Current Imaging of Anterior and Posterior Instability in the Athlete

Charles Qin, MD, Grant Jones, MD*

KEYWORDS

- Imaging • Shoulder instability • Athlete

KEY POINTS

- Careful assessment of imaging plays an important role in deciding the optimal treatment approach for shoulder instability.
- Orthogonal radiographs are critical to not miss the presence of dislocation, particularly posterior.
- Certain associated soft tissue pathologies such as humeral avulsion of the inferior glenohumeral ligament lesions must not be missed in the assessment of shoulder instability, and thus a contrast study should be considered if there is uncertainty of the diagnosis.
- Computed tomographic scans and the development of 3D reconstructions have allowed for a more nuanced approach to quantifying humeral and glenoid-sided bone loss.

INTRODUCTION

The last two decades have seen tremendous advancements in technology available for shoulder stabilization surgery.[1] As the orthopedic surgeon's armamentarium to treat shoulder instability has grown, so has imaging modalities such as computed tomography (CT) and MRI that are workhorses in the evaluation of shoulder instability. Concepts such as glenoid track in the setting of bipolar lesions and critical bone loss have been refined with the advancements in imaging. Accordingly, it is vital that the orthopedic surgeon be facile in utilizing and interpreting the basic and advanced imaging of an unstable shoulder.

Recognition of relevant pathology is critical to planning a surgical treatment that minimizes the risk for recurrent instability. The purpose of this review is to (1) discuss the use of radiography, CT, and MRI in evaluating shoulder instability and (2) demonstrate how various imaging modalities are useful in identifying critical pathologies in the shoulder that are relevant for treatment.

Department of Orthopaedics, Sports Medicine Research Institute, Wexner Medical Center, The Ohio State University, Columbus, OH, USA
* Corresponding author. 2835 Fred Taylor Drive, Columbus, OH 43202.
E-mail address: grant.jones@osumc.edu

Clin Sports Med 43 (2024) 575–584
https://doi.org/10.1016/j.csm.2024.03.018
sportsmed.theclinics.com
0278-5919/24/© 2024 Elsevier Inc. All rights reserved.

RADIOGRAPHS

Radiographs remain the first-line imaging modality used in the evaluation of shoulder instability. They can be useful to assess bony alignment as well as the presence of bony lesions or fractures of the glenoid or humerus, as well as confirm a reduced joint following a closed reduction procedure in the acute or traumatic setting. While they are available and relatively inexpensive, they do not provide sufficient detail with regards to glenoid and humeral bone loss, may under-recognize a bony Bankart lesion, and do not provide any detail about the soft tissue structures of the shoulder. Nonetheless, it is standard practice to obtain a 4 view radiographic series including the anteroposterior (AP), scapular Y, Grashey, and axillary views of the shoulder. In patients who are not able to abduct the arm, a Velpeau view may be an acceptable substitute. The researchers believe that an orthogonal view, whether Velpeau or axillary, is critical to have unambiguous evidence of the AP glenohumeral alignment. The Velpeau view is taken with the patient standing but bent 30° backwards whereas the axillary view is taken with the patient seated and the arm abducted enough such that the glenohumeral joint is central to the image detector (**Fig. 1**). Indirect signs of posterior dislocation have been described including the trough sign that demonstrates anterior humeral head impaction against the glenoid or the lightbulb sign (**Fig. 2**).[2] Despite these signs, the treating provider still may have doubt whether a dislocation is present. If that is the case, the provider should obtain cross-sectional imaging to confirm the diagnosis as cases of traumatic posterior dislocation can be missed leading to inferior outcomes.[3]

There are additional views that have been described in the evaluation of glenohumeral instability including the Stryker notch and west point views, which increase the recognition of Hill–Sachs and Bankart lesions, respectively. The Stryker notch view is obtained with the arm extended and the palm of the hand placed behind the patient's head. The west point view is obtained with the patient prone and the arm abducted 90° from the long axis of the body. Finally, Ikemoto and colleagues described the Bernageau profile view in 2010 whereby the distance between the anterior and posterior glenoid rims were measured for the injured and uninjured shoulders to assess bone loss. This view was obtained with the arm forward flexed to 160°, the chest in contact with the radiographic cassette at 70° and the X-ray tube angulated

