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Metal artefacts severely hamper magnetic resonance imaging of the rotator cuff tendons after rotator cuff repair with titanium suture anchors

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Abstract

Background: The rate of retear after rotator cuff surgery is 17%. Magnetic resonance imaging (MRI) scans are used for confirmative diagnosis of retear. However, because of the presence of titanium suture anchors, metal artefacts on the MRI are common. The present study evaluated the diagnostic value of MRI after rotator cuff tendon surgery with respect to assessing the integrity as well as the degeneration and atrophy of the rotator cuff tendons when titanium anchors are in place.

Methods: Twenty patients who underwent revision surgery of the rotator cuff as a result of a clinically suspected retear between 2013 and 2015 were included. The MRI scans of these patients were retrospectively analyzed by four specialized shoulder surgeons and compared with intra-operative findings (gold standard). Sensitivity and interobserver agreement among the surgeons in assessing retears as well as the Goutallier and Warner classification were examined.

Results: In 36% (range 15% to 50%) of the pre-operative MRI scans, the observers could not review the rotator cuff tendons. When the rotator cuff tendons were assessable, a diagnostic accuracy with a mean sensitivity of 0.84 (0.70 to 1.0) across the surgeons was found, with poor interobserver agreement (kappa = 0.12).

Conclusions: Metal artefacts prevented accurate diagnosis from MRI scans of rotator cuff retear in 36% of the patients studied.

Keywords

diagnostic value, interobserver agreement, metal artefacts, MRI, rotator cuff, shoulder

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Introduction

Recurrent or persisting symptoms after rotator cuff surgery can be a result of retears or nonhealing of the repaired tendon(s). The mean rate of retear after rotator cuff surgery is reported to be 17%, with a wide range (11% to 94%).[1] A magnetic resonance imaging (MRI) scan is the preferred means of diagnosing retears and evaluating the muscle quality of the rotator cuff.[2] Many surgeons use metal (often titanium) suture anchors for cuff repair, which are placed at the rotator cuff footprint on the humeral head.[3–5] These titanium anchors cause metal artefacts on postoperative magnetic resonance images and therefore potentially limit the diagnostic value of the scan (Fig. 1).[2–4,6,7]

Literature on the diagnostic accuracy of MRI after rotator cuff repair is scarce.[8–10] Only a few studies describe the diagnostic quality of these scans in

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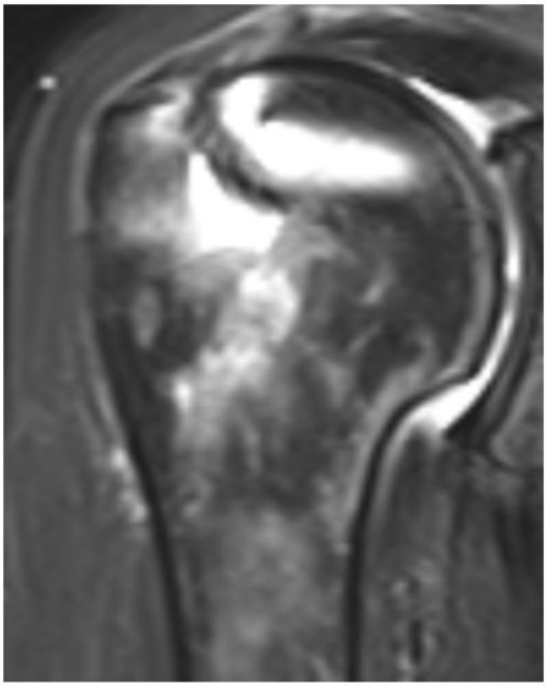

Figure 1. Magnetic resonance imaging of the shoulder. Coronal slice made with a T2 weighted fast spin echo sequence with clear metal artefacts after cuff repair with a titanium anchor.

detecting a retear[8,9] or assess interobserver agreement in detecting retears.[10] None of the existing studies have investigated the degree to which metal artefacts reduce the diagnostic value of the postoperative MRI and thereby decrease interobserver agreement.

The present study aimed to determine the extent to which metal artefacts caused by titanium suture anchors inserted during the initial surgery hamper the MRI-based assessment of the rotator cuff tendon integrity and the degeneration and atrophy of the rotator muscles.

