10.5005/jp-journals-10017-1030

ORIGINAL RESEARCH

The Anatomic Variability of the 'Rotator Interval Capsule': A Comparison of Arthroscopic and Open Investigations

Steven J Svoboda MD, **Dean C Taylor** MD, **Robert A Magnussen** MD

ABSTRACT

Introduction: Variably present rotator interval capsular openings (RICOs) complicate anterior shoulder capsular anatomy. Open and arthroscopic approaches may lead to differences in the appearance and size of RICOs. The purposes of this study are to: (1) Confirm that RICOs viewed from inside and outside the joint are the same structures, and (2) compare the size of RICOs when approached in an open manner *vs* arthroscopically.

Materials and methods: Twelve fresh cadaveric shoulders were randomized to two different approaches in order to identify and mark RICOs. In the first group, the superior glenohumeral ligament (SGHL) and middle glenohumeral ligament (MGHL) were marked arthroscopically. Sutures were placed in these structures in an open fashion. Repeat arthroscopy was then performed to determine whether the sutures penetrated the marked SGHL and MGHL. In the second group, these steps were reversed and arthroscopically placed sutures were evaluated in an open manner. Dimensions of the RICOs were measured both arthroscopically and open in each shoulder.

Results: All specimens had a RICO visualized both arthroscopically and open. Five of 12 specimens had an additional second RICO. RICO size measurements were similar for the arthroscopic and open techniques. Sutures placed via both the arthroscopic and open technique were noted to penetrate the marked structures in all cases. In addition, sutures placed through the SGHL while viewing arthroscopically always captured the coracohumeral ligament (CHL). Sutures placed through the SGHL with an open technique never engaged the CHL.

Conclusion: The capsular openings in the rotator interval were confirmed to be the same structures when observed arthroscopically and through an open approach.

Keywords: Rotator interval, Shoulder instability, Foramen of Weitbrecht, Foramen of Rouviere.

Svoboda SJ, Taylor DC, Magnussen RA. The Anatomic Variability of the 'Rotator Interval Capsule': A Comparison of Arthroscopic and Open Investigations. The Duke Orthop J 2013;3(1):54-60.

INTRODUCTION

There is a great deal of confusion about the rotator interval region of the shoulder in regards to both terminology and anatomy.The general agreement is that the rotator interval is bordered by the supraspinatus superiorly, the subscapularis inferiorly, the coracoid process medially, and the bicipital groove laterally.[1-12] While the borders are well defined, the anatomy of the capsule of the shoulder within the rotator interval is variable.

The capsule within the rotator interval is known to have variably present openings described by classical anatomists. These capsular foramina have been visualized through open surgical dissection and have been termed synovial recesses,[13,14] subscapularis bursae,[13] the rotator interval,[15] the Foramen of Weitbrecht[16] and the Foramen of Rouvière.[17] In this paper, we will refer to these foramina as 'rotator interval capsular openings' (RICOs). The development of shoulder arthroscopy coincided with the development of new terminology describing the anterior capsular anatomy. Readily visible thickenings of the anterior capsule have been termed ligaments. Two such ligaments, the middle glenohumeral ligament (MGHL) and superior glenohumeral ligament (SGHL) are located within the area of the rotator interval. These ligaments appear as bands or folds when viewed arthroscopically and change in appearance when viewed from an open approach.[18] These ligaments likely form the borders of the foramina visualized with open approaches to the shoulder, but there is no data to confirm this correlation. Clarity in this matter is critical as surgeons continue to describe treatment of various patterns of shoulder instability through surgical manipulation of rotator interval structures. Many open and arthroscopic procedures have been reported,[2,5,8-11,19-26] incorporating different techniques and different anatomic structures. The indications outlined for these procedures are varied, but most procedures designed to address instability have been based on plication of capsular tissue, either through arthroscopic closure of anterior capsular foramina (usually by closing the MGHL to the SGHL) or open techniques that close visualized capsular foramina and incorporate variable amounts of capsular plication. Further confusion results when these procedures are referred to as 'rotator interval' closure, when in fact it is capsular foramina that are closed rather the interval itself—rotator interval closure would require suturing of the subscapularis tendon to the supraspinatus tendon.

When reviewing the surgical literature of the rotator interval, one can easily be confused by the anatomic variability, inconsistent terminology, and poorly defined correlation between arthroscopic and open descriptions of the anatomy. The purposes of this study are: (1) To confirm that RICOs viewed from inside and outside the joint are in fact the same structures, and (2) to compare the size of RICOs when approached in an open manner *vs* arthroscopically.

MATERIALS AND METHODS

Twelve fresh cadaveric shoulders were randomized to two different approaches to identify, mark and measure RICOs in the anterior shoulder.