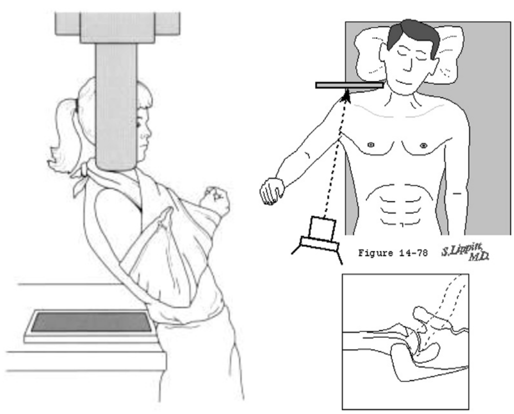

Fig. 1. The Velpeau view with the patient standing but bent 30° backwards (*left*) the axillary view with the patient seated and their arm abducted enough such that the glenohumeral joint is central to the image detector (*right*).

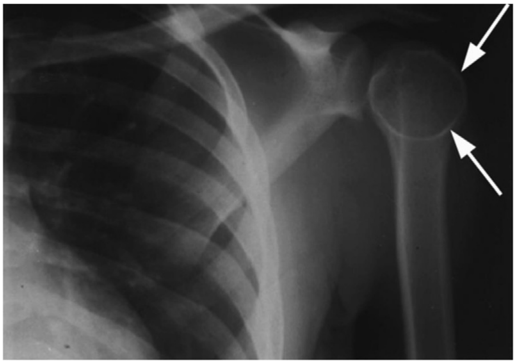

Fig. 2. "Lightbulb" sign suggestive of posterior dislocation.

30° in the craniocaudal direction. This view allows for dedicated assessment of the anterior glenoid rim which is difficult to obtain in standard views (**Fig. 3**). Ikemoto and colleagues[4] reported that this view was an acceptable substitute to CT in up to 80% cases.

COMPUTED TOMOGRAPHIC SCAN

In almost all situations, CT scan is critical to understanding the bony pathology present in shoulder instability. Bony Bankart lesions that are anteroinferior glenoid rim fractures seen in anterior shoulder instability are best detected on CT. CT is also useful

Fig. 3. Bernageau profile view.

to characterize the displacement and size of these lesions, both of which are critical in deciding how to address them. CT is also critical when applying the glenoid track concept in the setting of bipolar bone lesions. Glenoid bone loss and glenoid diameter can be measured through best fit circle technique on a 2D or 3D sagittal image of the glenoid fossa. Furthermore, CT evaluation of the Hill–Sachs lesion has been shown to be as accurate as arthroscopy evaluation. In the case of posterior instability, posterior bone loss of the glenoid and the presence, depth, and width of a reverse Hill–Sachs lesion can be evaluated. Often, posterior instability can be nontraumatic and related to anatomic differences such as glenoid hypoplasia and retroversion which is best assessed on CT.[5] Thin slice CT with multiplanar reformatting has allowed for 3D reconstructions that allow the most meticulous inspection of any bony pathology present in the unstable shoulder.

MRI AND MAGNETIC RESONANCE ARTHROGRAPHY

MRI is critical to assessing the soft tissue structures of the shoulder and the various pathologies associated with shoulder instability. Noncontrast MRI allows detection of labral tears in 70% of cases.[6] In noncontrast MRI, labral pathology is best assessed on proton density and T2-fat suppressed sequences. The abduction and external rotation (ABER) shoulder position has been used in an additional sequence to help increase the sensitivity of detecting anteroinferior labral (**Fig. 4**).[7,8]

T2 sequences can be useful in identifying the hyperintense signal of bone marrow edema that can represent an impaction fracture when assessing for Hill–Sachs and reverse Hill–Sachs lesions. MRI can also be useful in the setting of an irreducible posterior dislocation to identify the interposed tissue blocking closed reduction, which is commonly the rotator cuff, the biceps tendon, or avulsed capsule.[2]

Labral and ligamentous pathology has traditionally been difficult to conclusively discern on images provided by an 1.5 Tesla (T) MR machine. This is in large part due to lack of great definition of the chondral–labral interface. The use of intra-articular contrast can be instrumental in defining any separations at this interface.

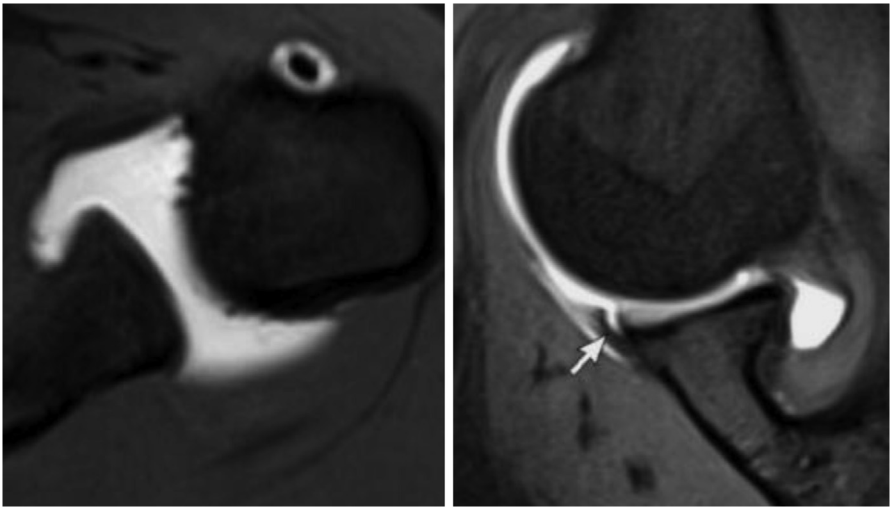

Fig. 4. MR arthrogram axial sequence demonstrating no obvious anteroinferior labral tear on the left panel. A tear can be visualized in the ABER position on the right panel.

However, with improvements in shoulder coil design and fast spin-echo imaging sequences 1.5 T MRI can be adequate. 3T MRI leads to further improvements with recent evidence supporting its use and potentially as an acceptable substitute to magnetic resonance arthrography (MRA).[9]

Ultimately, MRA remains the gold standard for the imaging evaluation of shoulder instability.[10] MRA is an MRI performed after the shoulder joint has been injected with a contrast agent such as diluted gadolinium. The distention of the dye outlines the cartilage, ligaments, and labrum which improves its sensitivity in detecting tears over traditional noncontrast MRI. In the acute situation with effusion present, a noncontrast study may suffice. The authors recommend an MRA in the subacute or chronic setting or if suspicious for a humeral avulsion of the inferior glenohumeral ligament (HAGL). Regardless of whether the orthopedic surgeon chooses to order contrast or noncontrast MRI, it is critical that he or she discuss with the collaborating musculoskeletal imaging radiologist beforehand to ensure the correct imaging sequences are obtained and that they are adequate to identify the pathology in question.

3D MRI is a new emerging technology in the field of shoulder instability. With 3D MRI, image postprocessing creates 3D reformatting of osseous structures with concomitant assessment of soft tissue structures, avoiding the need from radiation associated with a 3D CT. 3D MRI, in one clinical study, has been shown to be as accurate in assessing glenoid bone loss as arthroscopic assessment. Sequence acquisition times are admittedly slower for 3D MRI and may represent a barrier for inclusion into current clinical practice.[11]

