New Technique of Making 3D Cuff Tear Image using MRI - Clinical Diagnostic Utility and Precision of 3D Cuff Tear Images

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Abstract
It is difficult to evaluate the accurate shape and size of rotator cuff tear using common methods of sagittal, coronal and transverse images of MRI. We created the special software for constructing 3D MRI image of rotator cuff tear. The purpose of this study was to evaluate the utility of the 3D-MRI for diagnosing the shape and size of rotator cuff tear before operation.

18 patients (mean, 67.8 years) were underwent non-contrast MRI before arthroscopic rotator cuff repair (ARCR). Slices were made in oblique coronal, oblique sagittal, and transversal orientation. The sequences for 3D-cuff tear image were T2-weighted imaging. We constructed 3D MRI image of rotator cuff tear using our software. On the other hand, anterior-posterior and medial-lateral diameters were directly evaluated by using a measurement probe during ARCR. The shape and size of rotator cuff tear were evaluated.

All intraoperative findings showed the shapes which were similar to those of the 3D-MRI findings. 86.7% cases in this study had the same size between pre-operative 3D MRI images and intra-operative measuring images. The results of this study suggested that the measurements using 3D-MRI before operation was very close to actual rotator cuff tear. The quality and utility of this method overwhelm those of past ones, and further development can be expected in diagnosis for rotator cuff tear.

Keywords: 3D image; Rotator Cuff Tear; MRI-aided diagnosis; Software; Arthroscopy

Core Tip
The purpose of this study was to evaluate the utility of the 3D-MRI for diagnosing the shape and size of rotator cuff tear before operation. The quality and utility of this method overwhelm those of past ones, and further development can be expected in diagnosis for rotator cuff tear.

Introduction
Recently, ultrasonography is being used for the diagnosis of rotator cuff tear; however, the diagnostic precision of ultrasonography for rotator cuff tear is questionable. Sonographers with less experience may be less accurate [1].

According to the proper diagnosis rate, MRI is indispensable in diagnosing rotator cuff tears [2,3].

Patte (1990) classified rotator cuff tears into large, middle-sized and small tears [4]. It is possible to measure the size of rotator cuff tear in a normal two-dimensional (2D) MRI slice. However, as for the three-dimensional form of the tear, a detailed evaluation of cuff tear form is difficult with only coronal, sagittal and axial section on MRI. Although it is important to recognize the tear form for planning the operation before arthroscopic rotator cuff repair (ARCR), studies about the three-dimensional form of the rotator cuff tear are insufficient.

LeGars (1997) and Sashi (2000) attempted to create three-dimensional images of rotator cuff tears; however, there has been no study on the clinical application. The previous reports were cadaver studies that used MR arthrography [5,6].

Physical findings are examined in patients with shoulder pain by means of medical interviews. A diagnosis is made based on consideration of physical and image findings and a treatment strategy is determined. Image diagnosis is vital to determining...
the treatment strategy. XP and MRI are often used for image diagnosis of rotator cuff tears, but neither method can provide three-dimensional images. Emphasis has recently been placed on preoperative planning using three-dimensional (3D) images, such as those from 3D templates of artificial joints and patient-specific instruments (PSIs). Three-dimensional images are clearly also useful in preoperative planning for ARCR.

So we made 3D images of rotator cuff tear by using a 3D image construction software preoperatively. The purpose of this paper is to check the consistency between 3D image of rotator cuff tear and the arthroscope findings.

**Research and Literature**

We made 3D images of rotator cuff tear by using a 3D image construction software (ZedView; LEXI Co., Ltd., Tokyo, Japan) preoperatively, and considered the operative plan. We create a special version of software by adding an automatic alignment function. This software was not expensive and economical. It took about twenty minutes for making a 3D image using this software.

For making 3D image, slices were made in oblique coronal, oblique sagittal, and axillar orientation. DICOM data of T2-weighted image (T2WI) from 1.5-T MRI (no direct and indirect enhancement, no fat suppression) is imported into this software.

