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SCIENTIFIC ARTICLE

Incidence of gadolinium or fluid signal within surgically proven glenoid labral tears at MR arthrography

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Abstract

Objective To determine how often patients with surgically proven labral tears have labral signal on shoulder MR arthrography (MRA) that is not equal to gadolinium or fluid on T1- and T2-weighted images, respectively.

Materials and methods Consecutive patients with surgical repair of a SLAP or Bankart labral tear within 95 days of an MRA were included. Using cartilage signal as an internal reference, two musculoskeletal (MSK) radiologists retrospectively categorized labral signal as T1-hyperintense, T1-gadolinium, T2-hyperintense, or T2-fluid. In patients without T1-gadolinium or T2-fluid labral signal, secondary findings such as the orientation, extent, shape, and width of the abnormal signal was recorded. Statistical analyses were performed using Fisher's test and ANOVA.

Results Sixty-one labral tears (36 SLAP and 25 Bankart) in 54 patients (mean age, 30.7; F:M 8:46) met the inclusion criteria. In 67% and 76% of SLAP and Bankart labral tears, T1-gadolinium signal was present ($p = 0.43$). T2-fluid signal was present in 50% and 92% of these same labral tears ($p = 0.001$). The absence of T1-gadolinium or T2-fluid signal was more common in SLAP tears (33%) compared to Bankart tears (8%) ($p = 0.02$). In the SLAP cases, at least two secondary findings of a SLAP tear were present in 92% (11/12).

Conclusions Lack of surfacing T1-gadolinium or T2-fluid labral signal is unusual in Bankart tears but relatively common in SLAP tears. However, a SLAP tear was diagnosed in 92% of these 12 cases when two secondary findings were present.

Keywords Labrum · MRI · MR arthrography · SLAP · Bankart

The University of Virginia Institutional Review Board (IRB) gave permission for this study.

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Introduction

Shoulder MR arthrography (MRA) is generally accepted as the most accurate modality for the detection of glenoid labral tears [1, 2]. The presence of gadolinium within the labrum is considered the primary criterion for diagnosing of a tear in many studies, with labral morphology and location typically considered secondary signs of a tear [2–6]. The diagnostic accuracy of MRA for detecting superior labral anterior posterior (SLAP) and Bankart labral tears is excellent with a sensitivity and specificity of 75–89% and 78–99% for SLAP tears and 88–95% and 86–93% for Bankart tears, respectively [1, 7–10].

However, we noticed that some arthroscopically proven SLAP and Bankart labral tears did not have signal intensity as hyperintense as gadolinium or fluid on MRA. Instead, intermediate signal intensity in a pattern otherwise suggestive of labral tear was present. We postulated that using T1-gadolinium or T2-fluid labral signal as the sole determinant of a tear would result in lower detection of labral tears, but we did not know the extent.

The objective of our study was to determine how often T1-gadolinium and/or T2-fluid signal was absent on MRA in arthroscopically proven and subsequently repaired glenoid labral tears. In patients without T1-gadolinium or T2-fluid signal within the labral tear, we secondarily sought to quantify the incidence of specific MRA imaging features to include morphologic abnormalities and other findings associated with both SLAP and Bankart tears.

Materials and methods

After approval by the University of Virginia institutional review board, a chart review was performed on patients who underwent arthroscopic labral repair over a 13-month period. Cases were identified using CPT codes inclusive of SLAP repair, Bankart repair, and anterior capsulorrhaphy. Patient charts and imaging were then reviewed to confirm that an MRA had been performed within 95 days of surgery. Detailed exclusion criteria are listed in Table 1.