GLENOID BONE LOSS

Initial radiographs can clue the orthopedic surgeon in on any significant fractures or bone loss in the setting of anterior or posterior shoulder instability. However, further evaluation with CT and potential MRI is needed to characterize the extent and size of bone loss that is essential to surgical planning. In the case of anterior shoulder instability, assessing the CT for critical bone loss is critical when deciding between a soft tissue or bony stabilization procedure. Critical bone loss, the maximum amount of anteroinferior bone loss after which a soft tissue labral repair and capsulorraphy portends worse outcomes compared to Laterjet or other bone block procedures, has been reported to be as low as 13.5%.[12] While this number is an ongoing source of debate, the methodology to measure glenoid bone loss relative to the native glenoid width must be straightforward and reproducible. There are 2 commonly described techniques. The “circle method” assumes that normal inferior glenoid contour is a true circle and a best fit circle drawn with the existing glenoid contour can be used to determine the native glenoid width and the defect width (**Fig. 5**). Bone loss is then defined as the ratio of the defect width to the native glenoid width. Variations, including the “Sugaya method,” have been described with the use of an en face 3D CT sagittal view of the glenoid and shown to be an accurate alternative.[13] The other technique has been described by Giles and colleagues who attempted to apply an MRI-based formula that calculates native glenoid width in relation to glenoid height which is typically unchanged in cases of shoulder instability to CT data. Ultimately, they concluded that the most accurate method to quantify bone loss was to apply a CT-based formula to CT data.[14]

These two methodologies can be used in the setting of posterior bone loss as well. The key difference is that there is even less consensus on critical bone loss in the setting of posterior instability. Preliminary laboratory data suggest that a shoulder with greater than 20% bone loss remains unstable after isolated soft tissue repair.[15]

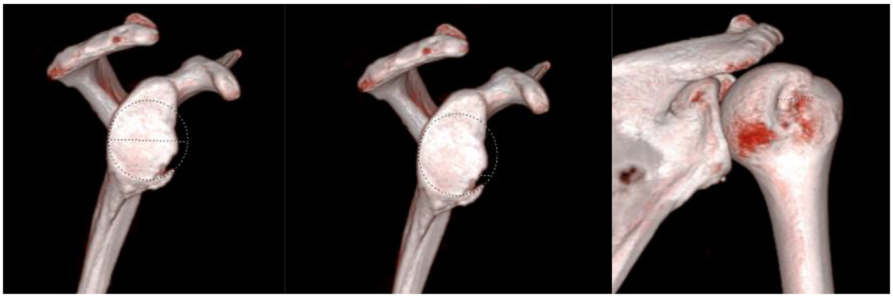

Fig. 5. Best fit circle method to estimate glenoid bone loss in the setting anterior instability. The left panel demonstrates a perfect circle estimation of the true glenoid diameter. The middle panel demonstrates the amount of bone loss according to the perfect circle method. The right panel demonstrates the Hill–Sachs interval, which is the width of the Hill–Sachs lesion in addition to the osseous bridge between the lateral most aspect of the Hill–Sachs and the medial most insertion point of the rotator cuff.

In addition, as opposed to traumatic bone loss which is characteristic in anterior dislocation, glenoid dysplasia and retroversion may be the primary driving factors in posterior instability. In cases of anterior instability with bone loss, the authors recommend 3D CT evaluation of glenoid bone loss when available with the circle method. We have encountered scenarios in which the 2D CT images are not formatted perfectly to the plane of the glenoid face, and therefore has underestimated the true extent of missing bone. A 3D CT with humeral subtraction affords the surgeon the ability to assess the bone loss in all planes and to be able to plan both dimensions and morphology of bone block needed in cases exceeding critical bone loss. In the setting of posterior instability, the authors recommend obtaining an MRI to assess glenoid morphology and if there is any concern about posterior bone loss or dysplasia, to obtain a CT scan to characterize further.