Materials and methods

A retrospective case cohort study was carried out. Between June 2013 and June 2015, 337 patients underwent rotator cuff surgery in our clinic. Based on clinical symptoms, 24 (7%) of these patients underwent revision surgery of the rotator cuff. Four patients who had not undergone an MRI prior to the revision surgery were excluded. The study population consisted of 20 patients who underwent revision surgery of the rotator cuff and who had undergone a postoperative MRI scan after the primary cuff repair and before revision (Fig. 2). The revision procedures were performed arthroscopically (45%) or using the mini-open technique (55%).

The magnetic resonance images included sagittal, coronal and transversal oblique turbo spin echo sequences, T1, T2 and PD weighted (TR/TE 600-3670/12-93). Slice thicknesses ranged from 3 mm to 3.5 mm, with a gap of 1 mm. The field of view was 200 mm, with a matrix between 256×256 and 384×308. Images were acquired using a high field 1.5 Tesla (T) MRI (Magneto Avento; Siemens, Munich, Germany) with a dedicated shoulder coil.

Data on patient characteristics (sex, age, side of the operation and surgical technique) were collected retrospectively. The intra-operative findings of the revision surgery were considered the gold standard; therefore, the surgical reports were retrieved from the digital medical records (EZIS; ChipSoft, Amsterdam, The Netherlands). To assess the diagnostic utility of the MRI for evaluating the rotator cuff after surgery involving titanium suture anchors, the 20 anonymized scans were evaluated by four specialized shoulder surgeons. The surgeons were blinded for patient characteristics. The scans were scored as outlined below.

Scoring of scans

Retears. The rotator cuff was evaluated for the presence of retears. This was scored on a three-point grading scale, where 0 indicates 'no retear', 1 indicates 'retear' (partially or fully) and 2 indicates 'not assessable as a result of metal artefacts'.

Fatty degeneration and atrophy. Fatty degeneration and atrophy of the rotator cuff muscles using the Goutallier and Warner classification.[11,12] The Goutallier classification quantifies the extent of fatty degeneration of the rotator cuff muscles, where 0 = normal muscle, 1 = some fatty streaks, 2 = more muscle than fat, 3 = equal amount of fat and muscle, and 4 = more fat than muscle.[11] The Warner classification is a grading scale for muscle atrophy ranging from 'no', 'mild' and 'moderate' atrophy to 'severe' atrophy.[12] The classification is based on the oblique sagittal-plane MRI, where an imaginary straight line connects the coracoid either to the scapular spine or to the tip of the scapula.

Hampering of metal artefacts. The extent to which metal artefacts reduce the visibility of the tendons and muscles of the rotator cuff was scored on a visual analogue scale (VAS) ranging from 0 = 'not assessable as a result of metal artefacts' to 10 = 'the anatomic structures were not obscured in any way by metal artefacts'.