All included patients had the standard institutional arthrogram injection, which consisted of 12 ml of a 1:200 gadolinium dilution using either a 22- or 25-gauge needle. The patients then underwent a 1.5-Tesla Siemens MRI exam (Erlangen, Germany) with the patient's arm in a neutral to mildly external rotated position. The following pulses sequences were utilized: T1-weighted (T1-w) fat-suppressed (FS) oblique coronal (TR/TE 400–750/10–15 ms, 3-mm slice thickness, 0.3-mm interslice gap, 320 × 320 matrix, 150–160 mm field of view), T2-weighted (T2-w) FS oblique coronal and oblique sagittal (TR/TE 3800–5000/55–65 ms, 3-mm slice thickness, 0.3 interslice gap, 320 × 320 matrix, 150–160 mm field of view), T1-w oblique sagittal (TR/TE 400–750/10–15 ms, 3-mm slice thickness, 0.3-mm interslice gap, 384 × 384 matrix, 150–160 mm field of view), T2-w FS axial (TR/TE 3800–5000 ms, 3-mm slice thickness, no interslice gap, 320 × 320 matrix, 150–160 mm field of view), T1-w axial (TR/TE 400–750/10–15 ms, 3-mm slice thickness, no interslice gap, 384 × 384 matrix, 150–160 mm field of view), and T1-w oblique axial (TR/TE 400–750/10–15 ms, 3-mm slice thickness, no interslice gap, 320 × 320 matrix, 150–160 mm field of view).

Two musculoskeletal (MSK) radiologists with 1 and 8 years of experience evaluated each labrum in consensus with cartilage signal used as the reference standard in determining relative levels of hyper or hypo-intense signal. On T1-w images, signal was classified as "T1-gadolinium" if it was hyperintense relative to cartilage whereas signal was classified as "T1-hyperintense" if it was hyperintense relative to background labral signal but was similar or hypointense relative to cartilage (Fig. 1). On T2-w images, signal was classified as "T2-fluid" if brighter than cartilage and was described as "T2-hyperintense" if it was hyperintense relative to the labrum but was of similar to hypointense signal relative to cartilage (Fig. 2). When evaluating labra with hyperintense T1-w or T2-w signal but without "T1-gadolinium" or "T2-fluid" signal, secondary criteria were evaluated. Secondary criteria for SLAP tears included abnormal width or depth of signal, irregular labral contour, extension of abnormal signal posterior to the biceps tendon attachment, and laterally oriented signal. Secondary criteria for a Bankart tear included globular internal signal extending to the surface, inhomogenous internal signal, or a Hill–Sachs fracture.

Statistical analysis was performed utilizing a two-tailed Fisher's exact test comparing gender and difference in signal intensity across SLAP and Bankart labral

Table 1 Exclusion criteria

Exclusion criteria	Number of patients excluded
Patients with history of prior shoulder surgery	5
Patients without a tear retrospectively visible on MRA	3
Delay of greater than 95 days between MRA and arthroscopy	27
Technical factors/poor MRI quality	6
Patients over the age of 55	4