Group 1

In the first group, evaluation began arthroscopically. A standard posterior arthroscopic portal was created followed by an accessory posterior portal positioned so that instruments could be passed to the anterior aspect of the joint. Measurement of the RICO then proceeded. The width of the superior border of the primary RICO was defined as the distance from the lateral insertion of the SGHL on the humerus to the medial origin of the SGHL on the superior glenoid. The length of the primary RICO along the superior border of the subscapularis tendon between the SGHL and MGHL was measured in the positions of maximal external rotation, neutral, and maximal internal rotation. The distances were measured with an arthroscopic measuring device (Measurement Probe, Arthrex, Naples, FL) (Fig. 1). Each measurement was taken in triplicate and the average value [mean standard deviation (SD) in millimeters] was recorded for each specimen.

The MGHL and SGHL were then identified and a radiofrequency probe (OPES Arthroscopic Ablation Probe, Arthrex, Naples, FL) was used to mark the ligaments. The SGHL was marked immediately adjacent to the biceps tendon and bicipital sling and the MGHL was marked at the level it crossed the superior border of the intra-articular portion of the subscapularis tendon. Figure 2 shows an example of the marked MGHL and SGHL.

The arthroscope and instruments were then removed from the joint and a standard deltopectoral approach to the shoulder was performed. The subscapularis muscle and tendon were reflected off the anterior shoulder capsule with care taken not to disrupt the capsule. The coracohumeral ligament (CHL) was also reflected off the coracoid as necessary to allow for visualization of the anterior capsular anatomy.The RICO was then measured along its superior border and the subscapularis tendon (in the three positions described above) using the same measuring device that was used arthroscopically (Fig. 3). A '0' Prolene suture was then placed through the superior edge of the visualized RICO from superficial to deep into the glenohumeral joint. A second suture was passed through the inferomedial aspect of the capsular opening (see Fig. 3).

The arthroscope was then placed back into the posterior portal and the location of suture entry into the anterior joint capsule was evaluated. In each case, it was determined whether the suture pierced the structures that had previously

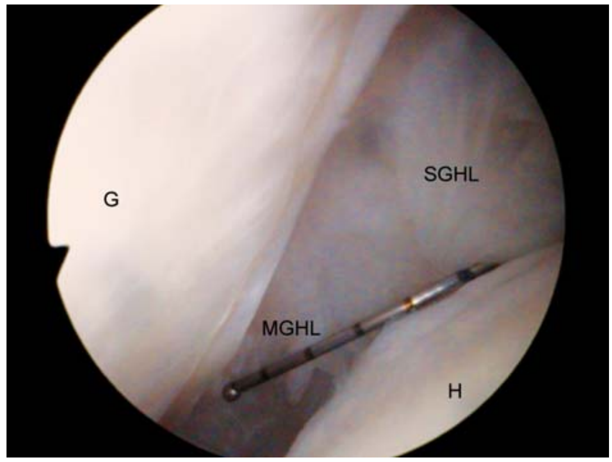


Fig. 1: Arthroscopic measurement of the RICO width in a right shoulder viewing from a posterior portal. The humeral head (H) and glenoid (G) are labeled. The measuring device is measuring along the superior surface of the subscapularis tendon from the medial aspect of the SGHL adjacent to the biceps sling to the lateral aspect of the MGHL

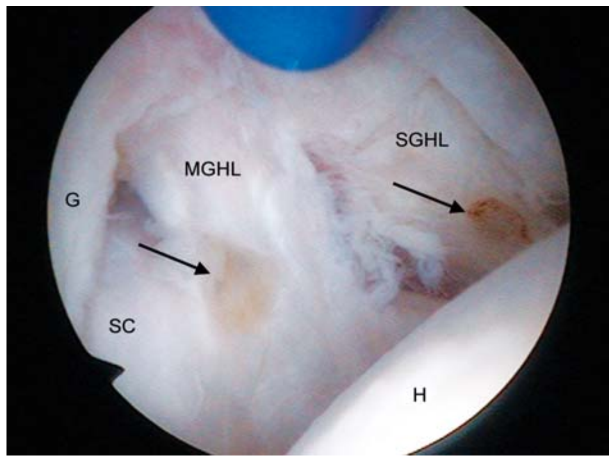


Fig. 2: Arthroscopic view of a right shoulder from the posterior portal. The humeral head (H), glenoid (G), and subscapularis (SC) are visible. The SGHL and MGHL have been marked arthroscopically with a radiofrequency probe (arrows)

