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ACR Appropriateness Criteria® on Acute Shoulder Pain

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The shoulder joint is a complex array of muscles, tendons, and capsuloligamentous structures that has the greatest freedom of motion of any joint in the body. Acute (<2 weeks) shoulder pain can be attributable to structures related to the glenohumeral articulation and joint capsule, rotator cuff, acromioclavicular joint, and scapula. The foundation for investigation of acute shoulder pain is radiography. Magnetic resonance imaging is the procedure of choice for the evaluation of occult fractures and the shoulder soft tissues. Ultrasound, with appropriate local expertise, is an excellent evaluation of the rotator cuff, long head of the biceps tendon, and interventional procedures. Fluoroscopy is an excellent modality to guide interventional procedures. Computed tomography is an excellent modality for characterizing complex shoulder fractures. Computed tomographic arthrography or fluoroscopic arthrography may be alternatives in patients for whom MR arthrography is contraindicated. A multimodal approach may be required to accurately assess shoulder pathology. The ACR Appropriateness Criteria® are evidence-based guidelines for specific clinical conditions that are reviewed every 2 years by a multidisciplinary expert panel. The guideline development and review include an extensive analysis of current medical literature from peer-reviewed journals and the application of a well-established consensus methodology (modified Delphi) to rate the appropriateness of imaging and treatment procedures by the panel. In those instances in which evidence is lacking or not definitive, expert opinion may be used to recommend imaging or treatment.

Key Words: Appropriateness Criteria®, acute shoulder pain, labral tear, shoulder arthroplasty, septic arthritis, rotator cuff repair

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The ACR seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria® through society representation on expert panels. Participation by representatives from collaborating societies on the expert panel does not necessarily imply society endorsement of the final document.

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Variant 1. Any etiology; best initial study

Radiologic Procedure	Rating	Comments	Relative Radiation Level
X-ray shoulder	9		☢
CT shoulder without contrast	1		☢☢☢
CT arthrography shoulder	1		☢☢
MRI shoulder without contrast	1		○
MR arthrography shoulder	1		○
Ultrasound shoulder	1		○
X-ray arthrography shoulder	1		☢

Note: Rating scale: 1, 2, and 3 = usually not appropriate; 4, 5, and 6 = may be appropriate; 7, 8, and 9 = usually appropriate.

SUMMARY OF LITERATURE REVIEW

Introduction

The shoulder has the greatest freedom of motion of any joint in the body. The shoulder joint is a complex array of muscles, tendons, and capsuloligamentous structures that demonstrate a wide variety of pathology. Acute (<2 weeks) shoulder pain can be attributable to structures related to the glenohumeral articulation and joint capsule, rotator cuff, acromioclavicular joint, and scapula. Radiography is a safe, fast, low-cost imaging modality that effectively demonstrates many forms of shoulder pathology. However, a multimodal approach may be required to accurately assess shoulder pathology.

Radiography

Radiography is a useful initial screening modality for acute shoulder pain of all causes (see Variant 1). Radiography is useful in the evaluation of fractures of the shoulder girdle. All radiographic shoulder studies should include frontal examinations. The frontal views can be straight anteroposterior (AP) projections with the humerus in the neutral position or with the humerus in internal or without external rotation. Local protocols for radiographic evaluation of the shoulder for trauma vary widely. However, the shoulder trauma protocol should have ≥3 views, of which 2 are orthogonal. For trauma, a Grashey projection is recommended to profile the glenohumeral joint, which is AP to the scapula, by turning the patient into a 30° posterior oblique profile [1]. For trauma, this examination should have an axillary lateral view, a scapular Y view, or both [1-4]. The axillary lateral view or scapular Y view is advisable if there is a question of instability or dislocation [1,5]. However, the position required for the axillary lateral view may be painful for patients who have just dislocated their shoulders. Care should be taken if the shoulder has just been reduced because this positioning may lead to redislocation.

Variant 2. Radiographs noncontributory; persistent significant pain; physical examination and history nonspecific; next study

Radiologic Procedure	Rating	Comments	Relative Radiation Level
MRI shoulder without contrast	9		○
CT arthrography shoulder	5	If MRI contraindicated.	☢☢
Ultrasound shoulder	5	If MRI contraindicated.	○
MR arthrography shoulder	1		○
CT shoulder without contrast	1		☢☢☢
X-ray arthrography shoulder	1		☢
X-ray arthrography shoulder with anesthetic and/or corticosteroid	1		☢

Note: Rating scale: 1, 2, and 3 = usually not appropriate; 4, 5, and 6 = may be appropriate; 7, 8, and 9 = usually appropriate.

