Elastic Modulus of the Human Supraspinatus Tendon Insertion with Age-related Degeneration

INTRODUCTION

Rotator cuff tearing is most frequently observed in the supraspinatus tendon, especially in its articular side of the insertion. Intrinsic degeneration of the tendon has been believed as one of the most important pathogenetic factors of the tendon tearing (1). Among four histologic zones constituting tendon insertion, non-mineralized fibrocartilage shows the lowest elastic modulus in the normal rabbits (2). However, to date, the material properties of the supraspinatus tendon insertion in the human specimens with age-related degeneration have not been clarified yet.

Scanning acoustic microscopy (SAM) was developed to visualize opaque materials and to measure their tissue acoustic properties at a microscopic level. In SAM measurement, the sound speed (c) is defined as the following equation:

\[ c = \frac{E(1-\nu)}{\rho(1+\nu)(1-2\nu)} \]

where E is the Young’s modulus, \( \rho \) is the tissue density and \( \nu \) is the Poisson’s ratio. This equation indicates that the tissue sound speed measured with the SAM is directly proportional to the square value of its Young’s modulus.

Based on these facts, we measured the tissue sound speed of the human supraspinatus tendon insertion using SAM in order to clarify 1) the material properties of the 4 zones and 2) their age-related changes.

METHODS:

Thirty-one supraspinatus insertions harvested from 16 cadavers were used for the current study. There were 13 males and 3 females and their average age was 63 (range: 39-83). All specimens were fixed in 10% neutralized formalin for one week. After decalcified with ethylene-diamine-tetra-acetic acid, the specimens were embedded in paraffin, and then cut longitudinally in the direction of the tendon fibers at 5-μm thickness. Serial sections at the midportion of the supraspinatus tendon at its insertion were made for the comparison of the SAM measurement to the histologic and immunohistochemical staining.

SAM measurements:

A specially developed SAM system, operating in the frequency range of 100-200MHz was employed for this study. The sections for SAM measurements were mounted on the glass slides without being covered by the cover slips. The paraffin was removed from the sections with xylene followed by the graded alcohol method. Measurements were done with SAM in the articular side of the tendon insertion, since the histologic degenerative changes were the most evident in this side. The data of the sound speed obtained were converted into color signals on the computer. A two-dimensional distribution of the tissue sound speed was displayed and saved as an image file using color-coded scales.

Histologic assessments:

Azan staining was routinely employed to assess the overall histologic structure. Immunohistochemical staining for type II collagen was also performed to confirm the area of fibrocartilage at the insertion site. Avidin-biotinylated peroxidase complex method was employed using the monoclonal antibodies against type II collagen (anti-hCL(II), purified IgG, FUJI Chemical Industries Ltd., Japan). For each specimen, the fiber integrity of the supraspinatus tendon insertion and the presence of crater formation were graded to assess the degree of histologic degeneration at this site (score of regressive changes) (3).

RESULTS:

Histologically, most of the specimens represented microtear of tendon fibers as well as the crater formation (Figure 1-a). The mean score of regressive changes was 2.0 (standard deviation: 1.0). SAM measurements showed that the tissue sound speed gradually decreased from bone to tendon proper (Figure 2). It was interesting to note that non-mineralized fibrocartilage showed relatively higher sound speed than tendon proper.

No significant correlation was seen between the age and the tissue sound speed. On the other hand, a positive correlation existed between the tissue sound speed of tendon proper and the score of regressive changes (\( r=0.44 \), Figure 3).

DISCUSSION:

Different from the rabbits, human shoulders demonstrated that the sound speed of the non-mineralized fibrocartilage was relatively higher than that of the tendon proper. The elastic modulus might have increased in the non-mineralized fibrocartilage in human cadaveric shoulders with age-related degeneration, or this might otherwise be the normal finding in normal human shoulders. In the tendon proper, tissue sound speed showed a positive correlation with the score of regressive changes. In other words, tissue elasticity of the supraspinatus tendon proper increased with the progression of its histologic degeneration.

REFERENCES: