Agreement between Arthroscopy and Saline Magnetic Resonance Shoulder Arthrography in Adolescent Patients - Evaluation of Location and Extent of Injury of Labral Tears

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Objective: To compare potential differences in size and extent of labral tears on magnetic resonance arthrography of the shoulder performed with saline to shoulder to arthroscopy as the gold standard in adolescent patients with tears of the glenoid labrum.

Materials and methods: Pre-operative saline magnetic resonance arthrograms of the glenoid labrum were assessed by two radiologists for location and extent of the labral tear based on the clock-face method of visualization. The radiology findings were compared to the surgeon’s recorded arthroscopic findings (the start and end of the labral tear based on the clock-face method and the total range) in the operative report. One-way analysis of variance was used to compare saline magnetic resonance arthrograms and arthroscopic findings.

Results: Sixteen shoulder saline magnetic resonance arthrograms were included (15 underwent unilateral arthroscopic labral repair, 1 underwent bilateral arthroscopic labral repair. Most patients were male with an average of 17 years of age (range: 15-19 years) at the time of surgery. On average, 54 days elapsed between pre-operative imaging and surgery (range: 9-204 days). Both raters agreed that 100% of the examinations were of diagnostic quality. There were no significant differences between surgical report and the magnetic resonance arthrography raters for the mean clock face start (p = 0.47), end (p = 0.67), or total range of the tear (p = 0.97). The mean range of the tear was 4 hours for all three raters.

Conclusion: Saline contrast for magnetic resonance shoulder arthrography in adolescent patients is a reliable imaging technique when evaluating the glenoid labrum for the location and extent of injury and is a prudent alternative to gadolinium based contrast agents in adolescent patients.

Keywords: Arthrography, Arthroscopy, Shoulder, MRI, Adolescent, Saline

Introduction

Magnetic resonance arthrography (MRA) is often used over conventional MRI in the adolescent population for the evaluation of intra-articular cartilaginous and fibrocartilaginous injuries of the shoulder, as well as injuries to tendons and ligaments. Current MRA techniques use dilute gadolinium-based contrast agents (GBCAs), such as gadopentetate dimeglumine or gadoteridol, as gadolinium is inherently hyperintense on T1 weighted sequences due to resultant shortening of longitudinal regrowth [1]. Gadolinium-based MRA al-
most invariably uses fat saturated (FS) MR spin echo T1 weighted sequences, which allows for excellent contrast between the T1 bright intra-articular gadolinium and the lower signal intensity labrum and soft tissues. Normal saline (hereafter, saline) is inherently hyperintense on T2 weighted sequences due to a combination of high hydrogen ion content as well as F. Because of this, saline MRA (SaMRA), when used in conjunction with T2 FS sequences, also offers excellent contrast between the T2 bright intra-articular contrast and the lower signal intensity labrum and soft tissues. Saline is also a potentially safer alternative given rare adverse events varied between 10-15 ML. SaMRA included the following sequences: Axial T2 FS, Coronal T1, Coronal T2 FS, Sagittal T2 FS, and when tolerated by the patient, ABER (abduction with external rotation) T2 FS (Table 1).

The SaMRAs were independently reviewed, in random order to avoid bias, by two board certified pediatric radiologists with 5 and 12 years of experience. Readers were instructed to assess the location and extent of labral injury, were blinded to the arthroscopy surgical report at the time of review and were not involved with the arthrographic injections. The quality of the imaging study was initially scored as diagnostic, sub-optimal, or non-diagnostic. A study was considered diagnostic if the spatial and contrast resolution were such that the trabeculae and cortex were sharply defined, there was good definition of surrounding tissues, and there was good discrimination of rotator cuff tendons, biceps tendon, labrum, and cartilage from joint fluid. A study was considered suboptimal if the above-mentioned structures were blurred or not sharply defined and a study was considered nondiagnostic if the above-mentioned structures were obscured secondary to motion or other artifact. The extra-articular soft tissues about the rotator cuff were also assessed and rated as either normal or abnormal (abnormal T2 hyperintensity), as a full thickness rotator cuff tear with extravasation of intra-articular saline could manifest as increased signal intensity in the peri-articular soft tissues on fluid sensitive sequences. The SaMRA raters independently assessed the location and extent of the injury to the hour based on the clock-face method of visualizing of the glenoid labrum. A single orthopedic surgeon, with 15 years of experience, performed all the shoulder arthroscopies. The orthopedic surgeon assessed the location and extent of labral injury during arthroscopy using the same methodology as the radiologists. For reference and aligning with previous work [6], the labral tears were described with the following reference points: Superior (12:00) which is designated by the location of the biceps anchor, anterior (3:00), inferior (6:00), and posterior (9:00). This methodology is used in arthroscopy

Table 1: Specific sequences of the saline MRA protocol along with the scan time for each sequence.

