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Practice Quality Improvement for Patient Positioning on Shoulder Magnetic Resonance Imaging to Reduce Potential Diagnostic Errors

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DESCRIPTION OF THE PROBLEM

MRI is the leading imaging modality for evaluation of rotator cuff disease in the United States due to its high sensitivity and specificity [1]. However, several pitfalls are associated with misinterpretation of rotator cuff tear (RCT) on shoulder MRI, including magic angle artifact and lack of joint distention [2–5]. Internal rotation of the humerus is another potential cause of diagnostic error on shoulder MRI [6]. Humeral rotation at the glenohumeral joint is determined by positioning of the upper extremity prior to the MRI scan (Figure 1). With humeral internal rotation, normal connective tissue is interposed between the infraspinatus and supraspinatus tendons, mimicking infraspinatus tendon tear on coronal oblique sequences [5, 6]. Additionally, internal rotation of the humerus increases partial volume averaging for the supraspinatus tendon, producing the appearance of a false positive RCT [2, 6]. Internal rotation of the humerus is also associated with false positive subscapularis tendinopathy and decreased sensitivity for detection of anterior inferior labral tears [5, 7, 8]. Thus, internal rotation of the humerus should be avoided when performing shoulder MRI [6].

Anecdotally, we noticed that internal rotation of the humerus on shoulder MRI was not uncommonly encountered at our practice, but we did not know the actual prevalence of this positional error at our institution. Therefore, we conducted a practice quality improvement (PQI) project to 1) document the prevalence of internal rotation of the humerus on shoulder MRI at our outpatient imaging center and 2) to implement an intervention to eliminate internal rotation of the humerus at our practice.

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WHAT WE DID

This PQI project was determined by our institutional review board not to constitute human research. The PQI project complied with Health Insurance Portability and Accountability Act guidelines. This study was conducted in compliance with The American Board of Radiology's Part 4 of the Maintenance of Certification Program which mandates continuous practice quality improvement [9].

Subjects consisted of all consecutive outpatients who received a shoulder MRI at a single imaging center at our institution over two separate 4-month periods. The first cohort of shoulder MRIs consisted of all examinations performed from November 2014 through February 2015. The second cohort included all shoulder MRI examinations performed from May 2015 to August 2015. All MRI examinations were performed at 1.5 T (Magnetom Area; Siemens, Erlangen, Germany). Our goal was to eliminate internal rotation of the humerus during shoulder MRI. Internal rotation of the humerus was defined as $\geq 20^\circ$ [6].

To quantify humeral rotation, the axial image best demonstrating the glenoid fossa of the scapula and the bicipital groove of the humerus was selected for analysis [6]. First, a line parallel to the articular surface of the glenoid fossa was drawn (Figure 2). Then, a line that bisected the bicipital groove of the humerus to a point equidistant from all curved surfaces of the articular surface in the central region of the humerus was drawn. The angle between the scapular glenoid and humeral lines represented the degree of humeral rotation [6]. All measurements were performed by a single musculoskeletal radiologist.

In early March 2015, an electronic search of our institutional picture archive and communication system (PACS) was conducted to identify all shoulder MRI examinations obtained between November 2014 and February 2015 to establish a baseline prevalence of internal rotation of the humerus at our outpatient imaging center. Inclusion criteria included all shoulder MRIs for patients ≥ 18 years of age. Exclusion criteria were 1) a complete absence of axial sequences or 2) MRI artifacts that precluded adequate identification of humeral or scapular landmarks.

In late March 2015, the first author met with staff members at the outpatient imaging center 1) to educate MR technologists about the pitfalls of internal rotation of the humerus and 2) to create strategies to eliminate humeral rotation $\geq 20^\circ$ on shoulder MRI. The outcome of this radiologist-technologist collaboration resulted in an agreement to standardize a new patient position for all outpatient shoulder MRI. The "intervention" moving forward would require the technologist to elevate the elbow to chest level with cushions, and to apply external rotation to the humerus at the elbow. Elevation of the elbow was a key strategy to improve comfort, allowing patients to tolerate external rotation of the humerus. All MR technologists at the outpatient imaging center received a focused in service training on the new patient position. The new patient position for shoulder MRI was adopted in April 2015. Our goal was to obtain 100% compliance in avoiding internal rotation of the humerus ($\geq 20^\circ$). Our metric/benchmark for the PQI project was set for 100% compliance.

In September 2015, an electronic search of the PACS was conducted to identify all shoulder MRI examinations obtained between May 2015 and August 2015 to establish the prevalence

of internal rotation of the humerus following our PQI intervention. Inclusion criteria included all shoulder MRIs for patients ≥ 18 years of age. Exclusion criteria were 1) a complete absence of axial sequences or 2) MRI artifacts that precluded adequate identification of humeral or scapular landmarks.

Statistical analysis was performed using Stata Statistical Software Version 14 (Stata Corporation, College Station, Texas, USA). Pearson χ^2 test was used to compare the proportions of outcomes between baseline and post-intervention groups.

A P value $< .05$ was considered to indicate a significant difference.