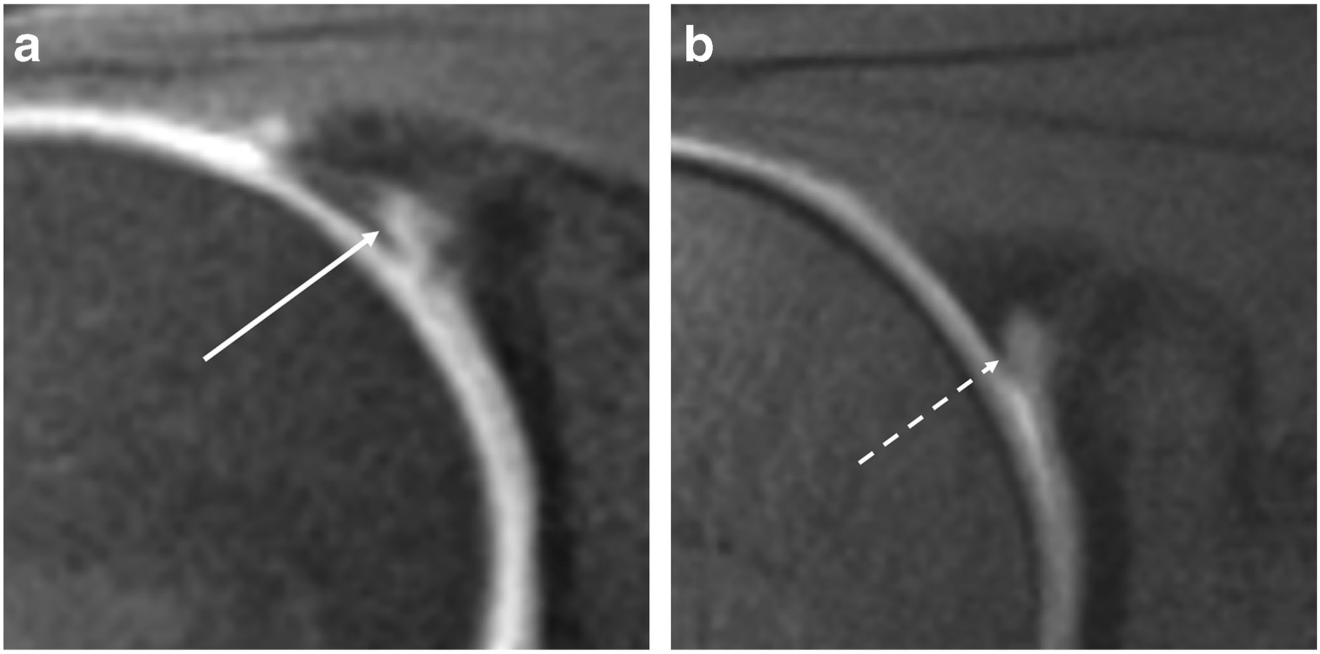

Fig. 1 T1-w gadolinium and T1-w hyperintense signal. Thirty-seven-year-old male with T1-w coronal oblique fat-saturated image performed as part of an MRA (**a**) demonstrates irregular, linear signal extending laterally in the labral substance with signal intensity similar to that of intra-articular gadolinium and brighter than cartilage (*solid arrow*), characterized as gadolinium signal. A T1-w coronal oblique fat-saturated MRA image from a 29-year-old male patient (**b**) demonstrates abnormal signal in the superior labrum which is abnormally wide, extends slightly laterally, and is similar in signal intensity to cartilage (*dashed arrow*); this lesion was classified as having T1 hyperintense but not gadolinium signal

tears. ANOVA was utilized to compare mean age and delay between MRA and surgery across tear types. A *p* value of 0.05 was used as the cutoff to determine statistical significance.