Variant 3. Radiographs noncontributory; age < 35 years, suspect labral tear with or without instability on physical examination

Radiologic Procedure	Rating	Comments	Relative Radiation Level
MR arthrography shoulder	9	See statement regarding contrast in text under "Anticipated Exceptions."	○
MRI shoulder without contrast	7	With optimized imaging equipment.	○
CT arthrography shoulder	5	If MRI contraindicated.	☢☢
CT shoulder without contrast	1		☢☢☢
Ultrasound shoulder	1		○
X-ray arthrography shoulder	1		☢

Note: Rating scale: 1, 2, and 3 = usually not appropriate; 4, 5, and 6 = may be appropriate; 7, 8, and 9 = usually appropriate.

The transthoracic view has little to offer but is not infrequent when outside radiographs become available for review. There have been several reports assessing special views for the evaluation of shoulder impingement and the anterior acromion [3,4,6]. An upright 30° angled caudad radiograph (Rockwood view) or a suprascapular outlet view will suffice in most cases [6,7]. A radiograph taken with the patient prone with the shoulder resting on a cushion and arm abducted 90°, with the forearm and hand in pronation, hanging downward off the edge of the table (Westpoint view), can improve detection of a bony Bankart lesion [1]. A radiograph taken with patient in the supine position with the arm externally rotated and abducted and the x-ray beam angled 10° cephalad and centered on the coracoid process (Stryker notch view) used with an AP internal rotation view, is a sensitive technique for the evaluation of a Hill-Sachs deformity [1].

Fluoroscopic arthrography was the mainstay of evaluation for rotator cuff tear until the advent of shoulder MRI. Fluoroscopic arthrography is currently used only as a potential study in patients with suspected rotator cuff disease who have contraindications to MRI and when shoulder ultrasound expertise is not available (see Variant 7). Fluoroscopic radiography is a useful modality for directing shoulder injections and aspirations (see Variant 8). Aspirations are useful in differentiating between inflammatory and septic arthropathy. Fluoroscopic arthrography can be a useful tool in experienced hands.

Variant 4. Radiographs noncontributory; questionable bursitis or long head of biceps tenosynovitis based on clinical findings including physical examination

Radiologic Procedure	Rating	Comments	Relative Radiation Level
MRI shoulder without contrast	9	MRI and ultrasound are equivalent in this evaluation.	○
Ultrasound shoulder	9	MRI and ultrasound are equivalent in this evaluation. If local expertise available. Study may include injection of anesthetic and/or corticosteroid if clinically warranted.	○
CT shoulder without contrast	1		☢☢☢
CT arthrography shoulder	1		☢☢
MR arthrography shoulder	1		○
X-ray arthrography shoulder	1		☢
X-ray shoulder bursography/ tenography with anesthetic and/or corticosteroid	1		☢

Note: Rating scale: 1, 2, and 3 = usually not appropriate; 4, 5, and 6 = may be appropriate; 7, 8, and 9 = usually appropriate.

Variant 5. Normal radiographs or radiographs that demonstrate coracoacromial arch osteophytes/syndesmophytes; suspect rotator cuff tear/impingement, age > 35 years

Radiologic Procedure	Rating	Comments	Relative Radiation Level
MRI shoulder without contrast	9		○
Ultrasound shoulder	8		○
MR arthrography shoulder	7	See statement regarding contrast in text under "Anticipated Exceptions."	○
CT arthrography shoulder	5	If MR or ultrasound cannot be performed.	☢☢
X-ray arthrography shoulder	1		☢
CT shoulder without contrast	1		☢☢☢

Note: Rating scale: 1, 2, and 3 = usually not appropriate; 4, 5, and 6 = may be appropriate; 7, 8, and 9 = usually appropriate.

