Editorial Commentary: Monitoring Tendon and Muscle Recovery After Rotator Cuff Repair Using Diagnostic Ultrasound Demonstrates that Early Repair is Beneficial for Many Patients With Reparable Tears

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Abstract: Rotator cuff repair is performed to effect healing of the enthesis; to restore shoulder comfort, strength, and function; to prevent tear propagation; and to prevent progression of atrophic muscle changes (fatty degeneration, fatty infiltration, and fatty atrophy) that eventually occur. Non-retracted and moderately retracted rotator cuff tears usually heal after repair, and muscle atrophy may recover over time. It follows that early rotator cuff repair is beneficial for many patients with chronic but reparable rotator cuff tears. Diagnostic ultrasound can provide quantitative information about the recovery of both muscle and tendon and represents a viable alternative to magnetic resonance imaging for evaluating healing after rotator cuff repair.

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Rotator cuff repair is performed to restore shoulder comfort, strength, and function, but also to prevent tear propagation and progression of the atrophic muscle changes that eventually occur. These atrophic changes are characterized as fatty degeneration, fatty infiltration, and fatty atrophy and are often used interchangeably.[1] Both muscle atrophy and fatty infiltration are independently associated processes[2] and independent predictors of outcome after rotator cuff repair.[3]

Mechanical unloading of the rotator cuff muscles that occurs with chronic tears has also been shown to increase the pennation angle of muscle fibers.[1,4] As the myotendinous unit retracts, the muscle fibers reorient, and interstitial fat and fibrous tissue gradually occupy the spaces between the reoriented muscle fibers[5], although the muscle fibers themselves do not degenerate.[1] Suprascapular nerve injury has also been implicated in the pathogenesis of atrophic muscle changes that occur with chronic rotator cuff tears. Retracted supraspinatus tears increase tension on the suprascapular nerve at the suprascapular notch,[6,7] and combined supraspinatus and infraspinatus tears may cause suprascapular nerve injury at the spinoglenoid notch.[8] Additionally, suprascapular nerve recovery has been demonstrated following rotator cuff repair.[8]

Despite these benefits of rotator cuff repair, the classic teaching has been that repair does not predictably reverse rotator cuff muscle atrophy or fatty infiltration.[3,9,10,11] Instead, the progression of muscle atrophy can be slowed or stopped in some cases by successful healing following repair.[12,13] Fabbri et al. demonstrated that patients who underwent arthroscopic rotator cuff repair had no muscle atrophy progression, as compared to patients undergoing long-term nonoperative treatment.[12]

However, the irreversibility of the progressive atrophic muscle changes associated with chronic rotator cuff tears has been challenged by several studies that have reported on varying degrees of reversal of muscle atrophy following successful rotator cuff repair.[14-17] A recent study found that preoperative tendon retraction was the most important predictor of improvement in muscle atrophy following repair, although patient age was important as well.[17] Other factors, such as tear acuity, location, and size, and patient factors, such as general health and compliance with postoperative exercise, may also play a role.

The authors report no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

0749-8063/21968/$36.00

https://doi.org/10.1016/j.arthro.2021.07.006

Magnetic resonance imaging (MRI) is the standard-of-care imaging modality for evaluating the rotator cuff myotendinous unit.[18] MRI is used to evaluate tear location, thickness (partial or full), tear size, and degree of retraction. MRI is also used for evaluating muscle quality, including fatty infiltration and atrophy, and for evaluating associated and adjacent soft tissue, cartilage, and bony lesions. The degree of muscle atrophy can be defined by the tangent sign, or by the occupation radio, which is the ratio of the cross-sectional area of the supraspinatus muscle to that of the entire supraspinatus fossa, at a standardized location, typically the most lateral sagittal oblique MRI image, where the scapular spine contacts the scapular body.[1] A recent study has demonstrated good to excellent agreement in rating muscle atrophy and cross-sectional area, but less agreement for fatty infiltration.[18]

Ultrasound is another diagnostic tool for evaluating rotator cuff disorders. Benefits of diagnostic ultrasound include affordability, portability, lack of ionizing radiation, and ease of use. Additionally, ultrasound is a dynamic study that can provide real-time feedback to patients regarding their pathoanatomy.[1] Diagnostic ultrasound has been found to have similar specificity and sensitivity to non-contrast enhanced MRI for both partial and full-thickness rotator cuff tears.[19] Limitations of diagnostic ultrasound are that it is highly operator-dependent and requires substantial experience and technical skill.[1] Ultrasound has typically been used mostly to evaluate rotator cuff tendons rather than their muscles. Additionally, shoulder surgeons lack confidence in the ability of diagnostic ultrasound to quantify rotator cuff muscle atrophy and fatty infiltration, as well as tendon retraction, medial to the acromion.[20]

Recently, several studies have demonstrated the utility of diagnostic ultrasound for evaluating rotator cuff muscle atrophy and fatty infiltration and have concluded that it may be comparable to MRI.[1,19,21,22] Khoury et al. evaluated 45 shoulders in 39 patients and determined that muscle occupation ratios had a correlation of .90 when measured using both MRI and ultrasound.[23] The authors also evaluated fatty infiltration using ultrasound to grade echogenicity as mild or marked and to qualitatively grade muscle pennation pattern as normal, effaced, or absent.[1,23] The authors could distinguish mild from severe fatty infiltration but were unable to distinguish moderate from severe fatty infiltration.[23]