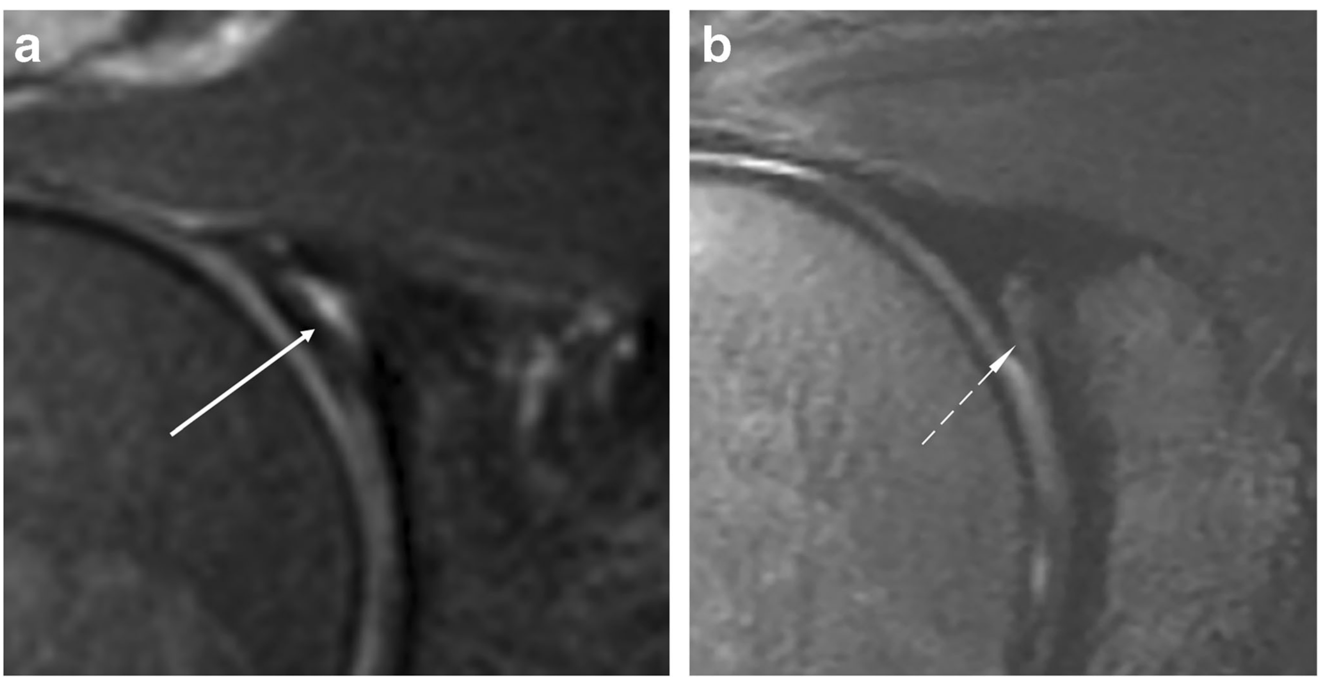

Fig. 2 T2-w fluid and T2-w hyperintense signal. A T2-w coronal oblique fat-saturated MRA image in a 37-year-old male patient (**a**) demonstrates laterally extending intra-labral signal in the superior labrum hyperintense to cartilage and similar in signal intensity to joint fluid (*solid arrow*), characterized as T2-w fluid signal. A T2-w coronal oblique fat-saturated MRA image from a different patient (**b**) shows abnormal linear signal extending laterally in the superior labrum with signal intensity similar to that of cartilage (*dashed arrow*), characterized as T2-w hyperintense but not fluid signal

Results

Ninety-nine patients underwent SLAP or Bankart labral repair following an MRA performed at our institution during the study period. After the exclusion criteria were applied (Table 1), a total of 54 patients (mean age 30.7 years; M:F 8:46) and 61 labral tears (36 SLAP and 25 Bankart) were included (Table 2). Mean patient age was significantly younger in the Bankart tears (mean 25.5 years) compared to the SLAP tears (mean age 33.1 years) ($p = 0.005$). There was no statistically significant difference in the in male/female ratio between the different labral tear types.

There was no significant difference in the percentage of SLAP and Bankart tears containing T1-gadolinium signal ($p = 0.43$) (Table 2). There were significantly more Bankart labral tears with T2-fluid signal compared to SLAP tears ($p = 0.001$) (Table 2). Patients with Bankart labral tears were more likely than those with SLAP tears to have both T1-gadolinium and T2-fluid signal present ($p = 0.04$) (Fig. 3). Similarly, SLAP tears more frequently had neither T1-gadolinium nor T2-fluid signal present when compared with Bankart labral tears ($p = 0.02$) (Table 2) (Fig. 4). No significant difference in the delay in the number of days between MRA and surgery was noted across the different signal groups and labral tear types.

All 12 SLAP tears without either T1-gadolinium or T2-fluid signal intensity within the labrum exhibited lateral orientation of the labral signal abnormality. Signal abnormality extending posterior to the biceps anchor was present in 83% ($n = 10$), irregular labral signal/morphology in 58% ($n = 7$) and abnormal width or depth of the signal abnormality in 50% ($n = 6$) of these 12 SLAP tears. Furthermore, all but one case had more than one of the aforementioned findings (Table 3). The two patients with Bankart tears that lacked either T1-gadolinium or T2-fluid signal both had inhomogeneous labral signal with one patient having a Hill–Sachs lesion. Both of these patients were also much younger (14 and 18 years old) than the mean age of the patients with Bankart tears (25 years) (Fig. 5).