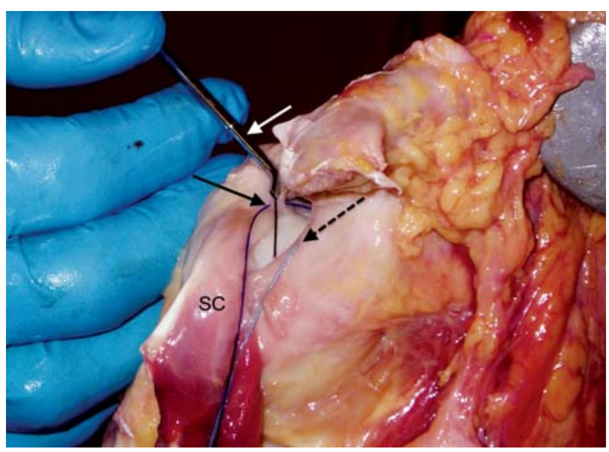
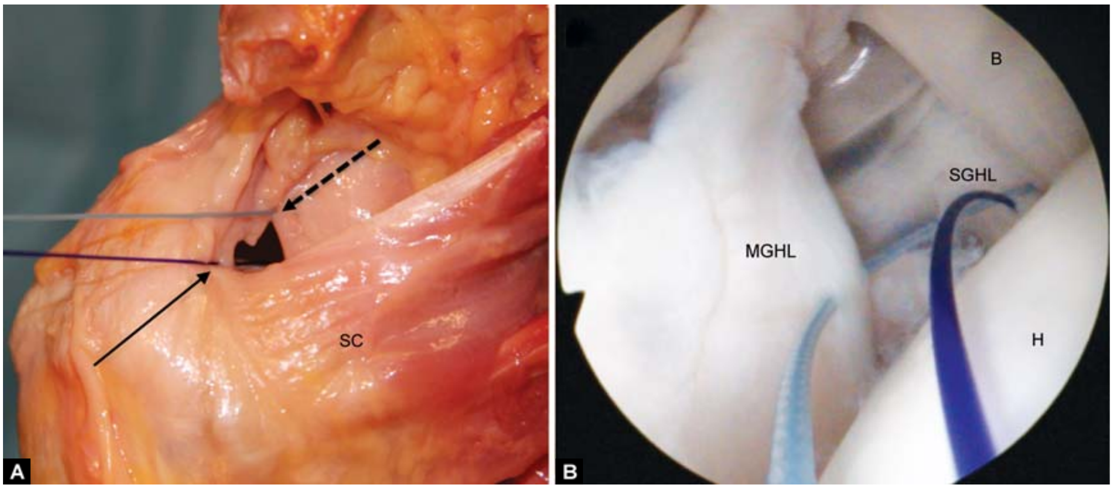


Fig. 3: Anterior view of an open dissection of a right shoulder demonstrating measurement of the width of the RICO with the same arthroscopic tool used in Figure 1 above (white arrow). The subscapularis (SC) has been reflected from medial to lateral to allow visualization of the capsule. Sutures have been placed in an open manner marking inferomedial (dashed arrow) and superolateral (solid arrow) borders of the RICO



Figs 4A and B: (A) Anterior view of a right shoulder demonstrating marking sutures placed in an open manner marking inferomedial (dashed arrow) and superolateral (solid arrow) borders of the RICO. The subscapularis (SC), which was elevated laterally during the dissection has been replaced in its anatomical location, (B) arthroscopic view of the same shoulder demonstrating the two sutures penetrated the middle MGHL and superior SGHL glenohumeral ligaments. The humeral head H and biceps tendon 'B' are also labeled

been identified under arthroscopy as the MGHL and SGHL. The joint was inspected to determine whether the suture pierced any other structures. Figures 4A and B demonstrate sutures placed in an open manner through the superomedial and inferolateral borders of the RICO as viewed open (Fig. 4A) and arthroscopically (Fig. 4B).

Group 2

In the second group, these steps were reversed. Evaluation began with a deltopectoral approach to the shoulder and release of the subscapularis tendon. The visualized RICO was then measured as above. The superior and inferior borders of the RICO were then marked with electrocautery and the incision closed.

A standard posterior arthroscopic portal and accessory portal were created and the arthroscope inserted into the joint. The RICO was measured arthroscopically as above. Following measurement, a '0' prolene suture was placed through the SGHL from outside-in using an 18 gauge spinal needle. An arthroscopic soft tissue penetrator (Arthrex Penetrator, Arthrex; Naples, FL) was then passed from an anterior arthroscopic portal through the MGHL. The intra-articular suture was captured by the soft tissue penetrator and delivered outside of the anterior portal.

The arthroscope was then removed from the joint and the anterior approach was reopened. In each case it was determined whether the arthroscopically placed suture had passed through the previously marked superior and inferior margins of the RICO as visualized from the open approach. It was also determined by open dissection whether the suture had penetrated any other structures in the rotator interval. Figure 5 shows an open view of sutures passed arthroscopically through the MGHL and SGHL. The SGHL suture exits lateral to the RICO and passes through the CHL as well.

