



# Measurement of volumetric bone mineral density in proximal humerus using quantitative computed tomography in patients with unilateral rotator cuff tear

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**Background:** The first purpose of this study was to reveal the clinically important region-specific volumetric bone mineral density (vBMD) of the proximal humerus in patients with unilateral rotator cuff tear (RCT), and the second was to evaluate the relationship between vBMD of the proximal humerus and BMD of the hip and lumbar spine measured using conventional dual-energy X-ray absorptiometry. Finally, we assessed whether any clinical factor could predict local osteoporosis of the proximal humerus.

**Methods:** The study enrolled 65 patients who underwent arthroscopic repair of a unilateral RCT between April 2010 and July 2011 and had computed tomography scans of bilateral proximal humeri. Considering the suture bridge technique for RCT repair to be the leading treatment, region-specific BMD was measured in 7 volumetric blocks in the proximal humerus. Image and quantification processing was used to calculate the vBMD of each block.

**Results:** The vBMD values in all 7 blocks of the symptomatic shoulder were significantly lower than those of the asymptomatic contralateral shoulder ( $P < .05$ ). Regardless of RCT, the greater tuberosity showed significant location-dependence in vBMD value; that is, the vBMD value was the highest in the posterolateral portion and the lowest in the medial portions. No significant correlation was found between vBMD of the greater tuberosity and clinical factors except female gender.

**Conclusion:** The present study demonstrated the regional and bilateral differences in vBMD within the greater tuberosity in patients with unilateral RCT. Aside from female gender, no other clinical factors presented as risk factors for a higher possibility of osteoporosis.

**Level of evidence:** Anatomy Study, Imaging.

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Tears of the rotator cuff tendons, which are common in patients aged older than 60 years, often cause shoulder pain and limited shoulder function.<sup>38</sup> These older patients tend to have osteoporosis of the proximal humerus as well as of the lumbar spine or hip. Several biomechanical studies have reported that bone mineral density (BMD) in humeral heads influences the pullout strength of implants and is the most important determining factor for the final fixation strength of inserted implants.<sup>2,25,26,36</sup> Furthermore, BMD was an independent determining factor affecting postoperative rotator cuff healing in a recent report.<sup>6</sup> Other previous data suggest that reduced BMD may compromise the outcome of rotator cuff repair because it influences the holding power of suture anchors<sup>25,38</sup> and causes excessive osteoclastic activity, which could impair bone ingrowth at the tendon-to-bone attachment sites.<sup>6,38</sup> Although the probability of local osteoporosis is expected to be high in the proximal humerus with a torn rotator cuff,<sup>25</sup> no method has been established to predict or evaluate the BMD of the proximal humerus preoperatively.

We therefore used quantitative computed tomography (QCT) to measure the clinically important region-specific volumetric BMD (vBMD) in 3-dimensional (3D) blocks of the proximal humerus in patients with unilateral rotator cuff tear undergoing repair with the suture bridge technique. Other aims of the current study were to assess the clinical factors affecting vBMD of the proximal humerus and to evaluate the relationship between vBMD of the proximal humerus and BMD of the hip and lumbar spine measured using conventional dual-energy X-ray absorptiometry (DXA). We hypothesized that there is a significant difference in vBMD of the proximal humerus between the side with rotator cuff tear and the contralateral side and that there are significant subjective differences in vBMD among different regions of the proximal humerus in patients with unilateral rotator cuff tear. Another hypothesis was that the prediction of local osteoporosis of the proximal humerus could be made using various clinical parameters and BMDs of the hip and lumbar spine measured by conventional DXA.

## Materials and methods

### Patients

The study enrolled 65 patients (28 men, 37 women), with a mean age of  $60.9 \pm 7.2$  years (range, 42-74) years and without any contralateral shoulder pain or disease, who underwent arthroscopic repair of unilateral rotator cuff tear between April 2010 and July 2011 and who had CT scans of the bilateral proximal humeri. All surgical procedures were performed by a single surgeon.

The sample size of 65 patients was obtained by a statistical power analysis, performed with preliminary vBMD data of 10 unilateral rotator cuff tear patients, to find the required number of individuals necessary to claim a significant difference of 10% in vBMD of the greater tuberosity between bilateral shoulders. The power analysis was performed with a statistical power of 80% and a type I error level of 0.05.

**Table I** Size of rotator cuff tear measured intraoperatively

Variable	Mean $\pm$ standard deviation (cm)	Range (cm)
Anteroposterior length	1.9 $\pm$ 1.1	0.5-5.0
Length of retraction	1.8 $\pm$ 0.9	0.5-4.7

**Table II** Patients categorized according to tear size (anteroposterior length and length of retraction)

Tear category	Patients
	No. (%)
Small, <1 cm	15 (23.1)
Medium, 1-3 cm	33 (50.8)
Large, 3-5 cm	4 (6.2)
Massive, >5 cm (or $\geq 2$ entire tendons involved)	13 (20.0)

### Evaluation of clinical parameters

Clinical parameters, such as the size of the rotator cuff tear measured during arthroscopy (Tables I and II), age, sex, arm dominance, symptom duration, smoking, shoulder stiffness, level of sports activity, and work demand, were collected (Table III). We defined shoulder stiffness as passive forward elevation of less than 120°, passive external rotation of less than 30°, and passive internal rotation at the back as lower than the third lumbar vertebra. The level of sports activity and the work demand were recorded as high, medium, or low.<sup>32</sup>

The areal BMD (aBMD) was measured at the last outpatient visit before the operation using the Lunar Prodigy enCORE 8.8 DXA scanner (GE Medical Systems, Milwaukee, WI, USA). The aBMDs of the proximal femur and lumbar spine, except for the Ward's area of the proximal femur, were recorded.<sup>1,6</sup> Among the BMD values measured at several locations in the hip or lumbar joints, we used the lowest BMD value in each joint for the correlation analysis.

The fatty infiltration of each rotator cuff muscle was evaluated according to the criteria established by Goutallier et al<sup>14</sup> using preoperative magnetic resonance imaging. This criteria, originally described for CT, was applied to the magnetic resonance images in the present study with reference to the studies of several researchers, including Fuchs et al.<sup>4,9,13,41</sup> The global fatty degeneration index was used for statistical analysis as an index of fatty degeneration grading.<sup>15</sup>

We measured strength of the rotator cuff muscles with the isokinetic muscle performance test preoperatively. We measured the isokinetic strength (peak torque [PT] and total work [TW]), deficit in abduction, external rotation, and internal rotation at a 60° per second load using the Biodex System 3 PRO (Biodex Corp, Shirley, NY, USA). Assuming the contralateral side was normal, we then computed a percentage of these values compared with the contralateral shoulder for each patient. We used the isokinetic strength (PT and TW) deficit in abduction for statistical analysis. The data of 36 patients were available for this analysis because 29 patients could not perform the test due to severe pain or

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