| Sequence                                         | Repetition time (ms) (TR) | Echo time (ms) (TE) | Time to complete (MM:SS) |
|--------------------------------------------------|---------------------------|---------------------|--------------------------|
| Axial T2 with fat time satuation                 | 3500                      | 60                  | 3:12                     |
| Coronal T1                                       | 850                       | 8                   | 2:53                     |
| Coronal T2 with fat satuaration                  | 3500                      | 60                  | 2:55                     |
| Sagittal T2 with fat satuaration                 | 3500                      | 60                  | 3:16                     |
| Abduction and external rotation with fat saturation | 3300                      | 50                  | 3:42                     |

Slice thickness 3 mm; Inter slice gap 0.3 mm; FOV 13 cm; Matrix 300 × 432

The use of saline contrast for shoulder MRA has been shown to demonstrate comparable sensitivity and specificity in the evaluation of joint pathology in the adult population when compared with traditional gadolinium-based MRA [4,5], but evidence in adolescent patients is currently absent. Accordingly, the purpose of this investigation was to examine differences in location and extent of injury between saline contrast for shoul-der MRA and surgery among a cohort of adolescent pa-tients who underwent arthroscopic surgery for tears of the glenoid labrum based on SaMRA.

Methods

This was an observational and retrospective study approved by the institutional review board. We began exclusively utilizing SaMRA at our institution in the fall of 2016. Between 2016 and 2019 a total of eighty two patients underwent SaMRA. Twenty-one of these pa-tients underwent SaMRA prior to same side shoulder arthroscopy during this time period and were initially included in the study. Patients that did not undergo subsequent arthroscopy following SaMRA were not included in the study as the objective of the study was to compare specific parameters, namely location and extent of injury. The only exclusion criteria were prior shoulder surgery, which led to the exclusion of two pa-tients. This resulted in the inclusion of a total of sixteen cases of glenoid labral tears. All patients included in the study underwent standard arthographic injection of io-dinated contrast under fluoroscopic guidance via a poste-rior approach prior to SaMRA imaging. Arthrography was performed with a 5 cm 21-gauge needle after local

fluoroscopic anesthesia was induced with 1% Lidocaine. The arthographic solution was a 1:2 dilution of Isovue 300 (ioipamidol iopamiro 200; Bracco Diagnostics, Milan, Italy) with normal saline and the volume injected varied between 10-15 ML. SaMRA included the following sequences: Axial T2 FS, Coronal T1, Coronal T2 FS, Sagittal T2 FS, and when tolerated by the patient, ABER (abduction with external rotation) T2 FS (Table 1).

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for both preoperative planning and for communicating reliable descriptions of labral pathology in operative reports. Our primary outcome variables from this analysis included the start of the tear, the end of the tear, and the total range of the tear, each recorded based on reference to the clock face.

**Statistical Methods**

Continuous variables are presented as means and standard deviations, and categorical variables are presented as the number included and the corresponding percentages. To test for differences between SaMRA and surgical findings of labral injury location designated by the clock-face, we used a one-way analysis of variance (ANOVA), where rater (surgical report, MRA rater 1, MRA rater 2) were the independent variables and the clock face start, clock face end, and range of tear were the dependent variables. All statistical tests were two-sided, statistical significance was defined as \( p < 0.05 \), and Stata version 15.0 was used for all statistical analyses.

**Results**

Sixteen shoulder SaMRAs performed without complication, all in patients that underwent subsequent same side shoulder arthroscopy, were included in the study. Fifteen of these patients underwent unilateral arthroscopic labral repair and one patient underwent bilateral arthroscopic labral repair as well as pre-operative bilateral SaMRAs. Most patients were male with an average of 17 years of age (range: 15-19 years) at the time of surgery (Table 2). On average, 54.39 days elapsed between pre-operative imaging and operative bilateral SaMRAs. Most patients were male with an average of 17 years of age (range: 15-19 years) at the time of surgery (Table 2). On average, 54.39 days elapsed between pre-operative imaging and operative bilateral SaMRAs. Most patients were male with an average of 17 years of age (range: 15-19 years) at the time of surgery (Table 2). On average, 54.39 days elapsed between pre-operative imaging and operative bilateral SaMRAs. Most patients were male with an average of 17 years of age (range: 15-19 years) at the time of surgery (Table 2).