HUMERAL BONE LOSS

An impaction fracture of the posterolateral humeral head in anterior dislocation (ie, Hill–Sachs deformity) and anterior humeral head in posterior dislocation (ie, reverse Hill–Sachs deformity) is crucial to recognize. While they can be subtle on radiographs, these bony lesions may be more readily identified on MRI or CT. Increased number of dislocations and long-term instability can lead to larger deformities. First described in 2007, the glenoid track concept describes the possibility of bipolar lesions engaging as the glenoid contact shifts from inferomedial to superolateral with elevation of the arm.[16] The glenoid track "calculator" has since been developed by inputting the Hill–Sachs interval, native glenoid diameter, and bone loss into a formula to characterize bipolar lesions as "on-track" or "off-track". For posterior dislocations, the authors are not aware of any standardized method of characterizing reverse Hill–Sachs lesions on imaging. Moroder and colleagues[17] has described the "gamma angle" in a series of 102 reverse Hill–Sachs which accounted for the depth and location of the Hill–Sachs into one measurement and found that higher gamma angles were associated with chronic locked posterior dislocations.

LABRAL TEARS AND VARIANTS

During anterior dislocation, tears of the anteroinferior labrum can occur either with intact periosteum (ie, Perthes lesion) or with an associated tear of the periosteum (ie,. soft tissue Bankart lesion). This usually results from significant tension of the inferior glenohumeral ligament (IGHL) during dislocation with those forces transferred to the labrum leading to tearing. Posterior dislocations are similarly associated with posterior labral tears. Traditionally, the Kim lesion describes an incomplete avulsion of the posterior labrum. More recently, Kim and colleagues[18] introduced a new classification of posterior labral tears based on MRA findings and reported on its correlation with arthroscopic findings (**Fig. 6**). Increased signal on T2 sequences at the interface between labrum and glenoid cartilage can be suggestive of these tears. However, suboptimal definition of this interface on noncontrast MRI sequences can make identification of these lesions difficult. As mentioned in a prior section, use of contrast can help delineate chondral–labral separation as well as the use of ABER arms positioning which tensions the IGHL. In the setting of posterior instability, MRA can demonstrate loss of posterior labral height as well as incomplete extrusion of contrast at the posterior labral–chondral junction. In some cases, the Bankart lesion can put tension on adjacent cartilage leading to damage. This is termed glenolabral articular disruption (GLAD). GLAD lesions can be recognized on the same sequences used to evaluate labrum. Typically increased signal on T2 sequences or contrast in the case of MRA can extend into the cartilage adjacent to a labral tear. To the author's knowledge, a reciprocal lesion of the posterior cartilage in posterior dislocations has not been named in the literature.

MRI is also helpful in assessing anterior labrum periosteal sleeve avulsion (ALPSA) lesions. As described by its name, the ALPSA lesion occurs when the labrum has displaced medially onto the glenoid neck typically in chronic settings. Often, depending on the chronicity there can be significant changes to the labral morphology and this is critical to assess when anticipating the quality and mobility of tissue for a soft tissue labral repair. The degree of displacement of an ALPSA lesion is best assessed on axial and sagittal images.

HUMERAL AVULSION OF INFERIOR GLENOHUMERAL LIGAMENT

The anterior band of the IGHL is the primary anterior stabilizer and experiences significant tension during anterior dislocation. While the adjacent labrum and scapular

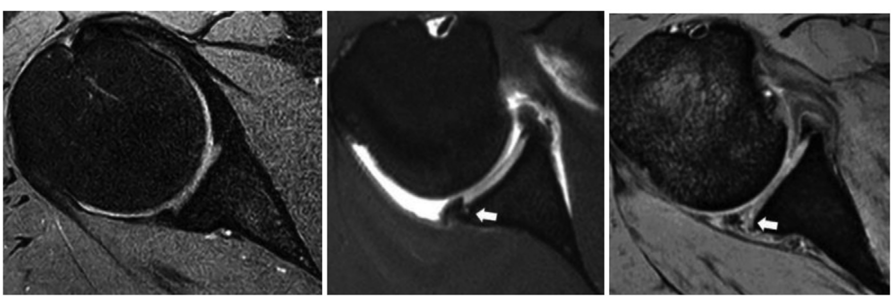

Fig. 6. MRA images of different posterior labral tears. The left panel demonstrates a type 1 tear without obvious detachment of the labrum from the glenoid surface. The middle panel demonstrates a type 2 tear with superficial and partial detachment (*arrowhead*). The right panel demonstrates a type 3 tear with complete detachment and contrast extravasation into the chondrolabral space (*arrowhead*). (*From*: Kim JH, Ahn J, Shin SJ. Occult, Incomplete, and Complete Posterior Labral Tears Without Glenohumeral Instability on Imaging Underestimate Labral Detachment. Arthroscopy. Jan 2024;40(1):58–67. https://doi.org/10.1016/j.arthro.2023.06.015.)