First, we created a 3D humerus image with an axillar view. (This software can extract only similarly shaded parts from shading on images. If shaded parts similar to the area surrounding the humerus remain, these can be manually erased to produce an image from which only the humerus is extracted.) The humerus was extracted in all slices referring to the region of interest (ROI) of a humeral intensity level (Figure 1a). (Coordinate axis data are written into the ROI of the humerus on all extracted slices.) Therefore it is possible to build 3D humerus image automatically [1].

Second, we set the ROI of the rotator cuff similar to that of the humerus by using a sagittal image, and constructed the 3D image of the rotator cuff automatically (Figure 1b).

Finally, the 3D images of humerus and rotator cuff, which were rendered mentioned above, were created and arranged in the anatomical position on top of the same screen (Figure 2a, b & c).

A total of 18 patients with rotator cuff tears were operated (9 men, 9 women; average age 67.8 years; right side 9 cases, left side 9 cases) from 2016 October to December. All cases were treated conservatively (medication, injection, physical therapy and rehabilitation) over three months, after that arthroscopic surgery were selected in all cases for rotator cuff repair. In accordance with the objectives of this paper, the accuracy of 3D images generated by this method was examined. First, the degree of consistency between values measured from 3D images and actual measured values from arthroscopy was examined. In the 3D MRI findings, the anterior-posterior (AP) and medial-lateral (ML) diameters of the rotator cuff tear were measured by using this software. The maximum values measured on 3D images were taken as the measured values.

On the other hand, AP and ML diameters were directly evaluated by using a measurement probe during ARCR.
(Figure 3). The measured values were the maximum values measured by placing a probe on the tear while directly viewing the tear under arthroscopy. We compared the two values (MRI findings and arthroscopic findings). To remove inter-observer bias, the only one operator measured the tear diameter in a 5-mm unit by using a measure probe in all cases. Among all 18 patients, the accuracy of tear diameter was most consistent when the difference between values measured from 3D images and the actual values measured from arthroscopic surgery was less than 5 mm.

Cases in the present study where either the AP or ML value showed an error of 5 mm or more were deemed inconsistent. Sixteen of the 18 cases were therefore consistent. The concordance rate of measured values between 3D MRI and arthroscopic was the same (88.9%) [2]. Actually it was hard to distinguish rotator cuff and brusa in the arthroscopy. Intensity of brusa, however, was delicately different from that of rotator cuff in the MRI. We performed ROI setting using this difference. It was impossible to detect them completely. This might show that the accuracy was not 100% (Table 1).

The form of the rotator cuff tears was classified as crescent shaped, U-shaped, V-shaped, L-shaped and others. The form was classified using 3D images and arthroscopic findings of each patient on an anonymous basis by a shoulder joint specialist other than the surgeon. The concordance rate was set as the accuracy.

There was no difference in the form of cuff tear between 3D MRI findings and arthroscopic findings (accuracy; 100%) (Table 2). It is difficult to evaluate the shape and size of rotator cuff tears accurately by using the common method of evaluation with sagittal, coronal, and transverse MRI images.

**Conclusion**

As a result, we made a special software for reconstructing 3D MRI images of rotator cuff tears. The preoperative simulation is usually carried out in surgery (brain surgery and other surgeries). In the orthopedics, computer simulation is performed in artificial joint operations [7,8].

Arthroscopic surgical repair of the rotator cuff became mainstream after 1911, when ARCR was first reported by Codman [9]. Currently, no evaluation with 3D MRI is carried out before ARCR, although it is important perform preoperative simulation in arthroscopic surgery.

The advantages of this method are as follows; 1) the procedure is not invasive and MR arthrography is not required. 2) Normal DICOM date and normal T2WI images are available for this 3D reconstruction method. 3) Creating 3D images of cuff tears by using this software does not require special technical capabilities.

The precision of the image that we created is important. This method nonetheless has potential issues. These include the fact that not all image processing can be performed automatically, and while the software is cheap and simple, processing cannot be performed without the software.

In this method, the accuracy of the evaluated cuff tear form was 100% and that of the cuff tear size was 86.7%. Therefore, this method is suitable for clinical application.

For preoperative planning and postoperative evaluation, 3D images of cuff tears are useful because they enable describing the cuff tear form in detail.

We believe that creating 3D images of cuff tears allows the exact depiction of the tear form, and will help in preoperative planning and postoperative clinical evaluations in the future.

**References**


