Measurement of Adult Hill-Sachs Lesions on Magnetic Resonance Arthrography

[1]Vishal Saxena, MD
[2]Alexander T. Ruutiainen, MD
[2]Andrew S. Wilmot, MD
[3]Luis I. Ruffolo, BA
[3]Stuart D. Kinsella, BA
[4]Nancy A. Chauvin, MD
[1]John D. Kelly IV, MD

[1]Department of Orthopaedic Surgery, University of Pennsylvania, Philadelphia, PA

[2]Department of Radiology, University of Pennsylvania, Philadelphia, PA

[3]Perelman School of Medicine at the University of Pennsylvania, Philadelphia, PA

[4]Department of Radiology, The Children's Hospital of Philadelphia, Philadelphia, PA

Introduction

Posterosuperolateral compression fractures of the humeral head, eponymously described by Hill and Sachs in 1940,[1] occur in 40-90% of anterior shoulder dislocations[2] and typically occur in conjunction with anterior capsulolabral tears (Bankart and variant lesions).[3,4] Repairing a Bankart lesion without simultaneously addressing significant Hill-Sachs lesions may result in repeated instability.[5-7] However, identifying which Hill-Sachs lesions are clinically important remains challenging.

Although Hill-Sachs lesion size affects glenohumeral stability,[8,9] no consensus exists on the best measurement technique. Recently, Kodali et al demonstrated that Hill-Sachs lesions could be measured on two-dimensional computed tomography. However, while depth of lesions could be reliably measured, width was consistently underestimated.[10] Thus, additional work is needed to determine a more accurate and practical method of quantifying Hill-Sachs lesion size.

Magnetic resonance (MR) imaging provides improved visualization of intra-articular structures and soft tissues. MR has high sensitivity (96.3%) and high specificity (90.6%) for detecting Hill-Sachs lesions.[11] Furthermore, Probyn et al showed that MR arthrography could detect Hill-Sachs lesions with 100% sensitivity and 93.3% accuracy compared to surgical findings.[5]

In this study, we describe two techniques for measuring the volume of Hill-Sachs lesions on MR arthrography that are reproducible and easy to perform.

Materials and Methods

This protocol received institutional review board approval. A custom data-mining tool called PRESTO[12] was used to conduct a retrospective search of all MR arthrograms performed at our institution from September 2010 through August 2012 whose reports included the text string "Hill-Sachs." Scans were included for measurement if both measuring radiologists (ATR and ASW) agreed on the presence of a Hill-Sachs lesion and excluded if they had reverse Hill-Sachs lesions or sequelae of prior surgeries. Measurements were performed on 33 consecutive scans meeting the inclusion and exclusion criteria.

Hill-Sachs lesions were defined as contour irregularities on the posterosuperolateral aspect of the humeral head that demonstrated T1 shortening (T1 hyperintensity), indicating extension of gadolinium into the depressed defect. Bone marrow edema and subchondral impaction fractures subjacent to the Hill-Sachs deformities were not included in the measurements. The contour of the normal humeral head was assumed to be ellipsoid in shape to define the posterolateral margin of the Hill-Sachs defect for the measurements.

Volumetric measurements of the size of Hill-Sachs defects were performed from the axial fat saturated T1 sequence. The first measurement technique, the additive cross-sectional volume method, is essentially a Riemann sum method for determining volume of a shape. The area of the Hill-Sachs deformity was traced using the polygonal area measurement tool on each image demonstrating the defect (Fig. 1). These