Table 2 SLAP and Bankart labral tears with gadolinium and fluid signal presence on MRA

Tear type	SLAP	Bankart	*p* value
Total	36	25	
Mean age	33.1	25.5	0.005
Male	29 (81%)	21 (84%)	0.73
Female	7	4	
Gadolinium within tear	24/36 (67%)	19/25 (76%)	0.43
Fluid within tear	18/36 (50%)	23/25 (92%)	0.001
Gadolinium and fluid within tear	18/36 (50%)	19/25 (76%)	0.04
No gadolinium or fluid within tear	12/36 (33%)	2/25 (8%)	0.02

Discussion

While labral tears are often identified on conventional shoulder MRI [3], shoulder MRA demonstrates higher sensitivity and specificity for labral tear detection, especially in high level athletes [4, 5]. The reported sensitivity and specificity of MRA for SLAP tears is 75–89% and 78–99%, respectively [1, 7–9] with a sensitivity and specificity in a recent meta-analysis of 0.87 and 0.92 [11]. The sensitivity and specificity of MRA in diagnosing anterior inferior labral tears is 88–95% and 86–93%, respectively [1, 7, 10].

One regularly observes signal within the labrum that is T1-w or T2-w hyperintense to cartilage on MRA, but not as bright as intra-articular gadolinium or fluid. Interpretation of these studies is sometimes challenging since they do not meet the criteria utilized for diagnosing a tear in some studies which is labral detachment or gadolinium extending into the SLAP or Bankart tear [1, 4, 5, 8–10, 12]. Unfortunately, there is little information regarding the frequency of hyperintense but not gadolinium T1-w signal present within glenoid labral tears at MRA in the published literature. Fortunately, there is literature on analogous fibrocartilaginous structures elsewhere in the body such as the knee meniscus, which is likely applicable to the glenoid labrum.

While the indications for performing shoulder and knee MRA are quite different, the concepts supporting the use of arthrography in both joints are in many ways analogous. Some advocate knee MRA as the technique of choice for diagnosing recurrent or residual tears in patients with prior meniscal surgery due to joint distention and the presence of gadolinium in the arthrogram mixture, which is less viscous than native joint fluid and may be more likely to extend into a tear [5, 13–16]. This is because the MRI criterion for diagnosing a knee meniscal tear, which is abnormal signal contacting a meniscal surface, can be a normal finding following partial meniscectomy or meniscal repair. However, De Smet et al. reported that on knee MRA, over one-third (11/30) of recurrent meniscal tears had T1-w hyperintense signal relative to the remainder of the meniscal tissue that was not as bright as gadolinium [17]. They suggested that this appearance might be due to some meniscal tears imbibing only minimal contrast, which might appear less intense than gadolinium due to volume averaging with the adjacent hypointense meniscus [17]. We theorize that a similar phenomenon may partially explain our 33% (12/36) incidence of arthroscopically proven SLAP tears demonstrating hyperintense T1-w signal less bright than gadolinium. As a result, we recommend not diagnosing a SLAP tear solely on the criterion of T1-gadolinium signal within the labrum since this practice will result in a significant under-appreciation of SLAP tears.

T2-w fluid signal was present even less often (50%) than T1-gadolinium signal (67%) in SLAP tears. This may result from inherently better contrast and spatial resolution of T1-w