MRI

MRI can aid in detecting osseous and soft tissue abnormalities that may predispose to or be the result of shoulder impingement [8,9]. The soft tissue abnormalities in the supraspinatus tendon, subacromial bursa, and biceps tendon are well seen [10]. The osseous lesions include morphologic abnormalities of the acromion and acromioclavicular joint. When a tendon has a signal intensity abnormality without focal disruption or associated findings to suggest a partial-thickness tear, the terms *tendinosis* and *tendinopathy* have been used to signify an underlying tendon degeneration or inflammation. These terms suggest that there is a chronic degenerative process. The presence of tendinous enlargement and a heterogeneous signal pattern that demonstrates diffuse increased signal intensity on T1 weighting, often with a slight increase in signal intensity on T2 weighting, is seen in patients with tendinosis. Partial-thickness tears of the rotator cuff can be seen inferiorly at the articular surface, superiorly at the bursal surface or within the tendon substance. Tears at the articular surface are the most common type of partial-thickness tears. These are the only types of partial-thickness tears demonstrated by conventional shoulder arthrography [11]. Full-thickness tears of the rotator cuff tendon can be accurately identified using conventional nonarthrographic MRI, with high sensitivity and specificity. Increased signal intensity extending from the inferior to the superior surface of the tendon on all imaging sequences is an accurate sign of a full-thickness rotator cuff tear [8]. Ten percent of rotator cuff tears are asymptomatic and present only with morphologic changes. Tendon retraction, muscle atrophy, and fatty infiltration are important findings that can be useful for decisions regarding conservative versus operative repair, type of operative repair (open, mini-open, or arthroscopic cuff repair; substitute; or muscle transfer) and to provide a postoperative prognosis. If there is any question concerning the distinction between a full-thickness and partial-thickness tear, MR arthrography (MRA) is recommended. It is particularly helpful if the abnormal signal intensity extends from the undersurface of the tendon.

Variant 6. Radiographs noncontributory; previous total shoulder arthroplasty; suspect rotator cuff tear

Radiologic Procedure	Rating	Comments	Relative Radiation Level
Ultrasound shoulder	9		○
X-ray arthrography shoulder	8	If ultrasound expertise not available.	☢
CT arthrography shoulder	7	With optimized imaging equipment.	☢☢
MR arthrography shoulder	6	See statement regarding contrast in text under "Anticipated Exceptions."	○
MRI shoulder without contrast	5	With dedicated metal suppression protocol.	○
CT shoulder without contrast	1		☢☢☢

Note: Rating scale: 1, 2, and 3 = usually not appropriate; 4, 5, and 6 = may be appropriate; 7, 8, and 9 = usually appropriate.

Variant 7. Radiographs noncontributory; status post prior rotator cuff repair; suspect retear

Radiologic Procedure	Rating	Comments	Relative Radiation Level
MRI shoulder without contrast	9	MRI, MR arthrography, and ultrasound are equivalent in this evaluation, depending on local expertise.	○
MR arthrography shoulder	9	MRI, MR arthrography, and ultrasound are equivalent in this evaluation, depending on local expertise. See statement regarding contrast in text under "Anticipated Exceptions."	○
Ultrasound shoulder	9	MRI, MR arthrography, and ultrasound are equivalent in this evaluation, depending on local expertise.	○
X-ray arthrography shoulder	5	If MRI or ultrasound cannot be performed.	☢
CT arthrography shoulder	5	If MRI or ultrasound cannot be performed.	☢☢
CT shoulder without contrast	1		☢☢☢

Note: Rating scale: 1, 2, and 3 = usually not appropriate; 4, 5, and 6 = may be appropriate; 7, 8, and 9 = usually appropriate.

The shoulder joint is the most unstable joint in the body. Instability can be difficult to diagnose, and the pain produced by the unstable shoulder could be mistaken for that of shoulder impingement, cervical disk disease, acromioclavicular joint disease, and other processes. During the past decade, MRI has allowed the direct visualization of many of the lesions related to instability, aiding in diagnosis as well as therapeutic planning and follow-up (see Variant 2). Although high-resolution nonenhanced MRI has been shown to have high accuracy rates for demonstrating labral tears, direct MRA with intra-articular injection of a dilute gadolinium solution has gained popularity during the past decade because of its ability to distend the joint and outline labral and capsular structures as well as the undersurface of the rotator cuff [9,11-20]. Currently, MRA is generally recommended for patients aged < 35 years, because instability has been shown to be predominately related to rotator cuff disease in older patients [21,22] (see Variant 3). Magnetic resonance imaging can also play an important role in imaging the postoperative shoulder and in the evaluation of shoulder hardware [23,24] (see Variants 6 and 7).