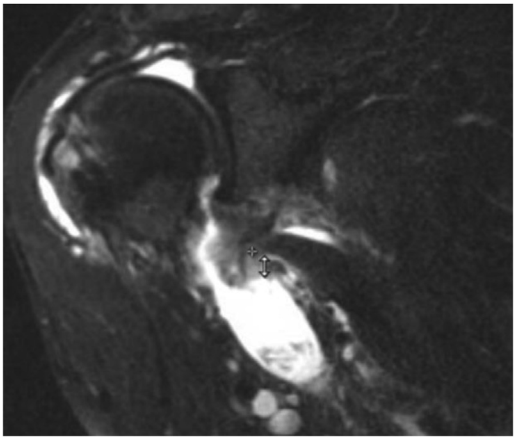

Fig. 7. HAGL lesion.

periosteum more commonly fails, the IGHL can fail at the humeral attachment which is termed a HAGL lesion. MRI is the imaging modality of choice for HAGL lesions. The IGHL is best identified on an arthrogram. In acute settings following dislocation, the joint effusion serves as a “traumatic arthrogram” and serves the same purpose as contrast in delineating the band like structure that is the IGHL. In the acute setting, all sequences on MRI but classically the coronal sequence will demonstrate contrast or joint effusion extending beyond the axillary recess because of the fully torn IGHL (**Fig. 7**). In the subacute setting, effusion from the acute HAGL lesion will be replaced by scar and granulation tissue making identification more difficult. Posterior HAGL lesions represent a significant capsular injury in posterior instability cases. They are important but difficult to identify on MRI as only 50% of posterior HAGL lesions were identified preoperatively in one study (**Fig. 8**). They can be partial or complete tears from the humeral attachment, or detached from both the glenoid and humeral side.[19] They have been associated with increased chondrolabral retroversion, as this may increase the translational forces that the posterior capsule is subjected to during instability events.

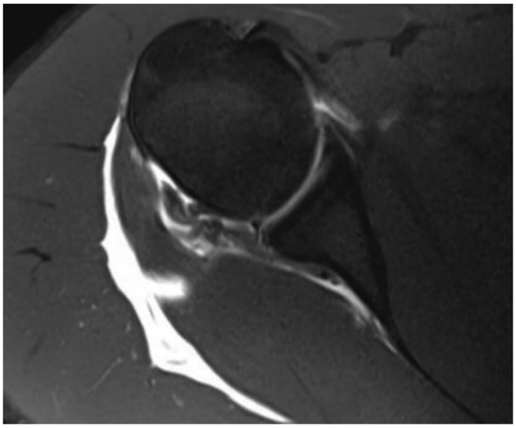

Fig. 8. Reverse HAGL lesion.

SUMMARY

We have reviewed the main concepts for current imaging of anterior and posterior instability, including the most common imaging findings as well as imaging modalities. An understanding of these concepts is critical for managing this complex issue.

CLINICS CARE POINTS

- A thorough understanding and interpretation of imaging is critical in the treatment of shoulder instability.
- The use of contrast and 3D reconstructions in imaging modalities may help enhance our assessment of shoulder instability.

DISCLOSURE

The authors report no relevant disclosures.