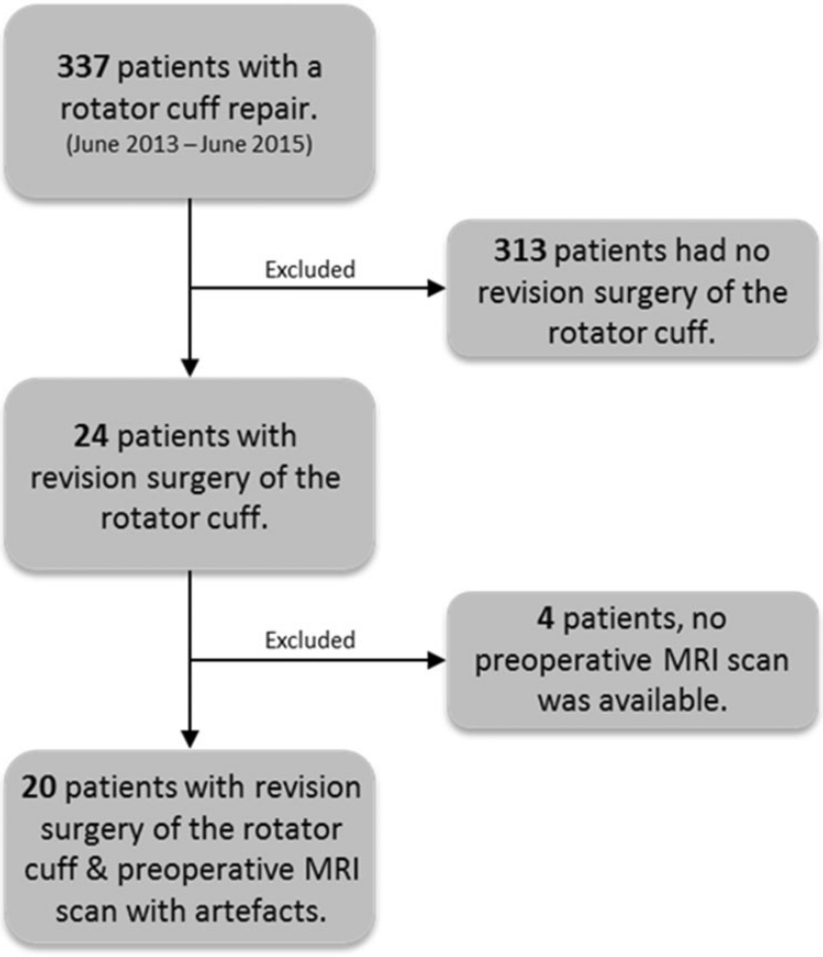

Figure 2. Flowchart of the study population. MRI, magnetic resonance imaging.

Statistical analysis

Patient ages are presented as the mean (SD). Categorical data (sex, affected side/tendons) are summarized by frequency and percentage. The univariate association between continuous patient characteristic variables was assessed using a Student's independent *t*-test for continuous variables. Categorical variables were compared using Pearson's chi-squared test and Fisher's exact test. $p < 0.05$ was considered statistically significant.

To evaluate the interobserver agreement in identifying a rotator cuff tear, a linear weighted kappa was calculated between the four observers. The kappa statistic was categorized as indicating poor (< 0.50), good (0.51 to 0.75) or excellent (> 0.75) agreement.[13] As an indicator of the hampering of accurate assessment, the number (percentage and range) of postoperative MRI scans that the orthopaedic surgeons rated as 'not assessable as a result of metal artefacts' was determined. These scans were excluded from the calculation of the MRI reassessments' sensitivity. The gold standard was the intraoperative findings (retear/intact).

A VAS scale was used to measure the extent to which metal artefacts reduce the visibility of the tendons and muscles. An average of the four surgeons' VAS ratings for the four tendons and muscles of the rotator cuff was calculated. For the degeneration and atrophy of the rotator cuff muscles, the intraclass correlation coefficient (ICC) for the Goutallier and Warner classification was determined. In the present study, the Goutallier and Warner classification served as the reference score for assessing interobserver reliability. Although we are aware that the tendon integrity score differs from the Goutallier and Warner classification, incorporating this scoring system provides information on the interobserver agreement of our sample of orthopaedic surgeons that is less subject to the metal artefacts' influence. As such, differences in interobserver agreement between these two scoring systems might serve as evidence of the metal artefacts' hampering

effect on the MRI scan. All data were analyzed using SPSS, version 23 (IBM Corp., Armonk, NY, USA).

Results

Patient characteristics are summarized in Table 1. The study cohort consisted of 20 patients (65% male), with a mean (SD) age of 56 (8.8) years. The revision cuff repairs were performed either using the mini-open technique (55%) or arthroscopically (45%). There were no differences between the characteristics (sex, age, side of the operation and surgical technique) of the patients undergoing revision cuff surgery and those of the overall cuff repair group.

Table 1. Patient characteristics.

	All cuff repairs ($n = 337$)	Re-repairs cuff ($n = 20$)	p-value
Factor			
Age (years), mean (SD)	59 (9.6)	56 (8.8)	0.54
Male, *n* (%)	179 (53.1)	13 (65.0)	0.36
Left shoulder, *n* (%)	124 (36.8)	7 (35.0)	0.53
Tendon(s) repaired, *n* (%)			
SSP	198 (58.8)	5 (25.0)	0.22
ISP	6 (1.8)	2 (10.0)	
SSC	4 (1.2)	0 (0.0)	
Combination	128 (37.9)	12 (60.0)	
Intact cuff	1 (0.3)	1(5.0)	

SSP, supraspinatus; ISP, infraspinatus; SSC, subscapularis.