In the study entitled "Diagnostic Ultrasound Shows Reversal of Supraspinatus Muscle Atrophy Following Arthroscopic Rotator Cuff Repair" authors Pagán-Conesa, García-Ortiz, Emilio José Salmerón-Martínez, Moya-Martínez, and López-Prats report on using diagnostic ultrasound to evaluate and quantify supraspinatus muscle atrophy, and to determine whether there is any relationship between supraspinatus repair and eventual recovery of the myotendinous unit.[24] The authors develop and use various quantitative ultrasound-based measures to conclude that atrophic muscle changes can be reversed following supraspinatus repair.[24]

Specifically, the measures comprise the occupation ratio previously described by Thomazeau,[14] a representative histogram of supraspinatus muscle pixilation as a marker of atrophy, a histogram ratio that normalizes pixel distribution to that of the trapezius muscle, echogenicity reduction following repair, muscle pennate pattern, and pennation angle changes following repair. Other studies have reported on echogenicity,[23] but measures such as the histogram and histogram ratio are novel and have not yet been validated. Pennation angle is thought be a marker for fatty infiltration. Some studies have measured changes in pennation angle following repair.[25] However, it remains unclear how often pennation angle can be determined precisely. It is also unclear how often muscle visualization by ultrasound is obscured by acromion shadowing, although this may be less of an issue for the supraspinatus than for the posterior cuff muscles.[26] The authors stress that one advantage of these quantitative measures is that they are obtained in a semiautomated manner that minimizes operator dependency.[24]

The authors demonstrate that Patte II rotator cuff tears,[27] with intermediate retraction to the level of the humeral head, had the greatest improvements after repair, as demonstrated by diagnostic ultrasound. Patte III tears demonstrate less muscle recovery after repair, and Patte I tears typically did not have muscle atrophy preoperatively, so there was little room for improvement. The authors suggest that more timely repairs produced better clinical and ultrasound-based results, irrespective of whether single or double repair was carried out. Conversely, larger more retracted tears demonstrated inferior clinical and ultrasound-based results.

Concerns have been raised that two-dimensional assessment of muscle, such as from a single MRI slice or from diagnostic ultrasound, does not predict muscle volume and is of limited use for quantifying muscle atrophy or fatty infiltration.[28] The rotator cuff muscles are fusiform so that a smaller preoperative muscle cross-sectional area may simply reflect retraction of the myotendinous unit. Consequently, lateralization of the supraspinatus muscle following repair may falsely increase the occupation ratio and change the portion of the muscle being evaluated for fatty infiltration.[1,29]

Some authors have suggested that immediate postoperative imaging should be used as a baseline because this corrects for the effect of myotendinous retraction.[29,30] Jo et al. examined the effect of arthroscopic rotator cuff repair on rotator cuff muscle atrophy at

various time points, including preoperatively, immediately postoperatively, and 1 year postoperatively.[31] They found that rotator cuff muscle atrophy typically improves after arthroscopic repair, but that increased atrophy is seen 1 year postoperatively as compared with immediately postoperatively. Hamano et al. found that muscle atrophy and fatty infiltration improved after rotator cuff repair, but they compared MRI-based measures at 2 years to those at 2 weeks postoperative to eliminate any effects related to medial tendon retraction.[32] Kim et al. compared MRI findings at 6 months following supraspinatus repair to those obtained 1-2 days following MRI and found that the supraspinatus cross-sectional area decreased significantly, whereas the Goutallier stage and Thomazeau grade remained similar.[33]

Additionally, there remains the possibility that some of the intact repairs in the study by Pagán-Conesa et al. may have been retears with continuity,[34] in which the repair is characterized by a distinctive continuity of nontendinous tissue from the footprint to the retracted tendinous portion.[35] This has been described previously using MRI,[34,35] but it is unclear whether these retears with continuity are identified accurately by ultrasound or whether the authors entertained this possible outcome following repair. Previous study has demonstrated that retracted tears are a risk factor for retears with continuity.[36] The myotendinous junction retracts in these retears with continuity, which would obviously influence pennation angle and cross-sectional area measures.

Overall, the authors focused on differences between preoperative and 12 months postoperative ultrasound, but as noted above, the improvements may relate to lateralization of supraspinatus muscle following repair. The authors chose to omit the discussion of the 1-month and 6-month postoperative findings because their statistical analysis did not reveal any differences. I am surprised by their decision because if the authors could demonstrate that muscle atrophy did not progress between 1 month and 12 months, then this would represent an even more important finding and would demonstrate that repair prevents progression of atrophic muscle changes. The authors conceded that they could not measure reproducibly sagittal cross-sectional area by ultrasound, so they could not demonstrate any increase in muscle volume following rotator cuff repair.[24] Using preoperative measures, rather than immediate postoperative measures as the baseline and failing to quantify volumetric muscle changes are the two principal limitations of their study.

Despite these limitations and concerns regarding the use of diagnostic ultrasound for quantifying muscle recovery following rotator cuff repair, the study by Pagán-Conesa et al. reinforces our understanding that early repair of supraspinatus tendon tears that are not severely retracted leads to tendon healing in most cases, substantial clinical improvement, and the potential for some muscle recovery.[24] Additionally, the study extends previous work on using diagnostic ultrasound to evaluate both rotator cuff tendons and muscles. Finally, this study should spawn additional studies into the utility of ultrasound for evaluating muscle atrophy and fatty infiltration and explore ultrasound's potential role as a tool to evaluate biological and other repair strategies that may promote tendon and muscle healing and recovery.

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