Table 2: Description of the study cohort. Data are presented as means (sd) or number (% of the study sample).

| Characteristic                        | Mean (sd) or n (%) |
|--------------------------------------|-------------------|
| Age (years)                          | 17.1 (1.2)        |
| Sex (female)                         | 3 (19%)           |
| Post-Operative Diagnosis (per arthroscopy) | 16 (100%)        |

Table 3: MRI image characteristics for the study cohort.

| Image Characteristic                  | MRA rater 1 | MRA rater 2 |
|--------------------------------------|-------------|-------------|
| Image quality of the study           | Diagnostic study | 16 (100%) | 16 (100%) |
|                                      | Sub-optimal study | 0 (0%)    | 0 (0%) |
|                                      | Non-diagnostic study | 0 (0%)    | 0 (0%) |
| Extra-articular soft tissues         | Normal      | 16 (100%)  | 14 (87%)  |
| about the rotator cuff?              | Abnormal T2 high signal | 0 (0%)  | 2 (13%) |

Table 4: Mean (SD) values for clock face start, end, and range for labral tears as rated by the surgical report and two MRA raters.

| Rater                  | Surgical report | MRA rater 1 | MRA rater 2 | P value |
|------------------------|-----------------|-------------|-------------|---------|
| Clock face start       | 3.37 (2.13)     | 5.03 (4.33) | 3.45 (3.30) | 0.46    |
| Clock face end         | 6.50 (1.08)     | 7.07 (2.23) | 7.30 (2.23) | 0.67    |
| Clock face range       | 3.54 (1.05)     | 3.52 (2.03) | 3.45 (2.14) | 0.97    |
cost savings along with shorter overall scan time are some additional benefits to SaMRA. The estimated cost savings at our institution based on performing a total of 90 shoulder MRAs annually along with the institutional cost for a single dose of Multi-Hance ($2 per mL for a 10 mL bottle) is approximately $1,800 per year. Given that the estimated decrease in scan time, due to completely eliminating the T1 FS sequences typically included in Gadolinium-based MRA protocols, for an adolescent patient undergoing a shoulder MRA (including repositioning for an ABER sequence) is approximately 10 minutes, this translates to an estimated scan time savings of 15 hours annually at our institution.

Despite the potential of SaMRA as an alternative, there are several limitations associated with this technique in the shoulder. Differentiating extravasation through a full thickness rotator cuff tear from a bursal fluid collection is a potential difficulty given that saline is generally isointense to bursal fluid (either subdeltoid or subacromial). The estimated decrease in scan time, due to completely eliminating the T1 FS sequences typically included in Gadolinium-based MRA protocols, for an adolescent patient undergoing a shoulder MRA (including repositioning for an ABER sequence) is approximately 10 minutes, this translates to an estimated scan time savings of 15 hours annually at our institution.

In addition to being a potentially safer option, some cost savings along with shorter overall scan time are some additional benefits to SaMRA. The estimated cost savings at our institution based on performing a total of 90 shoulder MRAs annually along with the institutional cost for a single dose of Multi-Hance ($2 per mL for a 10 mL bottle) is approximately $1,800 per year. Given that the estimated decrease in scan time, due to completely eliminating the T1 FS sequences typically included in Gadolinium-based MRA protocols, for an adolescent patient undergoing a shoulder MRA (including repositioning for an ABER sequence) is approximately 10 minutes, this translates to an estimated scan time savings of 15 hours annually at our institution.

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or subacromial) on T2 weighted sequences. In the adolescent population, however, full thickness rotator cuff pathology is rare, and is typically accompanied by a gap in the tendon [14], likely easing this limitation to some degree. It should also be noted that, SaMRAs may lead to diagnostic difficulty when arthropgraphic injection is performed via the rotator cuff interval guidance.

In addition to the possible challenges related to the saline technique, our study had additional limitations. Our sample was small and not random, as each patient underwent arthroscopic glenoid labral repair. Our study sample also did not include a control group without labral injury, as operative assessment would not have been performed. Intrinsic selection bias was likely present for the raters, though they were not informed that all cases were positive. We also did not control for the time interval between MRI to arthroscopy, which ranged from just over a week to just over seven months. The abnormal labrum may have undergone some change during this time, limiting the accuracy of MRA.

Though GBCAs are diluted in MRA and are administered intraarticularly and there is a low likelihood for reabsorption, there is a possibility for greater cumulative exposure to GBCA’s throughout one’s life.

Conclusion

Our study adds to body of literature confirming that saline is a safe, accurate, and readily available alternative to GBCAs for MR shoulder arthrography. However, unlike the previous studies, our cohort was adolescent, the age group ideally suited for saline arthrography given the possibility of greater cumulative exposure to GBCA’s throughout one’s life.

Compliance with Ethical Standards

This study received approval from the local institutional review board before commencement.

Funding

This study was unfunded.

Conflicts of Interest

The authors declare no conflicts of interest related to this study. Unrelated to this study, Dr. Howell has received research support from the Eunice Kennedy Shriver National Institute of Child Health & Human Development, the National Institute of Neurological Disorders And Stroke, and from a research contract between Boston Children’s Hospital, Cincinnati Children’s Hospital Medical Center, and ElMindA Ltd. Dr. Albright has received research support from Pediatric Orthopedic Society of North America (POSNA) and from Arthrex Inc. He has also received honoraria from Arthrex for speaking about surgical outcomes. The other authors declare no potential conflicts of interest.

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