Intra-operatively, retears of the rotator cuff were found in 95% of cases. A combination of the supraspinatus, infraspinatus and subscapularis tendon was ruptured in 60% of the patients. There was an isolated tear of the supraspinatus tendon in 25% of the cases, infraspinatus tendon in 10% of the cases and subscapularis tendon in 5% of the cases.

As shown in Table 2, the shoulder surgeons judged approximately one-third (36%; range 15% to 50%) of the postoperative MRI scans of the rotator cuff to be 'not assessable' as a result of metal artefacts. The interobserver agreement for retears was poor, with a kappa of 0.12 (0.00 to 0.29). The mean sensitivity was 0.84 (0.70 to 1.00). High inconsistency in MRI assessments was found among the assessors: they were in complete agreement in only 2/20 (10%) of the MRI assessments, where one case concerned a retear and the other was judged as 'not assessable' by all four observers.

Figure 3 gives an overview of the extent to which metal artefacts hamper the visibility of the tendons and muscles of the rotator cuff. The supraspinatus tendon was most disturbed by the metal artefacts: it was completely unaffected by these in only 15% (3/20) of MRI assessments.

Good agreement was found between the assessors for the Goutallier and Warner classification (ICC of 0.67 and 0.73) (Table 3). Almost all muscles were given a VAS score of > 8, suggesting that diagnostics were not disturbed by metal artefacts.

Discussion

The present study has shown that metal artefacts caused by titanium suture anchors in rotator cuff surgery negatively affect MRI scans' diagnostic accuracy and interobserver agreement in detecting retears of the rotator cuff on MRI scans.

Table 2. Interobserver agreement and sensitivity.

Kappa	Surgery 2	Surgery 3	Surgery 4	Not assessable as a result of metal artefacts	Sensitivity (without missing)
Surgery 1	0.29	0.08	<0	15	75
Surgery 2		0.08	0.18	35	92
Surgery 3			0.07	45	70
Surgery 4				50	100
Mean			0.12	36	84

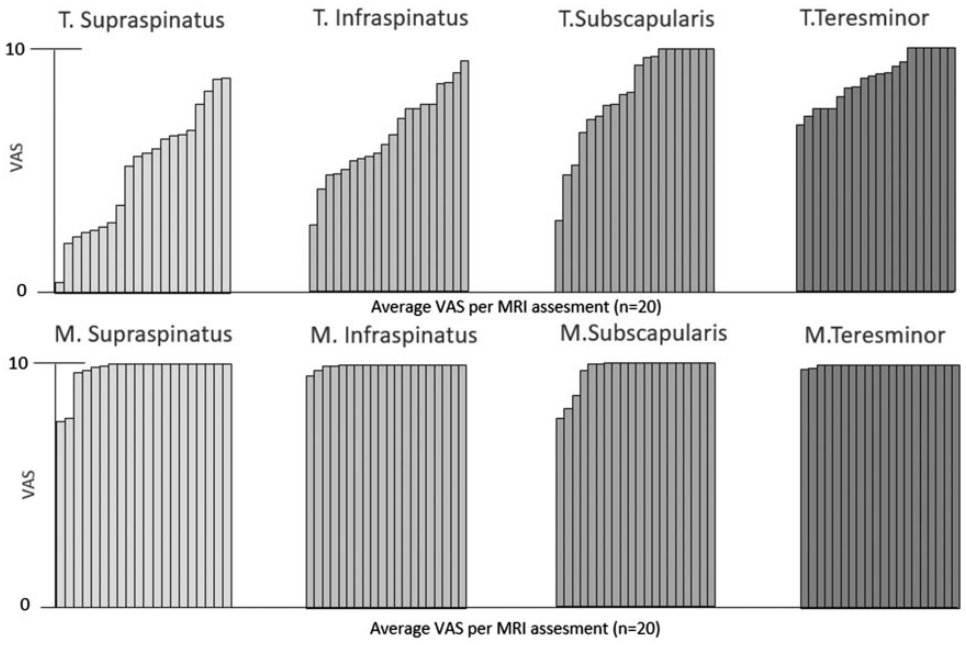

Figure 3. The extent metal artefacts hamper tendons and muscles to evaluate the rotator cuff. Tendons and muscles hampered as a result of metal artefacts ($n = 20$). Scoring was conducted on a visual analogue scale (VAS) scale by four specialized shoulder surgeons. 0 indicates that, as a result of metal artefacts, it was impossible to distinguish the anatomic structure, whereas 10 indicates that the anatomic structure was not obscured in any way by metal artefacts. MRI, magnetic resonance imaging.