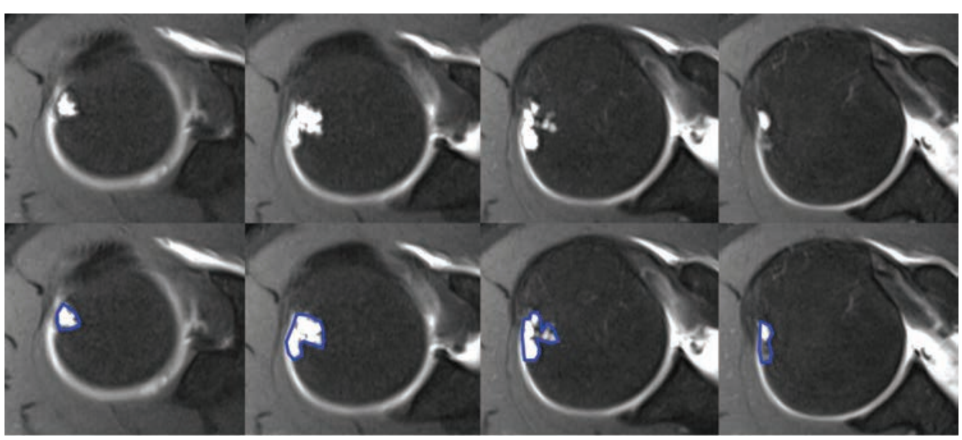
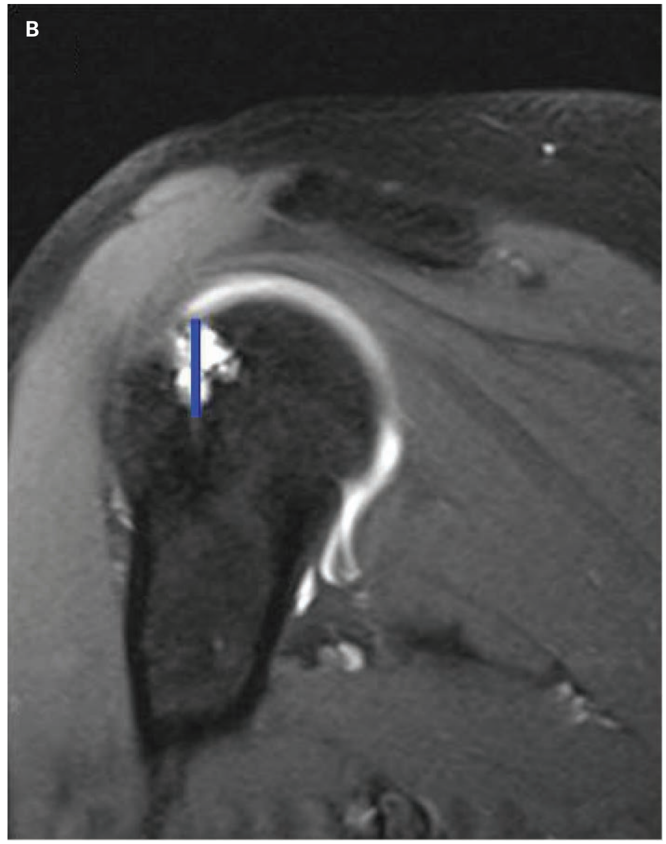


Figure 1. Demonstration of the additive cross-sectional method. The contour defect of the Hill-Sachs lesion (top of panel) has been traced with the polygonal area measurement tool on this fat saturated T1-weighted image (bottom of panel). The process is repeated on all images demonstrating the contour defect.

Corresponding author:
Vishal Saxena, MD
Penn Medicine University City
3737 Market Street, 6th Floor
Philadelphia, PA 19107
vishal.saxena@uphs.upenn.edu



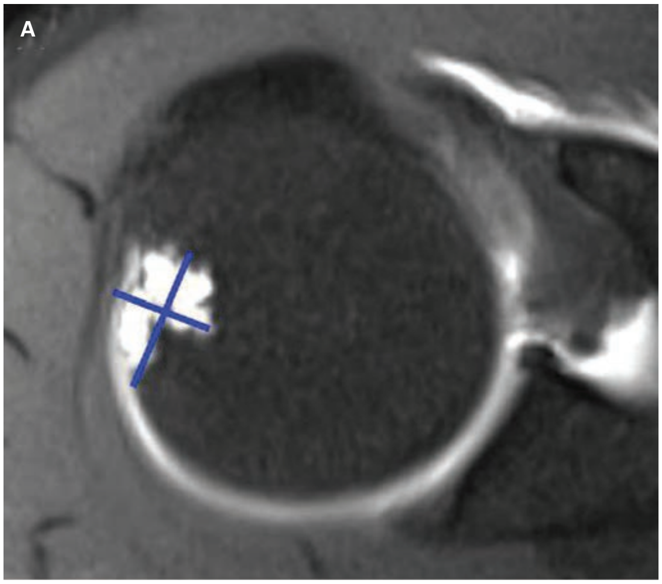


Figure 2. Coronal (A) and Sagittal (B) T2-weighted magnetic resonance imaging of the left shoulder. **Figure 2.** Demonstration of the triaxial method. (A) The fat saturated T1-weighted image with the largest cross-sectional area of the Hill-Sachs contour deformity has been identified. The longest axis has been measured (12.7 mm), along with a perpendicular short axis (9.8 mm). (B) The lesion is then triangulated on an orthogonal plane in order to directly measure its height.

measurements were multiplied by the slice spacing, including any interslice gap, and summed to give lesion volume. The second measurement technique, the triaxial volume method, is essentially the volume of an ellipse calculated from the maximum X, Y, and Z axes. This was performed by identifying the axial slice on which the Hill-Sachs lesion had the largest cross-sectional area and then obtaining a bi-axial measurement of the defect with perpendicular measurements (Fig. 2). The third axis was then obtained by triangulating to an orthogonal series, typically a sagittal oblique acquisition, and measuring the lesion height. The volume was calculated as the volume of an ellipsoid.

Intra-observer and inter-observer reliability were determined using the Spearman Rank Correlation Coefficient with $p < 0.05$ denoting significance.

Results

Hill-Sachs lesion volume was measured on 33 patients using both the additive cross-sectional and triaxial measurements. The range in Hill-Sachs lesion volumes was 37–2309 mm^3. Spearman Rank Correlation Coefficients for both observers using the same method (inter-observer reliability) and for the same observer using both methods (intra-observer reliability) are shown in Table 1. Overall, Spearman Coefficients were greater than 0.8 in all cases, indicating strong overall reliability. All measurements reached significance.