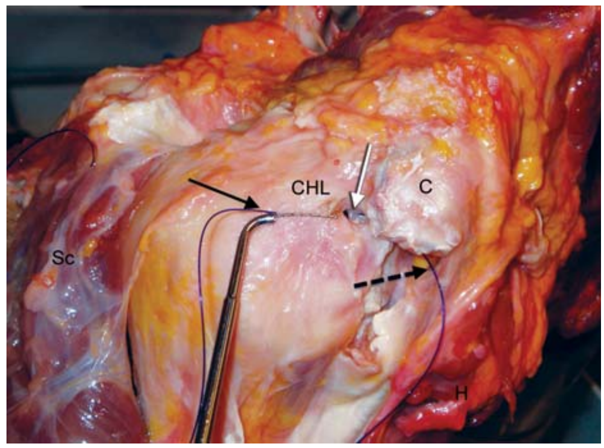


Fig. 5: Anterior view of a right shoulder demonstrating sutures passed arthroscopically through the MGHL (solid black arrow) and SGHL (dashed arrow). The SGHL suture exits 14 mm lateral to the RICO (white arrow) and passes through the CHL as well. The coracoid (C) is marked

STATISTICAL ANALYSIS

Data were recorded in an Excel spreadsheet (Microsoft, Redmond, WA) and analyzed using SAS 9.0 statistical software (SAS Institute, Cary, NC). Paired student t-tests were performed to compare the open and arthroscopic dimensions. Statistical significance was defined as $p < 0.05$.

RESULTS

All specimens (12 of 12) had a primary RICO visible through an open approach to the shoulder, consistent with the previously described Foramen of Weitbrecht (Fig. 6).[16] Figures 7A and B demonstrate the typical appearance of a specimen with one RICO as seen with the CHL intact and

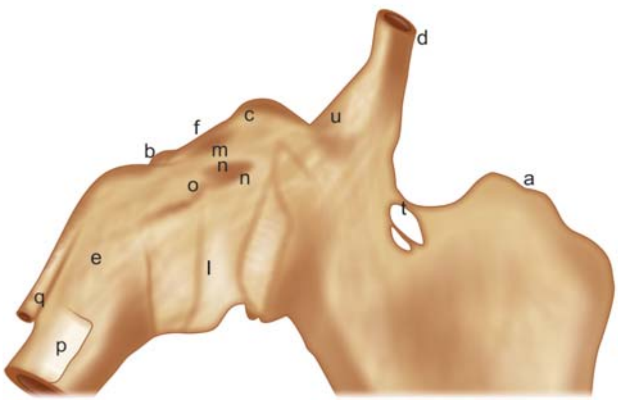


Fig. 6: Drawing from Weitbrecht's original article[16] showing the opening of the capsule in the region of the rotator interval, termed the 'Foramen Ovale' by Weitbrecht

then elevated. In each case, the marks and sutures confirmed this opening to be bordered by the SGHL and MGHL when visualized arthroscopically. Five of 12 specimens had an additional RICO visualized through the open approach (Fig. 8A). These RICOs corresponded to the arthroscopic appearance of either a foramen between the MGHL and the anterior band of the inferior glenohumeral ligament (consistent with the Foramen of Rouvière), or an opening between the labrum and anterosuperior glenoid (consistent with a sublabral hole) when viewed arthroscopically (Fig. 8B).

Arthroscopic sutures placed through the SGHL always captured the coracohumeral ligament (CHL), while those placed with the open technique penetrated no additional structures beyond the SGHL and MGHL.