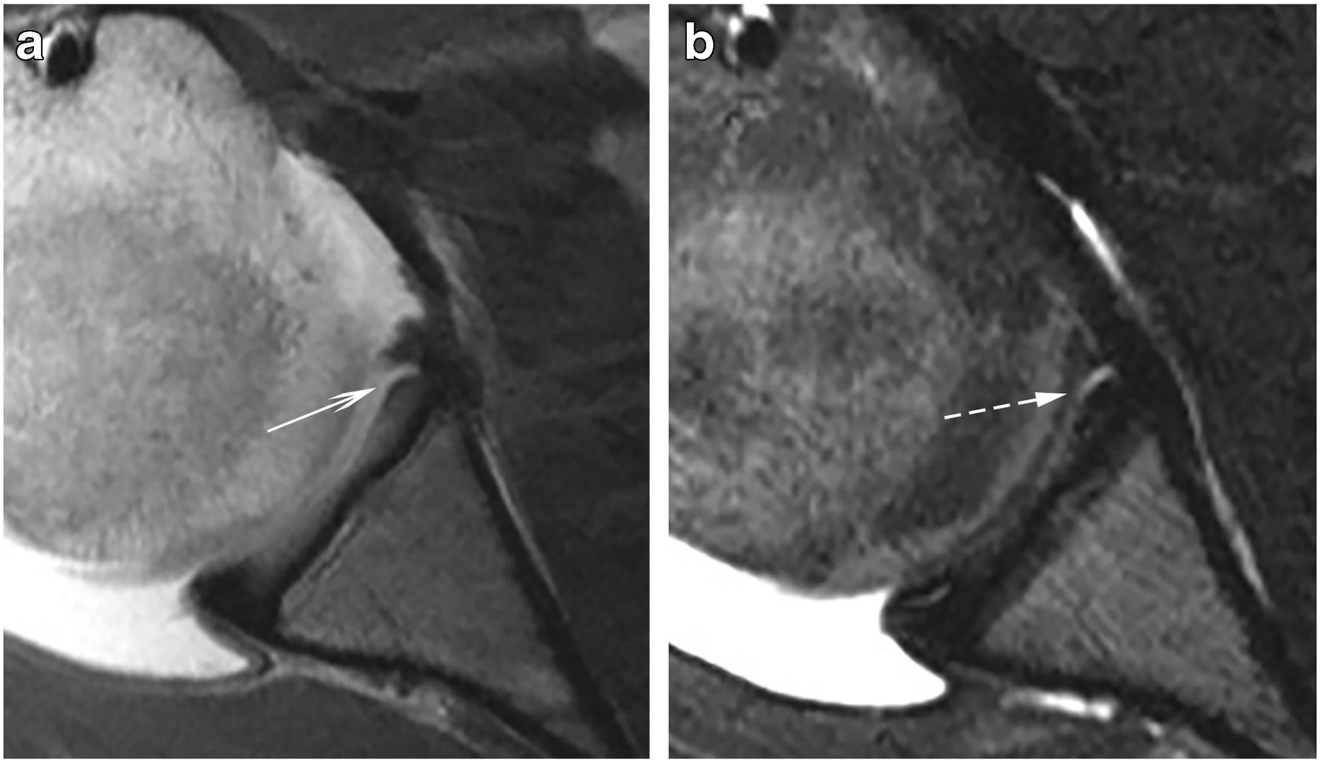

Fig. 3 A 19-year-old female with arthroscopically proven Bankart injury. Axial T1-w without (**a**) and T2-w with fat suppression (**b**) MRA images demonstrate both fluid (*dotted white arrow*) and gadolinium (*solid white arrow*) signal extending into the anteroinferior labral tear

relative to T2-w imaging, making the subtle findings of a SLAP tear more apparent on T1-w images even when accounting for possible effects of volume averaging [18, 19]. One would expect this finding to also be evident in Bankart tears. However, we found the reverse phenomenon true in Bankart labral tears with T2-w fluid signal present more often (92%) than T1-w gadolinium signal (76%). A potential explanation for this observation may be related to labral vascularity since the anterior inferior labrum is the most vascular portion of the labrum and greater vascularity should increase the potential to "heal." This is exemplified by the attempted healing or resynovialization of chronic anterior labral periosteal sleeve avulsion (ALPSA) injuries [20, 21]. A similar process has also been proposed to occur in some knee meniscal tears [16]. We hypothesize that this resynovialization can "trap" fluid beneath the Bankart tear and might account for Bankart tears