REFERENCES

1. Wolf BR, Tranovich MA, Marcussen B, et al. Team Approach: Treatment of Shoulder Instability in Athletes, *JBJS Rev*, 9 (11), 2021, 213-224.
2. Rouleau DM, Hebert-Davies J, Robinson CM. Acute traumatic posterior shoulder dislocation. J Am Acad Orthop Surg 2014;22(3):145–52.
3. Moussa ME, Boykin RE, Earp BE. Missed locked posterior shoulder dislocation with a reverse Hill-Sachs lesion and subscapularis rupture. Am J Orthoped 2013;42(12):E121–4.
4. Ikemoto RY, Nascimento LG, Bueno RS, et al. ANTERIOR GLENOID RIM EROSION MEASURED BY X-RAY EXAM: A SIMPLE WAY TO PERFORM THE BERNAGEAU PROFILE VIEW. Rev Bras Ortop 2010;45(6):538–42.
5. Provencher MT, LeClere LE, King S, et al. Posterior instability of the shoulder: diagnosis and management. Am J Sports Med 2011;39(4):874–86.
6. Kompel AJ, Li X, Guermazi A, et al. Radiographic Evaluation of Patients with Anterior Shoulder Instability. Curr Rev Musculoskelet Med 2017;10(4):425–33.
7. Schreinemachers SA, van der Hulst VP, Jaap Willems W, et al. Is a single direct MR arthrography series in ABER position as accurate in detecting anteroinferior labroligamentous lesions as conventional MR arthography? Skeletal Radiol 2009; 38(7):675–83.
8. Tian CY, Cui GQ, Zheng ZZ, et al. The added value of ABER position for the detection and classification of anteroinferior labroligamentous lesions in MR arthrography of the shoulder. Eur J Radiol 2013;82(4):651–7.
9. Magee TH, Williams D. Sensitivity and specificity in detection of labral tears with 3.0-T MRI of the shoulder. AJR Am J Roentgenol 2006;187(6):1448–52.
10. Subhas N, Benedick A, Obuchowski NA, et al. Comparison of a Fast 5-Minute Shoulder MRI Protocol With a Standard Shoulder MRI Protocol: A Multiinstitutional Multireader Study. AJR Am J Roentgenol 2017;208(4):W146–54.
11. Gyftopoulos S, Beltran LS, Yemin A, et al. Use of 3D MR reconstructions in the evaluation of glenoid bone loss: a clinical study. Skeletal Radiol 2014;43(2):213–8.
12. Shaha JS, Cook JB, Song DJ, et al. Redefining "Critical" Bone Loss in Shoulder Instability: Functional Outcomes Worsen With "Subcritical" Bone Loss. Am J Sports Med 2015;43(7):1719–25.

13. Sugaya H. Techniques to evaluate glenoid bone loss. Curr Rev Musculoskelet Med 2014;7(1):1–5.
14. Giles JW, Owens BD, Athwal GS. Estimating Glenoid Width for Instability-Related Bone Loss: A CT Evaluation of an MRI Formula. Am J Sports Med 2015;43(7):1726–30.
15. Nacca C, Gil JA, Badida R, et al. Critical Glenoid Bone Loss in Posterior Shoulder Instability. Am J Sports Med 2018;46(5):1058–63.
16. Yamamoto N, Itoi E, Abe H, et al. Contact between the glenoid and the humeral head in abduction, external rotation, and horizontal extension: a new concept of glenoid track. J Shoulder Elbow Surg 2007;16(5):649–56.
17. Moroder P, Tauber M, Scheibel M, et al. Defect Characteristics of Reverse Hill-Sachs Lesions. Am J Sports Med 2016;44(3):708–14.
18. Kim JH, Ahn J, Shin SJ. Occult, Incomplete, and Complete Posterior Labral Tears Without Glenohumeral Instability on Imaging Underestimate Labral Detachment. Arthroscopy 2024;40(1):58–67.
19. Rebolledo BJ, Nwachukwu BU, Konin GP, et al. Posterior Humeral Avulsion of the Glenohumeral Ligament and Associated Injuries: Assessment Using Magnetic Resonance Imaging. Am J Sports Med 2015;43(12):2913–7.