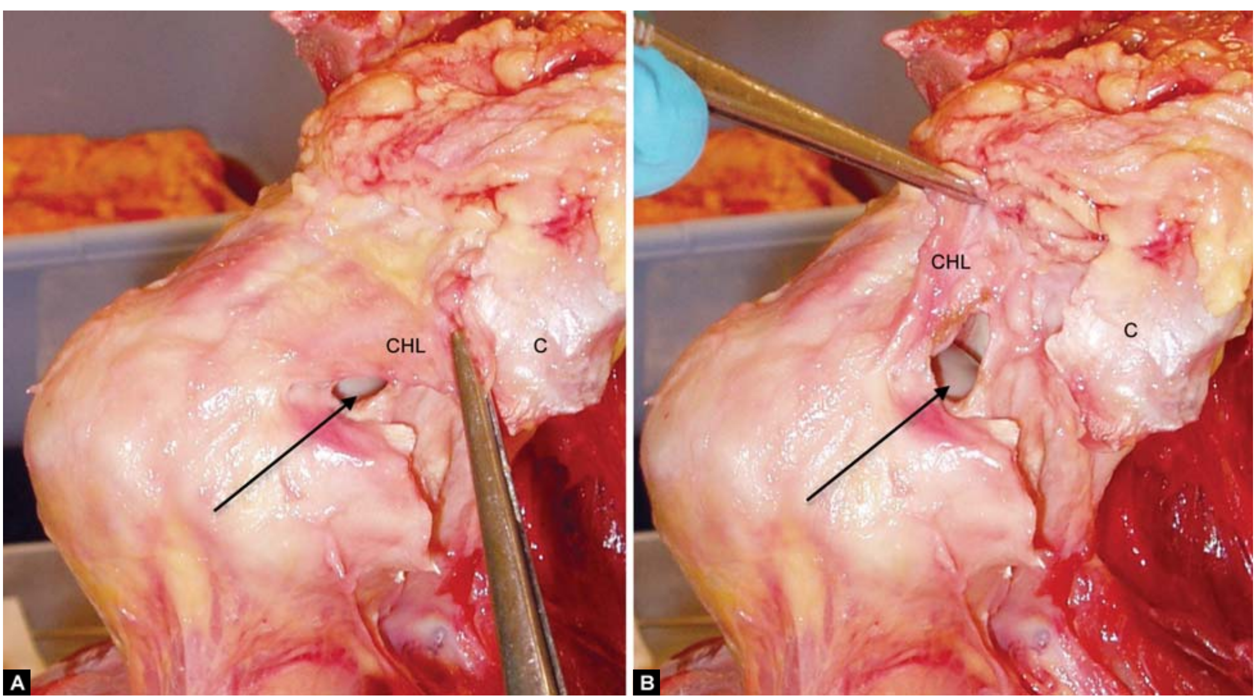
Rotator interval capsular opening dimensions as measured both arthroscopically and open are listed in Table 1. No significant differences were noted in any of dimensions when the results of the open and arthroscopic measurement techniques were compared.

DISCUSSION

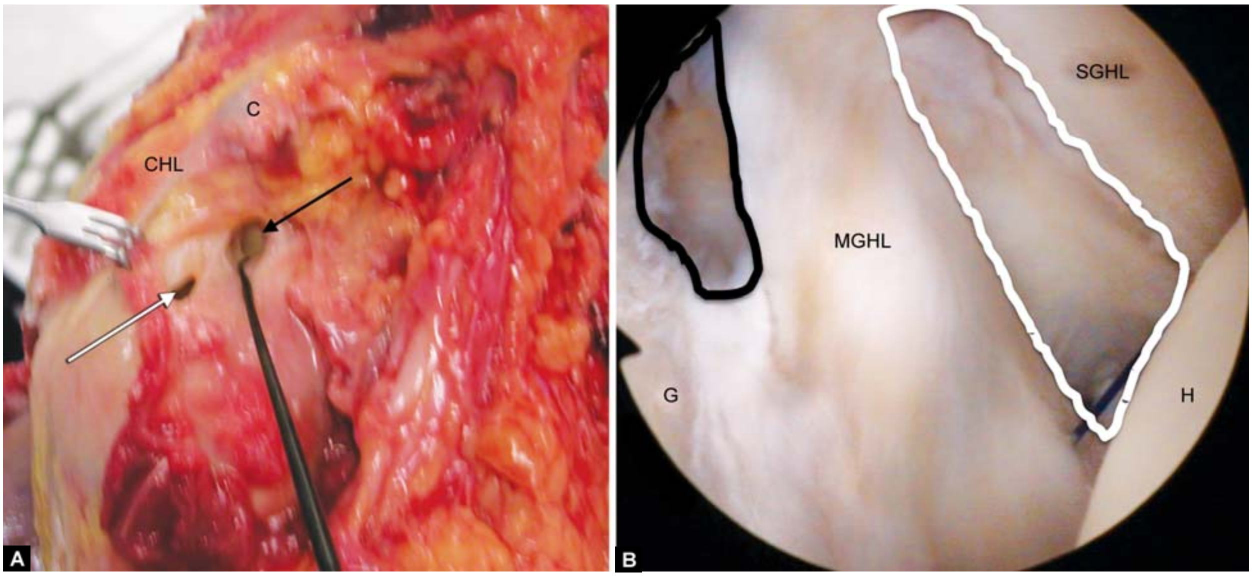
The most significant finding of the current study is confirmation that capsular openings noted in open anterior approaches to the shoulder correlate with arthroscopically identified openings in the anterior shoulder capsule bounded by the glenohumeral ligaments. Specifically, the primary foramen noted with an open approach (foramen of Weitbrecht) was bounded by the MGHL and SGHL. The dimensions of this foramen were similar when measured either open or arthroscopically. Similarly, 5 of 12 specimens

Table 1: Size of the primary rotator interval capsular opening (mean ± standard deviation)

	Arthroscopic measurement	*Open measurement*	*Significance*
Superior border (mm)	20.3 ± 4.4	19.6 ± 4.1	p = 0.69
Along the subscapularis in internal rotation (mm)	5.9 ± 2.9	4.2 ± 6.5	p = 0.42
Along the subscapularis in neutral rotation (mm)	8.4 ± 2.6	9.6 ± 6.9	p = 0.58
Along the subscapularis in external rotation (mm)	7.6 ± 2.7	11.5 ± 7.9	p = 0.12