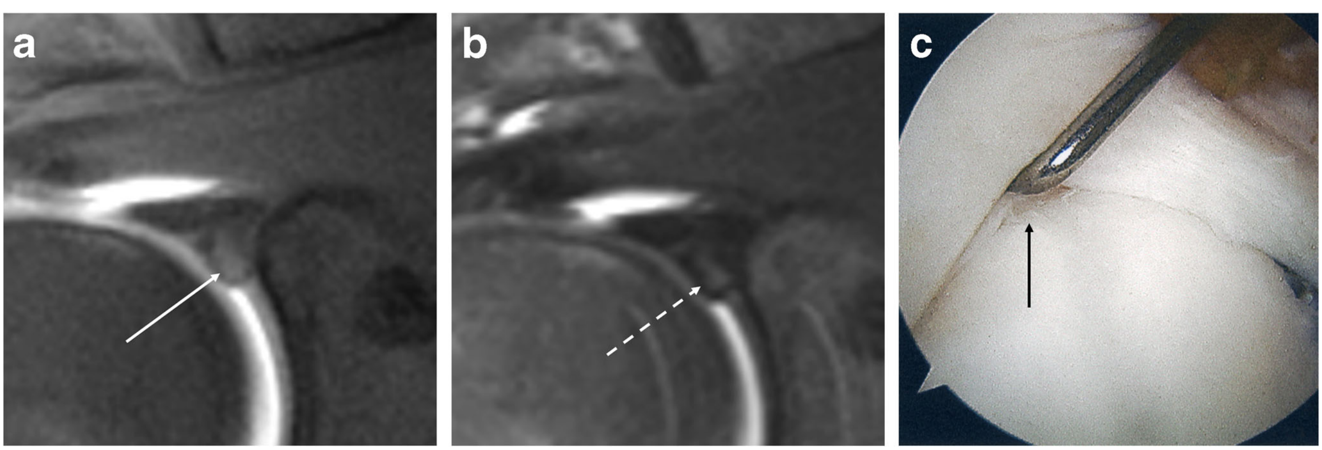

Fig. 4 A 25-year-old female patient with arthroscopically proven SLAP tear. T1-w (**a**) and T2-w (**b**) coronal oblique MRA images demonstrate T1 (*solid white arrow*) and T2 signal (*dashed white arrow*) less intense than gadolinium or fluid, similar to cartilage, but hyperintense compared to the background labrum. The signal is of abnormal width, extends laterally into the labrum, and extended posterior to the labrum on additional non-included images. Arthroscopy image (**c**) demonstrates a surgical probe within an irregular appearing SLAP tear (*solid black arrow*)

Table 3 SLAP tear without gadolinium or fluid within the labrum

SLAP Tear without gadolinium or fluid	12
Lateral orientation of signal	12/12 (100%)
Posterior to biceps anchor	10/12 (83%)
Irregular signal/morphology	7/12 (58%)
Abnormal width or depth	6/12 (50%)
All 4 findings	3/12 (25%)
3 out of 4 findings	6/12 (50%)
2 out of 4 findings	2/12 (17%)
1 out of 4 findings	1/12 (8%)

exhibiting a much higher incidence of T2-fluid compared to SLAP tears. It would also explain the concurrent lack of gadolinium within some fluid-containing Bankart tears, even with the joint distension provided by arthrography.

Neither T1-gadolinium nor T2-fluid labral signal was required to diagnose 33% of SLAP tears which represents a substantial minority of patients. The SLAP tears that did not exhibit T1-gadolinium or T2-fluid signal demonstrated lateral signal orientation in all tears and signal extension posterior to the biceps labral anchor in 83% of tears. Use of these secondary signs should increase the sensitivity in detecting SLAP tears when gadolinium signal is not present in the tear and may also help distinguish a SLAP tear from a sublabral foramen or a superior labral recess [22–24]. Only two Bankart tears did not demonstrate T2-fluid or T1-gadolinium signal intensity with both patients having inhomogeneous signal present in the anteroinferior labrum. However, since inhomogeneous signal in the anterior-inferior labrum is not especially unusual, the use of this secondary sign might be less helpful particularly in older patients. We did notice that the two patients without fluid or gadolinium signal in the Bankart tears were both teenagers. As a result, the finding of inhomogeneous anterior-inferior labral signal in patients under the age of 20 might be a more useful finding than when identified in older patients, but additional study is required due to the small number of patients in this category.