Table 3. Goutallier and Warner.

Goutallier	0	1	2	3	4
%	15	23	23	16	23
ICC	0.67				
Warner	None	Mild	Quite	Severe	
%	22	29	33	16	
ICC	0.73				

ICC, intraclass correlation coefficient.

The sensitivity for diagnosing a retear after rotator cuff repair in our study was 84% (range 0.70 to 1.00). Motamedi et al.[9] report a similar sensitivity of 91%. In their study, the 37 MRI scans of the rotator cuff with titanium suture anchors were assessed by one observer (a musculoskeletal radiologist) compared to four (shoulder surgeons) in the present study.

In the present study, the interobserver agreement found for MRI scans after cuff repair was poor (kappa 0.12). Khazzam et al.[10] report a markedly higher interobserver agreement (kappa 0.60) for assessing retears on MRI scans after initial cuff repair. This can be explained by the type of suture anchors inserted during the initial surgery: Khazzam et al.[10] only included MRI scans of the rotator cuff after surgery with non-metal suture anchors, whereas, in the present study, titanium anchors were used. Because metal anchors cause larger artefacts than non-metal anchors, the presence of the former is likely to have resulted in poorer agreement in the present study. Heterogeneity of the assessors' diagnostic MRI imaging capabilities is less likely to have negatively affected agreement because all assessors in the present study were highly specialized, high-volume shoulder surgeons with a substantial amount of work experience.

To control for differences in assessors' capabilities independently of the disturbance of metal artefacts, the assessors' agreement on muscles that were not hampered by metal artefacts was assessed using the Goutallier and Warner classification. Results showed a good ICC (ICC of 0.67 and 0.73) amongst the observers with regard to fatty degeneration and muscle atrophy. Given this high agreement on the Goutallier and Warner classification, the low interobserver agreement found is more likely to be a result of the metal artefacts' hampering effect than to differences in the observers' capabilities.

Alternative anchor material

With the emergence of anchors made of bio-compatible materials, fewer titanium anchors might be used in the near future. Bio-anchors do not induce metal artefacts and appear to be as effective in secure tendon-to-bone

repair as metal suture anchors.[14] Unfortunately, the use of some biodegradable anchors is also associated with complications, including foreign body reactions, cyst formation, fluid collection, osteolysis and chondral damage.[15] A promising alternative is polyetheretherketone anchors, which are nonbiodegradable. These anchors act like metal implants without inducing the metal artefact and also do not cause the aforementioned complications. Future use of this anchor material will resolve the metal artefact problem. However, because titanium anchors are still often used during rotator cuff repairs, hampered medical decision-making as a result of metal artefacts on postoperative MRIs will remain a problem in the forthcoming time

Improvement of or alternative imaging methods

If patients remain symptomatic (i.e. experiencing pain or malfunction after rotator cuff repair), imaging of the rotator cuff is important in order to determine possible treatment options. Limited imaging quality can result in invalid medical decision-making with consequences for the patient, such as unnecessary repeat surgery or conservative treatment. Given that metal artefacts hamper the adequate diagnosis of retears with conventional MRI scanning, the challenge is to find ways of overcoming this negative effect on MRI images. Technological improvement of scan sequences is one possibility to reduce metal artefacts. Ai et al.[16] show that metal artefact reduction sequences (MARS) yield up to 59% reduction compared to traditional fast spin echo sequences. However, at the time of this study, these MARS sequences were not available at our clinic and were also not widespread globally.