Figs 7A and B: Typical open appearance of a right shoulder specimen with one RICO: (A) Shows the RICO (arrow) with the CHL intact and (B) shows the RICO (arrow) with the CHL elevated off the coracoid (C)



Figs 8A and B: Open (A) and arthroscopic (B) views of a right shoulder with two rotator interval capsular openings. The foramen of Weitbrecht is marked with a white arrow in the open view and the corresponding RICO is outlined in white on the arthroscopic view. The foramen of Rouviere is marked with a black arrow in the open view and the corresponding RICO is outlined in black on the arthroscopic view. The coracoid (C) and coracohumeral ligament CHL are labeled in the open view and the glenoid (G), humeral head (H), and middle MGHL and superior SGHL glenohumeral ligaments are labeled on the arthroscopic view

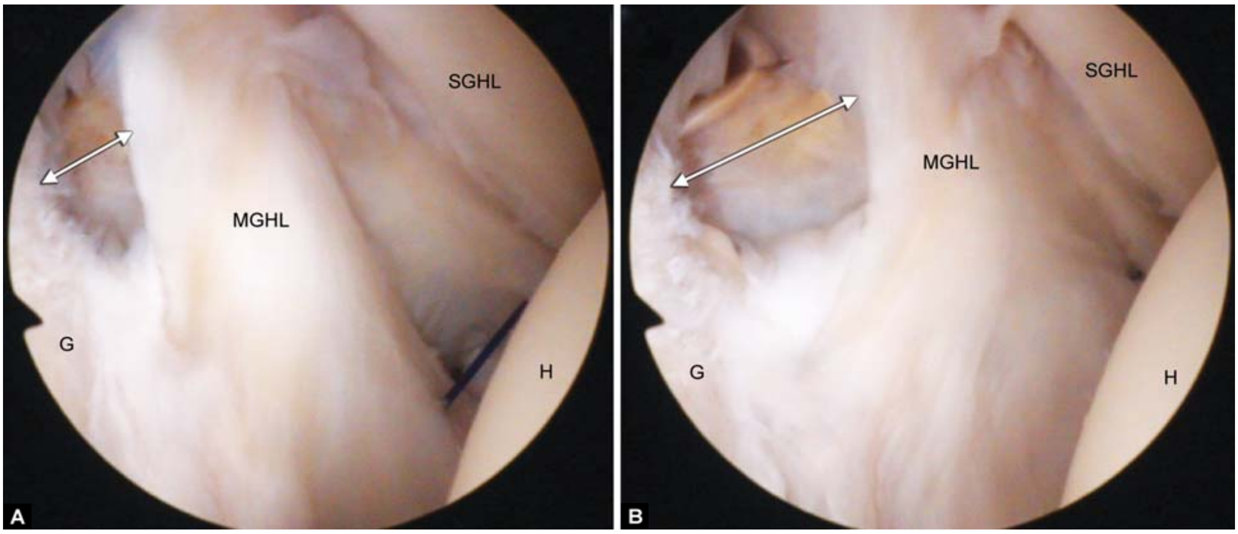
had a second capsular opening, corresponding arthroscopically to either a foramen inferior to the MGHL or a sublabral hole.

We are far from the first to note the presence of RICOs. Their description dates to the 18th and 19th centuries when Weitbrecht[16] and Rouvière[17] described them through open anatomic dissection. In 1949, the cadaveric study by DePalma et al[13] classified the variability of the anterior capsular structures. They recognized the capsular openings described by Weitbrecht and Rouviere and termed them 'superior and inferior subscapular bursae'. In their classification, DePalma et al found that the superior subscapular bursa between the SGHL and MGHL, corresponding to the Foramen of Weitbrecht, was present in approximately 80% of specimens. The inferior subscapular bursa, or Foramen of Rouvière, was present in approximately 40%. Similar results were reported by Steinbeck et al.[27] Interestingly, no RICOs were found in only 11.4% of DePalma's specimens and 9.6% of Steinbeck's specimens.

In more recent literature, the RICOs in the anterior capsule have been called 'lesions'[8] or 'defects'[3,4] implying pathologic findings rather than normal foramina of variable incidence and size. However, in 2001, Cole et al[3] supported the concept that RICOs are part of normal anatomy. Although they termed the openings 'defects', they found RICOs between the SGHL and the MGHL in 28 of 37 (76%) fetal shoulders. They did not comment on any capsular deficiencies beneath the MGHL. Cole et al concluded that these rotator interval capsular openings are likely congenital. The similar incidence of the primary RICO in the studies by DePalma et al and Steinbeck et al compared to the 76% by Cole et al reinforces the concept that these openings are a normal anatomic finding.

