MAGNETIC RESONANCE IMAGING-BASED MEASUREMENT OF 6-DEGREE-OF-FREEDOM RELATIVE MOVEMENT SCAPULA AND THORAX

Yasuo Nakamura\(^1\), Shinya Kiryu\(^2\), Mari Nakamura\(^3\), Toyohiko Hayashi\(^1\), Toshinori Kondo\(^3\) and Katsuya Nobuhara\(^3\)

\(^1\)Department of Biocybernetics, Faculty of Engineering, Niigata University, Niigata, Japan
2-8050 Ikarashi, Niigata 950-2181, JAPAN; E-mail: nakamura@bc.niigata-u.ac.jp
\(^2\)Graduate School of Science and Technology, Niigata University, Niigata, Japan
\(^3\)Nobuhara Hospital and Institute of Biomechanics, Hyogo, Japan

INTRODUCTION

The shoulder joint has numerous intricately-interlocking parts. Especially, glenohumeral joint, which consists of the head of humerus and the glenoid of scapula, is susceptible to injury from sports-related stresses and strains. To diagnose this injury, orthopedists need to evaluate the glenohumeral joint movements. The previous reports estimated the scapula movements indirectly using magnetic sensor (Meskers, 1998) or camera system. However, it was difficult to measure the scapula movements accurately, due to the influence of skin mobility. Using X-ray CT or MR devices, the three dimensional geometries of bone or soft tissue were obtained directly. However, these devices restrict the posture of shoulder joint that can be measured. To achieve \textit{in-vivo} measurement of various postures of the shoulder joint, an open MRI has been employed. However, there are few reports which evaluated the 6 D.O.F. postures of the shoulder using the bony shape reconstructed from open MRI images. The purpose of this study is to estimate the postural change of the scapula relative to thorax in 6 D.O.F., during humeral elevation on scapula plane.

METHODS

We employed an open MRI (Magnetom Open, Siemens, Germany) to measure the postural change of the shoulder joint (Figure 1). The MR device needs a certain time to obtain a 3-D image of the whole shoulder joint and thorax. A subject feels uncomfortable to keep the same posture for a long time. To reduce the measurement time, we measured the only glenohumeral joint part that included humeral head and part of scapula. To determine the position and orientation of the thorax, we used a thorax marker (length 65mm, width 35mm, thickness 3mm), which was able to be imaged by a MR device. The thorax marker was made from an acrylic plate and tubular markers (Gel marker, ALCARE Co., Ltd., Japan). The tubular markers were attached at four edge of the acrylic plate. We attached this marker on the subject’s thorax near the glenohumeral joint by the jig (Figure 2). The subjects laid themselves at prone position on the jig during the measurements.

Three volunteers (2 males and 1 female: 24.3±1.9 years old), who possessed no distinct kinetic dysfunctions in their shoulders, served as subjects in this preliminary study. Their shoulder movements were sampled at five humeral elevation angles (30°, 60°, 90°, 120°, 150°) on scapula plane by obtaining the sagittal MR images of the left shoulder. We acquired the 96 slice images of shoulder joint with 1.56mm slice thickness. The contour of scapula, humerus and marker were reconstructed from all MR images (Figure 3). We defined the coordinate systems of the thorax marker, humerus and scapula using marker shape and bony landmarks (Figures 3, 4a, 4b). The position and orientation of scapula and humerus were estimated using the registration technique (Besl, 1992). The scapula orientation was described using Euler angles (Veeger, 1993) relative to thorax marker.

RESULTS

Figure 5 shows the humerus orientations relative to the thorax marker at each humerus elevations on scapula plane. Figure 1: The measurement of the shoulder joint using the open MRI.

Figure 2: The jig mounted on the table of the open MR system. The thorax marker was attached on this jig.

Figure 3: The reconstructed scapula, humerus and marker at 30° and 120° humeral elevations.
for three subjects. The horizontal adduction of the humeral was about 30° for all subjects, during humeral elevation (Figure 5). This result shows that the subjects elevated their humerus on the scapula plane.

Figure 6 and 7 show the scapula translations and orientations for three subjects, respectively. The scapula shifted a little during the humeral elevation from 30° to 90°. During the humeral elevation from 90° to 120°, the scapula shifted large to superior, medial and posterior direction. As the humeral elevation angle increased along scapula plane, the orientation of the scapula changed from forward tilt to backward tilt, and the scapula rotated to lateral rotation direction.

DISCUSSION

During the measurements, the subject needed to keep a same posture. It took 13 minutes and 17 seconds to measure each humeral elevation in this study. In order to prevent thorax mobility during the measurements, we employed the jig. And also, in order to measure the glenohumeral joint in detail, we measured only the humeral head and glenoid periphery. We did not measure the whole thorax in this study. Therefore, to determine the thorax position and orientation in the MR images, we employed the thorax marker (Figure 2). Using a set of the jig and the marker, we succeeded to assess the scapula postures related to the thorax.

Next, we describe the postural change of the scapula in this study. When we measured the scapula using the open MRI, the subjects kept prone position on the table of MR device. Numerous previous reports employed the standing position to investigate the scapula movements. Therefore, the amount of the scapula rotation in this study was different from previous report (Fung, 2001). We think that this reason was the relaxation of the muscles, due to the prone position during measurements. However, the backward tilt and lateral rotation of scapula, in this instance, tended to agree with previous report.

In conclusion, we developed the innovative method to measure the postural change of the shoulder joint in 6 D.O.F. using an open MRI. The results showed that our method has a capability to evaluate the in-vivo shoulder joint static movement quantitatively. In a subsequent study, we will increase the number of subjects, and verify the accuracy of estimated position and orientation of the scapula.

ACKNOWLEDGEMENT

We would like to express our thanks to the Mr. Atsushi Nawata and ALCARE CO., Ltd. for their support.

REFERENCES