Our study was limited by only including patients who had arthroscopic labral repair following MRA; thereby excluding patients with labral tears reported on MRA but not confirmed at surgery. This limits our ability to determine the number of false positives we would have diagnosed if we only relied on morphologic changes and not T1 gadolinium or T2-fluid signal to diagnose a tear. We also used arthroscopy as the "gold" standard, which is accepted throughout the literature, even though some subtle nondisplaced tears such as Perthes lesions could be missed as they are difficult to detect both with MRA and arthroscopy [25]. The exclusion of patients who have had prior surgery may limit the applicability of our findings in postsurgical patients, as the literature on these patients has typically required extension of fluid or gadolinium into the labrum to diagnose a tear [26]. In addition, images were obtained on 1.5-T units and the results might be different using 3 T.

In conclusion, we found that one-third of SLAP tears lacked surfacing T1-gadolinium or T2-fluid labral signal; however, a SLAP tear was still confidently diagnosed in 92% of these cases when two secondary findings of a tear were present. T2-fluid labral signal was more commonly present in Bankart labral tears with only 8% of Bankart labral tears

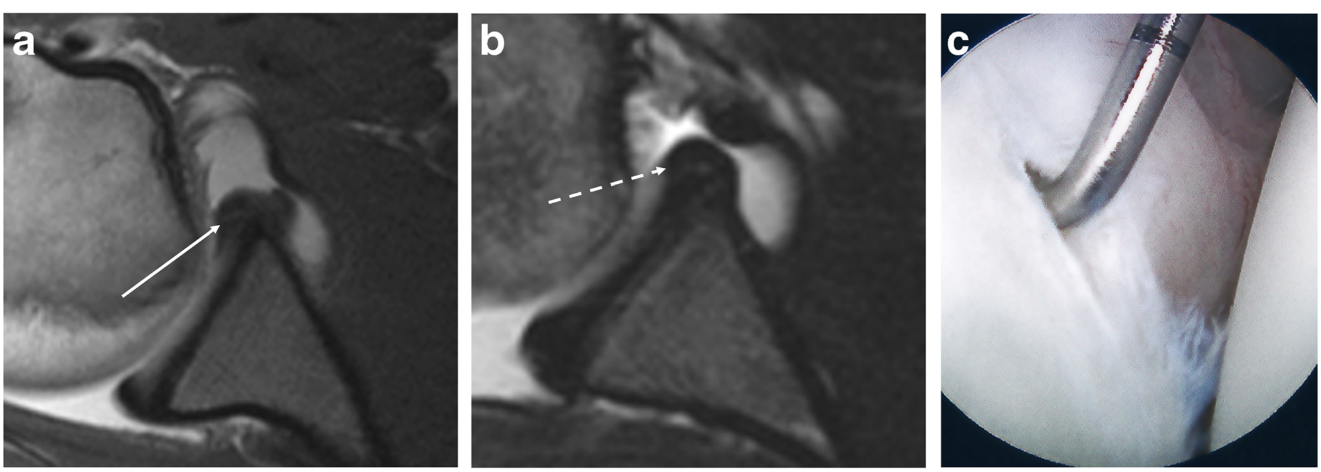

Fig. 5 A 14-year-old male with arthroscopically proven Bankart tear. Axial T1-w without (**a**) and T2-w with fat saturation (**b**) MRA images demonstrate subtle inhomogeneous anterior inferior labral signal abnormality on T1 (*solid white arrow*) and T2 (*dashed white arrow*) image extending to the labral surface but that does not meet criteria for gadolinium or fluid signal. This inhomogeneous signal would not be expected to be degenerative in such a young patient. The corresponding arthroscopy image (**c**) demonstrates the surgical probe within a Bankart tear

not exhibiting either T1-gadolinium or T2-fluid signal. The use of secondary signs in patients with Bankart tears was less conclusive due to the small numbers.

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Compliance with ethical standards

Conflict of interest No grants or conflicts of interest to disclose.

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