In recent years, many authors have reported on 'rotator interval closures' designed to treat various types of shoulder instability. Unfortunately, these descriptions have contributed to confusion in the literature because the procedures described rarely involve closure of the subscapularis to the supraspinatus. There has been no consistent anatomic procedure for a 'rotator interval closure', although most authors describe imbricating capsular structures, usually with closure of the primary RICO (Foramen of Weitbrecht) by closing the MGHL to the SGHL.

We believe that the term 'rotator interval closure' should only apply to procedures where the subscapularis is approximated to the supraspinatus resulting in an actual closing of the rotator interval, as strictly defined by Neer. In order to communicate effectively when describing the surgical procedures used in this study, we have elected to call the capsular foramina 'RICOs' and surgical closure of these foramina 'RICO closures'. It is clear that there are significant inconsistencies in accepted definitions of the term 'rotator interval'. These arise from the various points of reference to this region of the anterosuperior glenohumeral joint capsule. Surgeons need consistent terminology for this region and must recognize the subsets of consideration to include: (1) Closing capsular openings (as in most arthroscopic procedures and some open procedures), (2) closing tendon edges (as in some open procedures), and



Figs 9A and B: Arthroscopic view of a right shoulder with two RICOs. A suture has been placed through the SGHL and MGHL (A) Tightening the suture closes the lateral RICO (Foramen of Weitbrecht), (B) closing the SGHL to the MGHL widens the medial RICO (sublabral hole or Foramen of Rouviere) (white arrows). The glenoid (G) and humeral head (H) are labeled in both photos

(3) addressing the CHL. We suggest that the general term rotator interval capsular opening (RICO) be accepted for capsular foramina in the rotator interval region. Further, the RICO located between the SGHL and the MGHL should be called the primary RICO or the foramen of Weitbrecht. A second opening beneath the MGHL and above the SGHL should be called a secondary RICO, or the foramen of Rouvière.The sublabral hole should be considered a secondary RICO or a variant of the foramen of Rouvière.

This study presents several important implications for surgery to restore stability performed in the region of the rotator interval. We found that the capsular opening seen during open surgery corresponds to the structures seen at arthroscopy. The primary RICO (the Foramen of Weitbrecht) is seen during an open approach and corresponds to the capsular opening seen arthroscopically between the SGHL and the MGHL. The results of open studies, such as that by Field et al[5] can have implications for arthroscopic procedures, if those procedures achieve the same anatomic alterations.

The results of out study demonstrate that sutures passed arthroscopically through the SGHL using an outside-in technique may also capture the CHL. Other arthroscopic RICO closure techniques not involving the CHL have been described that close the SGHL to the MGHL with knots tied inside the joint. The biomechanical effects of these different types of arthroscopic techniques are unclear.

The anatomic variability demonstrated in this study, and previously described in the works of DePalma and Rouvière, suggest that closure of the primary RICO (the foramen of Weitbrecht) may not always produce the same effect. Outcome may be dependent on both the size of the RICO that is closed as well as the presence of a second RICO (foramen of Rouvière). In these shoulders, closure of the foramen of Weitbrecht will cause an unpredictable shift of the anterior capsular tissue due to the presence of the foramen below the MGHL or a sublabral hole. Figures 9A and B demonstrates the effect of closing the primary RICO, which widens the secondary RICO. This phenomenon warrants further research.

This anatomic study has significant limitations. Primarily, this study represents only an anatomic perspective and does not evaluate the effect on the anterior capsule or efficacy in controlling shoulder instability with any particular technique for RICO closure. Further, the approach to the anterior shoulder involved taking down the subscapularis tendon near its insertion. Although necessary for a cadaveric dissection, this technique has potential to alter the anatomical relationships visualized via the open approach.

CONCLUSION

Capsular openings in the region of the rotator interval visualized during open approaches to the shoulder correspond to openings seen arthroscopically. These openings are variable in appearance and size. For better understanding and improved communication about shoulder anatomy, the term 'rotator interval' should only be used to describe the space between the subscapularis and the supraspinatus.

ACKNOWLEDGMENTS

This project received funding from Arthrex, Inc. Arthrex provided the cadavers for the study as well as laboratory space.