Ultrasound (US) is the preferred method for imaging rotator cuff tears. For detecting an initial rotator cuff tear, US and MRI are comparable in both sensitivity and specificity.[17] When assessing rotor cuff retears, US is less affected by metal artefacts than MRI or computerized tomography (CT). However, the postoperative rotator cuff can show altered morphology for years following the repair, which can manifest as loss of fibular architecture and abnormal echogenicity on US and make it difficult to diagnose a retear.[18] Furthermore, the reliability of US is highly dependent on the operator's experience, and a US is not easily re-assessable compared to CT or MRI images. Finally, the amount of muscle atrophy is yet not quantified with US, in contrast to CT and MRI.

Other imaging modalities such as MR arthrography (MRA) or CT arthrography (CTA) are expected to improve diagnostics when metal anchors are present. Compared to conventional MRI and CT scans, MRA and CTA have a comparable or slightly improved sensitivity and specificity for detecting initial rotator cuff tears in non-operated shoulders. However, these are invasive procedures.[19,20] Furthermore, their accuracy decreases postoperatively. Scar tissue can act as a barrier that prevents contrast entering the subacromial space, therefore mimicking an intact cuff in case of a rupture. Furthermore, contrast in the subacromial space on the postoperative MRA or CTA does not always indicate a (clinically relevant) retear.[4,21]

Finally, it may be worth investigating the possibilities of reducing the main magnetic field. High field MRI (> 1 T) is currently used as a standard for musculoskeletal imaging.[22] Low field MRI (< 0.5 T), although rarely used at present, is hypothesized to be highly suitable for musculoskeletal imaging.[23,24] Interestingly, Radzi et al.[25] found that decreasing the main magnetic field (from 3 T to 1.5 T) resulted in a 16% reduction of metal artefacts. It is expected that low field MRI (0.25 T) would further decrease metal artefacts. A comparison between metal artefact hampering in conventional and low field MRI scanning of the rotator cuff after repair with metal suture anchors should therefore be undertaken in the near future.

Strengths and limitations

The present study is among the first to evaluate the extent to which metal artefacts hamper MRI imaging of the rotator cuff after a repair using metal suture anchors and the clinical implications of this hampering. A unique aspect of the present study is that, in addition to the classical assessment of diagnostic accuracy, the extent to which metal artefacts hamper the quality of medical decision-making based on MRI scans was evaluated. Because no standardized method was available to measure the extent to which metal artefacts hamper MRI, we developed a measurement based on proven classifications such as Warner's and Goutallier's. Future research could benefit from further validation of this method.

An important limitation of the present study was that only one patient in our dataset underwent revision surgery without having a retear (i.e. there was only one true negative). With only one 'negative' cuff tear, calculating specificity accurately was impossible because more true negatives are required to do so. However, because clinical practice attempts to avoid true negatives, the prevalence of true negatives for study purposes will remain low.

Second, the shoulder surgeons knew that the patients in the present study had undergone revision surgery because of suspected retears after rotator cuff surgery, which might have influenced the sensitivity that was measured.

The present study has shown that metal artefacts hamper the diagnostic accuracy of postoperative

MRIs and that these artefacts also cause poor interobserver agreement. Potential methods to overcome this hampering are the use of MR/CT arthrography or low field MRI for imaging of the rotator cuff tendons in patients with recurrent or persisting symptoms after rotator cuff surgery with metal suture anchors.

Declaration of Conflicting Interests

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Ethical Review and Patient Consent

Due to the retrospective nature of the study, ethical approval was not deemed necessary.

