAPORE MEDICAL COUNCIL CATEGORY 3B CME PROGRAMME (Code SMJ 201604B)

Question 1. Regarding glenohumeral osteoarthritis:

- (a) Avascular necrosis is a cause of secondary glenohumeral osteoarthritis.
- (b) Inflammatory arthropathy is not a cause of secondary glenohumeral osteoarthritis.
- (c) The majority of patients with glenohumeral osteoarthritis are treated with analgesics, with or without physical therapy.
- (d) Intra-articular injections of steroids or viscosupplements have been found to provide temporary relief.

True False

- | | |
|--------------------------|--------------------------|
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |

Question 2. The different options available in shoulder reconstruction surgery include:

- (a) Humeral head resurfacing.
- (b) Hemiarthroplasty.
- (c) Anatomic total shoulder arthroplasty.
- (d) Reverse shoulder arthroplasty.

- | | |
|--------------------------|--------------------------|
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |

Question 3. Concerning the potential complications of an anatomic total shoulder arthroplasty:

- (a) Rotator cuff failure is a potential complication.
- (b) Dislocation is not a recognised complication.
- (c) Periprosthetic fracture is the most commonly encountered complication.
- (d) Glenoid component loosening is the most commonly encountered complication.

- | | |
|--------------------------|--------------------------|
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |

Question 4. Regarding imaging evaluation of patients following an anatomic total shoulder arthroplasty:

- (a) Preliminary imaging evaluation is typically performed using plain radiographs.
- (b) Detection of component loosening using computed tomography (CT) may be limited by the presence of significant metal artefacts arising from the prosthetic implant.
- (c) CT arthrography has been reported to have a high positive predictive value in the diagnosis of glenoid component loosening.
- (d) Osteolysis, implant loosening and wear-induced synovitis may also now be evaluated using magnetic resonance imaging due to advances in metal artefact suppression imaging techniques.

- | | |
|--------------------------|--------------------------|
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |

Question 5. The indications for a reverse shoulder arthroplasty include:

- (a) Failed anatomic total shoulder arthroplasty secondary to rotator cuff dysfunction.
- (b) Rotator cuff arthropathy.
- (c) Severe proximal humeral fractures with greater tuberosity malposition or non-union.
- (d) Massive rotator cuff tear.

- | | |
|--------------------------|--------------------------|
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> |

Doctor's particulars:

Name in full : _____
 MCR number : _____ Specialty: _____
 Email address : _____

SUBMISSION INSTRUCTIONS:

(1) Log on at the SMJ website: <http://www.sma.org.sg/publications/smjcurrentissue.aspx> and select the appropriate set of questions. (2) Provide your name, email address and MCR number. (3) Select your answers and click "Submit".

RESULTS:

(1) Answers will be published in the SMJ June 2016 issue. (2) The MCR numbers of successful candidates will be posted online at the SMJ website by 30 May 2016. (3) Passing mark is 60%. No mark will be deducted for incorrect answers. (4) The SMJ editorial office will submit the list of successful candidates to the Singapore Medical Council. (5) One CME point is awarded for successful candidates.

Deadline for submission: (April 2016 SMJ 3B CME programme): 12 noon, 23 May 2016.