REFERENCES

1. Chung CB, Dwek JR, Cho GJ, Lektrakul N, Trudell D, Resnick D. Rotator cuff interval: Evaluation with MR imaging and MR arthrography of the shoulder in 32 cadavers. J Comput Assist Tomogr 2000;24:738-43.
2. Cole BJ, Mazzocca AD, Meneghini RM. Indirect arthroscopic rotator interval repair. Arthroscopy 2003;19:E28-31.
3. Cole BJ, Rodeo SA, O'Brien SJ, Altchek D, Lee D, DiCarlo EF, et al. The anatomy and histology of the rotator interval capsule of the shoulder. Clin Orthop Relat Res 2001:129-37.
4. Fealy S, Rodeo SA, Dicarlo EF, O'Brien SJ. The developmental anatomy of the neonatal glenohumeral joint. J Shoulder Elbow Surg 2000;9:217-22.
5. Field LD, Warren RF, O'Brien SJ, Altchek DW, Wickiewicz TL. Isolated closure of rotator interval defects for shoulder instability. Am J Sports Med 1995;23:557-63.
6. Harryman DT 2nd, Sidles JA, Harris SL, Matsen FA 3rd. The role of the rotator interval capsule in passive motion and stability of the shoulder. J Bone Joint Surg Am 1992;74:53-66.
7. Jost B, Koch PP, Gerber C. Anatomy and functional aspects of the rotator interval. J Shoulder Elbow Surg 2000;9: 336-41.
8. Nobuhara K, Ikeda H. Rotator interval lesion. Clin Orthop Relat Res 1987:44-50.
9. O'Brien SJ, Allen AA, Coleman SH, Drakos MC. The trans-rotator cuff approach to SLAP lesions: Technical aspects for repair and a clinical follow-up of 31 patients at a minimum of 2 years. Arthroscopy 2002;18:372-77.
10. Pradhan RL, Itoi E. Rotator interval lesions of the shoulder joint. Orthopedics 2001;24:798-801;quiz 02-03.
11. Van der Reis W, Wolf EM. Arthroscopic rotator cuff interval capsular closure. Orthopedics 2001;24:657-61.
12. Werner A, Mueller T, Boehm D, Gohlke F. The stabilizing sling for the long head of the biceps tendon in the rotator cuff interval. A histoanatomic study. Am J Sports Med 2000;28:28-31.
13. DePalma AF, Callery G, Bennett GA. Variational anatomy and degenerative lesions of the shoulder joint. Instr Course Lect 1949;6:255-81.
14. Moseley HF, Overgaard B. The anterior capsular mechanism in recurrent anterior dislocation of the shoulder. J Bone Joint Surg Br 1962;44:913-27.
15. Neer CS 2nd. Displaced proximal humeral fractures. I. Classification and evaluation. J Bone Joint Surg Am 1970;52: 1077-89.
16. Weitbrecht J. Syndesmology. Philadelphia: WB Saunders Company, 1742.
17. Rouvière H. Anatomie Humaine: Descriptive et topographique. Paris: Masson et Cie, 1924.
18. Pouliart N, Gagey OJ. The arthroscopic view of the glenohumeral ligaments compared with anatomy: Fold or fact? J Shoulder Elbow Surg 2005;14:324-28.
19. Fitzpatrick MJ, Powell SE, Tibone JE, Warren RF. The anatomy, pathology, and definitive treatment of rotator interval lesions: Current concepts. Arthroscopy 2003;19(Suppl 1):70-79.
20. Gartsman GM, Roddey TS, Hammerman SM. Arthroscopic treatment of anterior-inferior glenohumeral instability. Two to five-year follow-up. J Bone Joint Surg Am 2000;82-A: 991-1003.
21. Gartsman GM, Taverna E, Hammerman SM. Arthroscopic rotator interval repair in glenohumeral instability: Description of an operative technique. Arthroscopy 1999;15:330-32.
22. Karas SG. Arthroscopic rotator interval repair and anterior portal closure: An alternative technique. Arthroscopy 2002;18: 436-39.
23. Le Huec JC, Schaeverbeke T, Moinard M, Kind M, Diard F, Dehais J, et al. Traumatic tear of the rotator interval. J Shoulder Elbow Surg 1996;5:41-46.
24. 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;66:159-68.
25. Stokes DA, Savoie FH 3rd, Field LD, Ramsey JR. Arthroscopic repair of anterior glenohumeral instability and rotator interval lesions. Orthop Clin North Am 2003;34:529-38.
26. Treacy SH, Field LD, Savoie FH. Rotator interval capsule closure: An arthroscopic technique. Arthroscopy 1997;13: 103-06.
27. Steinbeck J, Liljenqvist U, Jerosch J. The anatomy of the glenohumeral ligamentous complex and its contribution to anterior shoulder stability. J Shoulder Elbow Surg 1998;7: 122-26.

ABOUT THE AUTHORS

Steven J Svoboda

Attending Surgeon, Department of Orthopaedic Surgery, Keller Army Hospital, United States Military Academy, West Point, USA

Dean C Taylor

Professor, Department of Orthopaedic Surgery, Duke Sports Medicine Duke University Medical Center, Durham, NC, USA

Robert A Magnussen (Corresponding Author)

Assistant Professor, Department of Orthopaedic Surgery, The Ohio State University, OH, USA, e-mail: robert.magnussen@gmail.com