References

1. Le BTN, Wu XL, Lam PH, et al. Factors predicting rotator cuff retears: an analysis of 1000 consecutive rotator cuff repairs. *Am J Sports Med* 2014; 42: 1134–1142.
2. Thakkar RS, Thakkar SC, Srikumaran U, et al. Complications of rotator cuff surgery – the role of postoperative imaging in patient care. *Br J Radiol* 2014; 87: 20130630.
3. Zlatkin MB. MRI of the postoperative shoulder. *Skeletal Radiol* 2002; 31: 63–80.
4. Beltran LS, Bencardino JT and Steinbach LS. Postoperative MRI of the shoulder. *J Magn Reson Imaging* 2014; 40: 1280–1297.
5. Bancroft LW, Wasyliw C, Pettis C, et al. Postoperative shoulder magnetic resonance imaging. *Magn Reson Imaging Clin N Am* 2012; 20: 313–325.
6. Knudsen HB, Gelineck J, Saibierg J, et al. Functional and magnetic resonance imaging after single-tendon rotator cuff reconstruction evaluation. *J Shoulder Elb Surg* 1999; 8: 242–246.
7. Vandevenne JE, Vanhoenacker FM, Parizel PM, et al. Reduction of metal artefacts in musculoskeletal MR imaging. *JBR-BTR organe la Société R belge Radiol = orgaan van K Belgische Ver voor Radiol* 2007; 90: 345–349.
8. Owen RS, Iannotti JP, Kneeland JB, et al. Shoulder after surgery: MR imaging with surgical validation. *Radiology* 1993; 186: 443–447.
9. Motamedi AR, Urrea LH, Hancock RE, et al. Accuracy of magnetic resonance imaging in determining the presence and size of recurrent rotator cuff tears. *J Shoulder Elb Surg* 2002; 11: 6–10.
10. Khazzam M, Kuhn JE, Mulligan E, et al. Magnetic resonance imaging identification of rotator cuff retears after repair: interobserver and intraobserver agreement. *Am J Sports Med* 2012; 40: 1722–1727.
11. Goutallier D, Postel JM, Bernageau J, et al. Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. *Clin Orthop Relat Res* 1994; 304: 78–83.
12. Warner JJP, Higgins L, Parsons IM, et al. Diagnosis and treatment of anterosuperior rotator cuff tears. *J Shoulder Elb Surg* 2001; 10: 37–46.
13. Svanholm H, Starklint H, Gundersen HJG, et al. Reproducibility of histomorphologic diagnoses with special reference to the kappa statistic. *APMIS* 1989; 97: 689–698.
14. Pawaskar AC, Kekatpure A, Cho N-S, et al. Magnetic resonance appearance of bioabsorbable anchor screws for double row arthroscopic rotator cuff repairs. *Indian J Orthop* 2015; 49: 164–170.
15. Dhawan A, Ghodadra N, Karas V, et al. Complications of bioabsorbable suture anchors in the shoulder. *Am J Sports Med* 2012; 40: 1424–1430.
16. Ai T, Padua A, Goerner F, et al. SEMAC-VAT and MSVAT-SPACE sequence strategies for metal artifact reduction in 1.5t magnetic resonance imaging. *Invest Radiol* 2012; 47: 267–276.
17. De Jesus JO, Parker L, Frangos AJ, et al. Accuracy of MRI, MR arthrography, and ultrasound in the diagnosis of rotator cuff tears: A meta-analysis. *Am J Roentgenol* 2009; 192: 1701–1707.
18. Adler RS. Postoperative rotator cuff. *Semin Musculoskelet Radiol* 2013; 17: 12–19.
19. Charousset C, Bellaïche L, Duranthon LD, et al. Accuracy of CT arthrography in the assessment of tears of the rotator cuff. *Bone Joint J* 2005; 87B: 824–828.
20. Roy J-S, Braën C, Leblond J, et al. Diagnostic accuracy of ultrasonography, MRI and MR arthrography in the characterisation of rotator cuff disorders: a meta-analysis. *Br J Sports Med* 2015; 49: 1316–1328.
21. Mohana-Borges AVR, Chung CB and Resnick D. MR Imaging and MR Arthrography of the postoperative shoulder: spectrum of normal and abnormal findings. *RadioGraphics* 2004; 24: 69–85.
22. Chung CB and Steinbach LS. *MRI of the upper extremity: shoulder, elbow, wrist and hand*. Philadelphia, PA: Wolters Kluwer Health/Lippincott Williams & Wilkins, 2010.
23. Ghazinoor S, Crues JV and Crowley C. Low-field musculoskeletal MRI. *J Magn Reson Imaging* 2007; 25: 234–244.
24. Lee CS, Davis SM, McGroder C, et al. Analysis of low-field magnetic resonance imaging scanners for evaluation of knee pathology based on arthroscopy. *Orthop J Sport Med* 2013; 1: 2325967113513423.
25. Radzi S, Cowin G, Robinson M, et al. Metal artifacts from titanium and steel screws in CT, 1.5T and 3T MR images of the tibial Pilon: a quantitative assessment in 3D. *Quant Imaging Med Surg* 2014; 4: 163–172.