CT

CT is useful for characterizing fractures, if more information is needed preoperatively. It can demonstrate fracture complexity, displacement, and angulation, especially with the use of reconstructed images [25,26]. Multidetector CT can produce high-quality isotropic imaging. This can be helpful in evaluating a shoulder with metallic hardware. The evaluation of a metallic prosthesis can be optimized by using a higher voltage (140 kVp), higher exposure (200-400 mAs), and reduced pitch with slice overlap (<1). This will improve image quality but also result in increased radiation dose [27]. This panel's consensus opinion is that CT shoulder arthrography is superior to MRI or MRA in the evaluation of the rotator cuff in the setting of a previous shoulder arthroplasty (see Variant 6). Computed tomographic arthrography is useful for the evaluation of the postoperative labrum, rotator cuff, and loosening around implants (see Variants 3, 6, and 7). Computed tomographic arthrography is a second-line procedure for shoulders with suspected instability or labral disorders, when MRA and MRI are unavailable or contraindicated [28] (see Variant 3).

Ultrasound

Ultrasound can be used to evaluate the acromioclavicular joint, the tendons of the rotator cuff, and the long head of biceps tendon. It is operator dependent and limited in evaluation of the other important deep shoulder structures and marrow. Ultrasound-guided injections and aspirations are helpful in treating and diagnosing shoulder pain, with appropriate local expertise (see Variants 7 and 8).

Ultrasound can be used to determine if a partial-thickness or full-thickness rotator cuff tear is present [29]. Ultrasound is equivalent to MRI, with appropriate local expertise, in the evaluation of rotator cuff tears [7]. Ultrasound can also play an important role in the evaluation of the postoperative shoulder and in rotator cuff integrity after shoulder replacement [30] (see Variants 2, 4, and 5-7).

Neoplasm

Neoplasm is another cause of shoulder pain, and (diagnostically) these lesions can be approached like other neoplasms in the musculoskeletal system (see the ACR Appropriateness Criteria® on soft tissue masses and the ACR Appropriateness Criteria on primary bone tumors).

Variant 8. Radiographs noncontributory; suspect septic arthritis

Radiologic Procedure	Rating	Comments	Relative Radiation Level
Ultrasound arthrocentesis shoulder	9	Ultrasound and x-ray guidance are equivalent.	○
X-ray arthrocentesis shoulder	9	Ultrasound and x-ray guidance are equivalent.	☢
MRI shoulder without and with contrast	7	Aspiration is the procedure of choice. May be appropriate if clinical concern warrants. See statement regarding contrast in text under "Anticipated Exceptions."	○
MRI shoulder without contrast	6	Aspiration is the procedure of choice. May be appropriate if clinical concern warrants.	○
CT shoulder without and with contrast	5	Aspiration is the procedure of choice. May be appropriate if clinical concern warrants.	☢☢☢
CT arthrography shoulder	1		☢☢
MR arthrography shoulder	1		○
Ultrasound shoulder	1		○
CT shoulder without contrast	1		☢☢☢

Note: Rating scale: 1, 2, and 3 = usually not appropriate; 4, 5, and 6 = may be appropriate; 7, 8, and 9 = usually appropriate.

Osteomyelitis

Osteomyelitis can be a cause of shoulder pain, although there are no current recommendations by this committee other than for osteomyelitis of the foot (see the ACR Appropriateness Criteria on suspected osteomyelitis of the foot in patients with diabetes mellitus).

SUMMARY

The mainstay in initial imaging of shoulder trauma is radiography. Radiography provides a quick, inexpensive evaluation for fracture and dislocation.

A good shoulder trauma radiography protocol includes AP, Grashey, axillary, and/or scapular Y projections. Special projections include the Rockwood view for evaluation of shoulder impingement, the Westpoint view for Bankart fractures, and the Stryker notch view for Hill-Sachs fractures.

MRI is currently the procedure of choice for the evaluation of occult fractures and the shoulder soft tissues, including the tendons, ligaments, muscles, and labrocapsular structures. The shoulder MRI protocol may or may not include gadolinium, depending on the clinical question. MRI and MRA are the modalities of choice in evaluation of patients aged < 35 years with shoulder pain and in patients with instability and/or questionable labral pathology.

Ultrasound with appropriate local expertise is excellent in the depiction of rotator cuff and long head of biceps pathology in the preoperative and postoperative shoulder. It is an excellent modality to guide injections and aspirations.

