Trabecular microstructure and surface changes in the greater tuberosity in rotator cuff tears

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Abstract Objective: When planning surgery in patients with rotator cuff tear, strength of bone at the tendon insertion and trabecular bone structure in the greater tuberosity are usually taken into consideration. We investigated radiographic changes in bone structure of the greater tuberosity in rotator cuff tears. Design: Twenty-two human cadaveric shoulders from subjects ranging from 55 to 75 years of age were obtained. The integrity of the rotator cuff was examined by sonography to determine if it is intact without any tear, or torn partially or completely. The humeral head was sectioned in 3 mm thick coronal slab sections and microradiographed. After digitization of the microradiographs and imaging processing with in-house semi-automated image processing software tools developed using software interfaces on a Sun workstation, the trabecular histomorphometrical structural parameters and connectivity in the greater tuberosity were quantified. The degenerative changes on the surface of the greater tuberosity were interpreted blindly by 2 independent readers. Results: Among the 22 shoulder specimens, the rotator cuff was found intact in 10 shoulders, partially in 7 and fully torn in 5. Statistically significant loss in apparent trabecular bone volume fraction, number of trabecular nodes, and number of trabecular branches, and a statistically significant increase in apparent trabecular separation and number of trabecular free ends were found in the greater tuberosity of the shoulders with tears. The loss was greater in association with full tear than in partial tear. Thickening of the cortical margin of the enthesis, irregularity of its surface, and calcification beyond the tidemark were observed in 2 (20%) shoulders with intact rotator cuff, in 6 (86%) shoulders with partial tear, and in 5 (100%) shoulders with full tear. Conclusions: Rotator cuff tears are associated with degenerative changes on the bone surface and with disuse osteopenia of the greater tuberosity. Aging, degenerative enthesopathy of the supraspinatus tendon, and rotator cuff tears appear closely related.

Keywords Trabecular microstructure · Osteoporosis · Degenerative changes · Image processing

Introduction

Rotator cuff tears and tendinopathies are common disorders. The radiologic assessment of the status of the rotator cuff per se has been well explored by arthrography, CT arthrography, ultrasound, MRI, and MRI arthrography [1, 2, 3, 4]. Conventional radiography is usually negative even in cases of torn rotor cuff. Especially acute rotator cuff tears can hardly be diagnosed. The earliest radiographic finding is a slight prominence on the great-
er tuberosity at the point of insertion of the supraspinatus tendon [33]. In long-standing cases, radiologic changes include narrowing of the acromiohumeral interval, erosion of the anterior acromion, ascent of the humeral head in relation to the glenoid, and degenerative changes at the humeral head, the tuberosities, the acromion, the acromioclavicular joint, and glenohumeral joint [5, 6, 7, 8, 9, 10, 11, 12]. Narrowing of joint space indicates cuff-tear arthropathy [8, 14].

In the management of patients with rotator cuff tear, the significance of the bony status at the tendon insertion and in the greater tuberosity has been well recognized [13, 14]. For example, the long-term success of the titanium anchors for the repair of rotator cuff tears is considered to depend on both the preoperative condition of the rotator cuff and on the bone quality [15, 16]. However, the trabecular structure in the greater tuberosity and the bony structure in proximity to the insertion of the supraspinatus tendon have not well been well characterized in relation to rotator cuff disease. We therefore analyzed the trabecular bone microstructure of the greater tuberosity quantitatively using microradiography and imaging processing technique, and evaluated the changes at the insertion of the supraspinatus.

### Materials and methods

#### Specimens and microradiography

Twenty-two unembalmed human cadaveric shoulder specimens from subjects 55–75 years old, half male and half female, were obtained. Specimens with any signs of arthritis, such as cystic changes as focal lucent defects with sharply defined margins in the greater tuberosity on radiograph and slab microradiograph were excluded. We also excluded specimens with generalized osteoporosis showing as decreased cortical thickness or increased cortical porosity on radiographs of the humerus were also excluded. The integrity of the rotator cuff, i.e., intact, partially torn, and completely torn, was carefully examined by sonography [4, 27].

Subsequent to anatomic dissection of the rotator cuff, the humeral head was sectioned into coronal sections of 3 mm thickness using a diamond saw under continuous water cooling and mounted in a clamp to assure consistent thickness and parallel surfaces (EXAKT System, Norderstedt, Germany) and to avoid morphological changes due to overheating.

Six-fold magnified radiographs were taken on fine-grain industrial film (Ready Pack, Kodak, Rochester, NY) without screens, using 50 kVp, 0.11 mA, 600 s. X-rays were produced using a Feinfocus model 160 x-ray source that utilized electromagnetic focusing of the electron beam. Focus spot sizes of 5 µm diameter are routinely achieved. The changes on the surface of the greater tuberosity were interpreted blindly by two readers independently, without knowledge of the integrity of the rotator cuff.

#### Imaging processing for trabecular bone segmentation and quantification

Microradiographs of the central section of the greater tuberosity were digitized with a laser film digitizer (Lumiscan 200, Lumisys,