Introduction: Tears of the rotator cuff (RC) are often accompanied by muscle atrophy, fatty degeneration and retraction of the RC muscles [1, 2]. Even after successful RC repair, reversing of the muscle is slow or irreversible [3]. The residual pre-operative RC muscle function is an important predictor for successful RC repair and good patient outcome [1, 4]. Magnetic resonance imaging (MRI) is frequently used pre-operatively in patients with RC disorders. Degenerative tendon changes and RC tears can be detected on MRI images with high sensitivity and specificity [5]. However, no reliable and validated method exists to determine the volumes of RC muscles in-situ. The aims of this study were to assess the reliability and validity of MRI at quantifying RC volumes and to develop a simple method to determine the volumes of RC muscles from MRI images clinically.

Methods: The volumes of RC muscles of 10 cadaveric shoulders (6 female, 4 male, mean age 76 years, range 67-82 years) were determined using two techniques: based on MRI images (V_{MRI}) and using a water displacement method after shoulder dissection (V_{wd}). Sagittal T1-weighted spin-echo MRI images were obtained perpendicular to the long axis of the scapula body (repetition time: 650 ms, echo time: 10 ms, image matrix: 512 by 224, slice thickness: 3 mm, spacing 0 mm, field of view: 18 x 18 cm). The cross-sectional areas (CSA) of the supraspinatus muscle (SS), subscapularis muscle (SubS), and the combined infraspinatus and teres minor muscle (IS/TM) were manually contoured on each MRI image and V_{MRI} was calculated using three-dimensional image analysis software (“Alice”, Hayden Image Processing Group, Waltham, MA) (Figure 1).

Results: The average V_{MRI} of the supraspinatus, infraspinatus/teres minor and subscapularis muscles were 36±12, 96±41, and 99±33 cm³, respectively. There was a significant correlation between V_{MRI} and V_{wd} (r_{SS} = 0.99, r_{IS/TM} = 0.99, r_{SubS} = 0.99) for each muscle. The average percent difference between V_{MRI} and V_{wd} was less than 4%. The intra-observer variability was below 3% and the inter-observer variability was below 4%. The Pearson correlation between V_{MRI} and the CSAs for Method 1 was: r_{SS} = 0.96, r_{IS/TM} = 0.94 and r_{SubS} = 0.75. For Method 2, the correlation was: r_{SS} = 0.96, r_{IS/TM} = 0.97, and r_{SubS} = 0.93. The intra- and inter-observer variabilities of Method 1 and 2 were under 4%.

Discussion: The results of our study show that MRI is a reliable and valid method to determine RC muscle volumes with low intra- and inter-observer variability. In previous studies, atrophy of RC muscles was determined based on the CSA from the image at the Y-shaped position [2, 4]. However, it had not been proven that the CSAs at this position were representative of the total muscle volume. We found that Method 1 and Method 2 were highly reliable for quantitative assessment of RC muscle volumes. However, Method 2, which could be easily obtained in clinical practice, is more accurate when compared to Method 1, particularly, when assessing the subscapularis muscle. The higher correlation seen between the CSA and the volume of the subscapularis muscle could be explained by the fact that the greater part of subscapularis muscle belly is located medially of the Y-shaped position. Therefore, its volume is better represented by another more medial image. The results of this study may help in pre-operative assessment of RC muscles for surgical planning and prediction of outcome after RC repairs.

Figure 1: Y-shaped image on an MRI scan of the left shoulder. Rotator cuff muscles were contoured using three-dimensional image analysis software.