Fluoroscopic arthrography was the mainstay of evaluation for rotator cuff tear until the advent of shoulder MRI. It is an excellent modality to guide injections and aspirations. Fluoroscopic arthrography is currently used only as a potential study in patients with suspected rotator cuff disease who have contraindications to MRI and when shoulder ultrasound expertise is not available.

CT without contrast is useful for characterizing fractures, if more information is needed preoperatively. It can demonstrate fracture complexity, displacement, and angulation, especially with the use of reconstructed images. This panel's consensus opinion is that CT shoulder arthrography is superior to MRI or MRA in the evaluation of the rotator cuff in the setting of a previous shoulder arthroplasty. CT arthrography is useful for evaluation of the cuff and loosening around implants. CT arthrography is a good alternative in patients who have a contraindication to MRI or MRA.

ANTICIPATED EXCEPTIONS

Nephrogenic systemic fibrosis is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It seems to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rates (ie, <30 mL/min/1.73 m^2), and almost never in other patients. There is growing literature regarding nephrogenic systemic fibrosis. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent pa-

Table 1. Relative radiation level designations

Relative Radiation Level	Adult Effective Dose Estimate Range (mSv)	Pediatric Effective Dose Estimate Range (mSv)
○	0	0
☢	<0.1	<0.03
☢☢	0.1-1	0.03-0.3
☢☢☢	1-10	0.3-3
☢☢☢☢	10-30	3-10
☢☢☢☢☢	30-100	10-30

Note: Relative radiation level assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The relative radiation levels for these examinations are designated as not specified.

tients unless the possible benefits clearly outweigh the risk and to limit the type and amount in patients with estimated glomerular filtration rates < 30 mL/min/1.73 m^2. For more information, please see the ACR's *Manual on Contrast Media* [31].

RELATIVE RADIATION LEVEL INFORMATION

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, an relative radiation level indication has been included for each imaging examination. The relative radiation levels are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the relative radiation level dose estimate ranges for pediatric examinations are lower compared with those specified for adults (Table 1). Additional information regarding radiation dose assessment for imaging examinations can be found in *ACR Appropriateness Criteria: Radiation Dose Assessment Introduction* [32].

For additional information on ACR Appropriateness Criteria, refer to http://www.acr.org/ac.