Results:

During the initial data acquisition period between November 2014 and February 2015, a total of 53 shoulder MRI examinations meeting inclusion criteria were identified at the outpatient imaging center. No examination had to be excluded. A total of 20 shoulder MRI examinations were found to have a humeral rotation $\geq 20^\circ$ (Table 1). A total of 37.7 % of shoulder MRI examinations were deemed to have suboptimal patient positioning. These results were shared with staff members at the outpatient imaging center before the practice improvement intervention was instituted to educate the MRI technologists about the problem and to inform them of the baseline prevalence of humeral rotation in their workspace.

There were a total of 69 shoulder MRI examinations meeting inclusion criteria at the outpatient imaging center during the re-evaluation data acquisition period between May 2015 and August 2015. No examination had to be excluded. A total of 5 shoulder MRI examinations were shown to have a humeral rotation $\geq 20^\circ$ (Table 1), which accounted for 7.2% of cases. The overall prevalence of internal rotation of the humerus on shoulder MRI was reduced by 30.5% in the post-intervention cohort ($p < 0.001$).

OUTCOMES

During a performance quality review of shoulder MRI performed at our outpatient imaging center, we found that more than one-third of imaging examinations were acquired with internal rotation of the humerus. Improper humeral rotation during shoulder MRI has known associations with the reporting of false positive rotator cuff tears and other misdiagnoses [2, 5–8]. Keeping avoidable diagnostic errors to a minimum should be the goal of every radiologist. As continuous practice quality improvement is a theme mandated by the American Board of Radiology [9], we sought to carry out a PQI project designed to optimize patient positioning for outpatient shoulder MRI.

Patient discomfort is a major reason why many shoulder MRI examinations are performed with the humerus in internal rotation. Successful external rotation of the humerus often poses a challenge for the MR technologist, as patient complaints about positional discomfort should not be ignored. Failure to address patient discomfort commonly leads to unwanted motion artifacts or a request by the patient to terminate the MRI prematurely. MR technologists are often faced with balancing patient comfort while needing to provide appropriate diagnostic images. Challenges for balancing the need to optimize diagnostic

sensitivity in the face of patient discomfort is not uncommon at the shoulder, and is also a factor when acquiring special sequences, such as the abduction external rotation (“ABER”) view [10].

Open communication with MR technologists is imperative when considering a program of performance improvement to optimize patient positioning on shoulder MRI. Educational sessions and on-the-job training are important steps for obtaining sustainable cooperation from MR technologists. Incorporating feedback from MR technologists into the performance improvement plan is also an important step to improve compliance. Overall, a team approach among MR technologists and radiologists is necessary to facilitate a successful PQI intervention.

We engaged the MR technologists at our outpatient imaging center about the importance of avoiding humeral internal rotation on shoulder MR. Together, we created a feasible plan of intervention to facilitate performance improvement. The feedback from MR technologists following the institution of the new standardized shoulder position was positive. Our strategy prioritized patient comfort, while facilitating external rotation of the humerus during shoulder MR. The key for appropriate humeral rotation at the shoulder is external rotation at the elbow and not the forearm. Pronation of the forearm does not affect humeral rotation [6]. This was coupled with elevating the upper arm to the level of the chest with appropriate upper extremity padding.

Overall, the majority of patients were able to tolerate shoulder MRI in external rotation following the PQI intervention, when proactive measures to address patient comfort were implemented. Thus, we were able to reduce the prevalence of internal rotation of the humerus from 37.7 % to 7.2%, a statistically significant difference. We did not achieve complete elimination of humeral internal rotation since a few patients simply could not tolerate external rotation during their shoulder MRI.

Radiology practices should strive to improve the care they provide. PQI interventions can improve the quality of care we deliver and also help to reduce unnecessary health care costs by reducing the need for potential additional follow-up tests. Our PQI project demonstrated that reduction in the prevalence of humeral internal rotation on shoulder MRI was possible with deliberate intervention.

Limitations:

This manuscript describes a PQI project and not a prospective study. The goals of the PQI project were only to document the prevalence of internal rotation of the humerus on shoulder MRI before and after a PQI intervention. No attempt was made to determine if false negative or false positive abnormalities were actually present due to internal rotation of the humerus for our patients. There also was no attempt to correlate MRI findings with clinical history, physical examination or operative findings. The educational level or mental capacity of patients also was not considered during the PQI project.

CONCLUSION

Over one-third of outpatient shoulder MRIs occur with improper internal rotation of the humerus. We were able to reduce the prevalence of humeral internal rotation on shoulder MRI at our outpatient imaging center by 30.5% after the successful implementation of a PQI project intervention. Avoiding internal rotation of the humerus on shoulder MRI should be a goal of radiology practices to reduce potential diagnostic errors.

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Fig 1.

(a) Example of internal rotation of the humerus at the glenohumeral joint. (b) An example of a humerus externally rotated at the glenohumeral joint.

Fig 2. Method used for quantifying humeral rotation at the glenohumeral joint. The degree of humeral rotation is the angle (dotted arrows) formed by a line parallel to the scapular glenoid fossa and a line that bisects the bicipital groove of the humerus at a point equidistant from all curved surfaces of the humeral articular surface.

Table 1.

Prevalence of outpatient shoulder MRI examinations with internal rotation of the humerus ($\geq 20^\circ$) before and after the practice quality improvement intervention

	# of MRI in Internal Rotation	Total # of MRI	Prevalence of MRI with Internal Rotation
Baseline	20	53	37.7 %
Post-Intervention	5	69	7.2 %