Discussion

This study describes two methods to quantify the volume of Hill-Sachs lesions on MR arthrography. Spearman Correlation Coefficients for intra-observer reliability between the additive

Table 1. Spearman Rank Correlation Coefficients for intra- and inter-observer reliability.

Comparison	Spearman Coefficient	P-value
Observer 1 Additive cross-sectional/Triaxial	0.905	0.00
Observer 2 Additive cross-sectional/Triaxial	0.918	0.00
Observer 1/Observer 2 Additive cross-sectional	0.827	0.00
Observer 1/Observer 2 Triaxial	0.823	0.00

cross-sectional and triaxial methods were greater than 0.9 for both observers (Table 1), demonstrating extremely high agreement between our method and the commonly used triaxial method. The Spearman Coefficient for inter-observer reliability of the additive cross-sectional method was also high (0.827), indicating that this method is reliable and produces similar results between users. Lower Spearman Coefficients for inter-observer reliability of the additive cross-sectional and triaxial methods can be attributed to observer differences in distinguishing between the outer margins of the Hill-Sachs lesion and surrounding bony edema. However, the intra-observer reliability was improved because measurements were made using the same definition of the lesion.

Both volumetric methods have limitations. First, the accuracy of the additive cross-sectional method is dependent on the slice thickness of the MR sequences, which are typically much thicker than high-resolution CT images. The triaxial method assumes the Hill-Sachs lesion is completely elliptical in shape and may lose accuracy in more irregular lesions. These irregular lesions may be more accurately measured using the additive cross-sectional method. Furthermore, we describe both methods using MR arthrography where gadolinium contrast within the lesion can be used to distinguish the contours of the depressed lesion from the subjacent marrow edema. However, not all patients with recurrent anterior instability are evaluated with MR arthrography. Additional investigation is needed to determine the accuracy of both methods in routine noncontrast shoulder MRIs.

The threshold size of Hill-Sachs lesions that requires operative intervention has yet to be determined. Many authors advocate surgical management of lesions greater than 20-40% of the humeral head. Voos et al found a significant association of Hill-Sachs lesions greater than 250mm^3 with recurrent instability.[7] It is therefore important to establish a consistent and reproducible method for measuring the size of such lesions. We have demonstrated two methods for MR arthrography, an additive cross-sectional method and a triaxial method that is standard practice amongst radiologists. The additive cross-sectional method has high concordance with the established triaxial method and both methods are reproducible and easy to perform. Reliable and accurate quantification of Hill-Sachs lesion volumes may offer a clinical benefit and help guide management of these lesions.

References

1. Hill HA, Sachs MD. The grooved defect of the humeral head. *Radiology* (1940).

2. Calandra JJ, Baker CL, Uribe J. The incidence of Hill-Sachs lesions in initial anterior shoulder dislocations. *Arthroscopy* (1989).

3. Armitage MS, Faber KJ, Drosdowech DS, et al. Humeral head bone defects: remplissage, allograft, and arthroplasty. *Orthop Clin North Am* (2010).

v4. Provencher MT, Frank RM, Leclere LE, et al. The Hill-Sachs lesion: diagnosis, classification, and management. *J Am Acad Orthop Surg* (2012).

5. Probyn LJ, White LM, Salonen DC, et al. Recurrent symptoms after shoulder instability repair: direct MR arthrographic assessment--correlation with second-look surgical evaluation. *Radiology* (2007).

6. Rowe CR, Zarins B, Ciullo JV. Recurrent anterior dislocation of the shoulder after surgical repair. Apparent causes of failure and treatment. *J Bone Joint Surg Am* (1984).

7. Voos JE, Livermore RW, Feeley BT, et al. Prospective evaluation of arthroscopic Bankart repairs for anterior instability. *Am J Sports Med* (2010).

8. Chen AL, Hunt SA, Hawkins RJ, et al. Management of bone loss associated with recurrent anterior glenohumeral instability. *Am J Sports Med* (2005).

9. Sekiya JK, Wickwire AC, Stehle JH, et al. Hill-Sachs defects and repair using osteoarticular allograft transplantation: biomechanical analysis using a joint compression model. *Am J Sports Med* (2009).

10. Kodali P, Jones MH, Polster J, et al. Accuracy of measurement of Hill-Sachs lesions with computed tomography. *J Shoulder Elbow Surg* (2011)

11. Hayes ML, Collins MS, Morgan JA, et al. Efficacy of diagnostic magnetic resonance imaging for articular cartilage lesions of the glenohumeral joint in patients with instability. *Skeletal Radiol* (2010).

12. Kim W, Boonn W. Evaluation of an open source tool for indexing and searching enterprise radiology and pathology reports. SPIE Medical Imaging, presentation 7628-04 (2010).