REFERENCES

1. Pavlov H, Warren RF, Weiss CB Jr, Dines DM. The roentgenographic evaluation of anterior shoulder instability. Clin Orthop Relat Res 1985; 194:153-8.
2. Brems-Dalgaard E, Davidsen E, Sloth C. Radiographic examination of the acute shoulder. Eur J Radiol 1990;11:10-4.
3. De Smet AA. Anterior oblique projection in radiography of the traumatized shoulder. AJR Am J Roentgenol 1980;134:515-8.
4. De Smet AA. Axillary projection in radiography of the nontraumatized shoulder. AJR Am J Roentgenol 1980;134:511-4.
5. Silfverskiold JP, Straehley DJ, Jones WW. Roentgenographic evaluation of suspected shoulder dislocation: a prospective study comparing the axillary view and the scapular "Y" view. Orthopedics 1990;13:63-9.
6. Kilcoyne RF, Reddy PK, Lyons F, Rockwood CA Jr. Optimal plain film imaging of the shoulder impingement syndrome. AJR Am J Roentgenol 1989;153:795-7.
7. Teefey SA, Rubin DA, Middleton WD, Hildebolt CF, Leibold RA, Yamaguchi K. Detection and quantification of rotator cuff tears. Comparison of ultrasonographic, magnetic resonance imaging, and arthroscopic findings in seventy-one consecutive cases. J Bone Joint Surg Am 2004;86-A:708-16.
8. Balich SM, Sheley RC, Brown TR, Sauser DD, Quinn SF. MR imaging of the rotator cuff tendon: interobserver agreement and analysis of interpretive errors. Radiology 1997;204:191-4.
9. Chandnani VP, Yeager TD, DeBerardino T, et al. Glenoid labral tears: prospective evaluation with MRI imaging, MR arthrography, and CT arthrography. AJR Am J Roentgenol 1993;161:1229-35.
10. Hodler J, Kursunoglu-Brahme S, Snyder SJ, et al. Rotator cuff disease: assessment with MR arthrography versus standard MR imaging in 36 patients with arthroscopic confirmation. Radiology 1992;182:431-6.
11. Legan JM, Burkhard TK, Goff WB II, et al. Tears of the glenoid labrum: MR imaging of 88 arthroscopically confirmed cases. Radiology 1991;179: 241-6.
12. Beltran J, Rosenberg ZS, Chandnani VP, Cuomo F, Beltran S, Rokito A. Glenohumeral instability: evaluation with MR arthrography. Radiographics 1997;17:657-73.
13. Gusmer PB, Potter HG, Schatz JA, et al. Labral injuries: accuracy of detection with unenhanced MR imaging of the shoulder. Radiology 1996;200:519-24.
14. Jee WH, McCauley TR, Katz LD, Matheny JM, Ruwe PA, Daigneault JP. Superior labral anterior posterior (SLAP) lesions of the glenoid labrum: reliability and accuracy of MR arthrography for diagnosis. Radiology 2001;218:127-32.
15. Jim YF, Chang CY, Wu JJ, Chang T. Shoulder impingement syndrome: impingement view and arthrography study based on 100 cases. Skeletal Radiol 1992;21:449-51.
16. Palmer WE, Brown JH, Rosenthal DI. Labral-ligamentous complex of the shoulder: evaluation with MR arthrography. Radiology 1994;190: 645-51.
17. Palmer WE, Caslowitz PL. Anterior shoulder instability: diagnostic criteria determined from prospective analysis of 121 MR arthrograms. Radiology 1995;197:819-25.
18. Shankman S, Bencardino J, Beltran J. Glenohumeral instability: evaluation using MR arthrography of the shoulder. Skeletal Radiol 1999;28: 365-82.
19. Steinbach LS, Palmer WE, Schweitzer ME. Special focus session. MR arthrography. Radiographics 2002;22:1223-46.
20. Tirman PF, Bost FW, Garvin GJ, et al. Posterosuperior glenoid impingement of the shoulder: findings at MR imaging and MR arthrography with arthroscopic correlation. Radiology 1994;193:431-6.
21. Neviaser RJ, Neviaser TJ. Recurrent instability of the shoulder after age 40. J Shoulder Elbow Surg 1995;4:416-8.
22. Steinbach LS, Chung CB, Yoshioka H. Technical considerations for MRI of upper extremity joints. In: Chung CB, Steinbach LS, eds. MRI of the upper extremity shoulder, elbow, wrist and hand. Philadelphia, Pa: Lippincott Williams & Wilkins; 2010:211.
23. Sperling JW, Potter HG, Craig EV, Flatow E, Warren RF. Magnetic resonance imaging of painful shoulder arthroplasty. J Shoulder Elbow Surg 2002;11:315-21.
24. Wagner SC, Schweitzer ME, Morrison WB, Fenlin JM Jr, Bartolozzi AR. Shoulder instability: accuracy of MR imaging performed after surgery in depicting recurrent injury—initial findings. Radiology 2002;222: 196-203.
25. Billet FP, Schmitt WG, Gay B. Computed tomography in traumatology with special regard to the advances of three-dimensional display. Arch Orthop Trauma Surg 1992;111:131-7.

26. Castagno AA, Shuman WP, Kilcoyne RF, Haynor DR, Morris ME, Matsen FA. Complex fractures of the proximal humerus: role of CT in treatment. Radiology 1987;165:759-62.

27. Buckwalter KA, Rydberg J, Kopecky KK, Crow K, Yang EL. Musculoskeletal imaging with multislice CT. AJR Am J Roentgenol 2001;176:979-86.

28. McMenamin D, Koulouris G, Morrison WB. Imaging of the shoulder after surgery. Eur J Radiol 2008;68:106-19.

29. Jacobson JA, Lancaster S, Prasad A, van Holsbeeck MT, Craig JG, Kolowich P. Full-thickness and partial-thickness supraspinatus tendon tears: value of US signs in diagnosis. Radiology 2004;230:234-42.

30. Prickett WD, Teefey SA, Galatz LM, Calfee RP, Middleton WD, Yamaguchi K. Accuracy of ultrasound imaging of the rotator cuff in shoulders that are painful postoperatively. J Bone Joint Surg Am 2003;85-A:1084-9.

31. American College of Radiology. Manual on contrast media v7. Available at: http://www.acr.org/SecondaryMainMenuCategories/quality_safety/contrast_manual.aspx.

32. American College of Radiology. ACR Appropriateness Criteria®: radiation dose assessment introduction. Available at: http://www.acr.org/SecondaryMainMenuCategories/quality_safety/app_criteria/RRLInformation.aspx. Accessed April 24, 2011.