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Effect of Patient's Positioning on the Grade of Tendinosis and Visible Range of Infraspinatus Tendon on Ultrasound

초음파 영상에서 극하근 힘줄병의 단계와 관찰가능 범위에 환자의 자세가 미치는 영향

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Purpose To investigate the effect of patient positioning on tendinosis grade, visible range, and infraspinatus tendon (IST) thickness, and to determine the feasibility of internal rotation (IR) position to assess IST on ultrasound (US).

Materials and Methods This study included 52 shoulders of 48 subjects who were evaluated for IST in three different positions: neutral position (N), IR, and position with the ipsilateral hand on the contralateral shoulder (HC). Two radiologists retrospectively graded IST tendinosis from grade 0 to grade 3 and the visible range from grade 1 to grade 4. The thickness of the IST was measured by another radiologist with a short-axis view. A generalized estimating equation was used for statistical analysis.

Results The tendinosis grades were higher in the HC position than in the IR position, with a cumulative odds ratio of 2.087 (p = 0.004, 95% confidence interval [CI]: 1.268–3.433). The tendinosis grades in the HC position (p = 0.370) and IR position (p = 0.146) were not significantly different from those in the N position. The overall difference in IST thickness was significant (p < 0.001), but the visible range

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(p = 0.530) was not significantly different according to position.
Conclusion Patient positioning significantly affected the grade of tendinosis and thickness but not the visible range of the IST. The IR position is a feasible position for assessing the IST on US.

Index terms Rotator Cuff; Infraspinatus; Ultrasound; Tendinopathy; Methods

INTRODUCTION

Ultrasound (US) is a preferred imaging modality to evaluate shoulder pain because of high accuracy, easy accessibility, low cost and ability of dynamic real-time assessment (1, 2). However, the accuracy of US can be affected by the experience of the examiner and the patient's positions (3, 4). For example, the top two preferred positions to evaluate supraspinatus tendon are the Crass position and the modified Crass position (5, 6). But when the supraspinatus tendon tear is evaluated in the modified Crass position, the longitudinal extent of the tear can be overestimated because of over-stretching of the tendon (4). Various other positions were introduced and studied for the evaluation of supraspinatus tendon (7, 8), yet the position for infraspinatus tendon (IST) was rarely studied (9).

Currently, the main two recommended positions to evaluate the IST are neutral (N) position with the hand on the ipsilateral thigh and the position with the ipsilateral hand on the contralateral shoulder (HC) (5, 6, 10). However, in our experience, IST appear much thicker on US in the HC position which gives an impression of more severe tendinosis when compared to the tendons in N position. Also, there were some patients who had very limited sonic window for the IST in N position because the significant proportion of the tendon were covered by the acromion. So, the authors utilized an internal rotation (IR) position which may not exaggerate the tendinosis but could bring out the IST to get sufficient sonic window.

Therefore, the purpose of this study was to retrospectively investigate the effect of patient positioning on the grade of tendinosis, visible range of IST, and thereby to know the feasibility of IR position to assess IST on US.

MATERIALS AND METHODS

STUDY POPULATION

The subjects of this study were searched retrospectively from the patients who had shoulder pain and underwent shoulder US in SMG-SNU Boramae Medical Center from December 2017 to May 2018. Among them, the patients examined by a musculoskeletal radiologist (with 16 years of experience) who evaluated IST in all three positions as a routine protocol were selected. The patients with tendon tear or the history of shoulder surgery were excluded because of the difficulty of reliable measurement of the tendon thickness.

This study was approved by the Institutional Review Board of SMG-SNU Boramae Medical Center, and the requirement of informed consent was waived because of the retrospective design (IRB No. 30-2019-6).

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US EXAMINATION

All subjects underwent shoulder US using a 4–14 MHz linear array transducer (PLT-1005BT, Aplio 500; Canon Medical Systems, Otawara, Japan). The patients were asked to make the three different positions to evaluate IST. The three positions were N, IR, and HC positions as shown in Fig. 1. For N position, the patient was seated with his arm adducted, elbow flexed 90°, and the supinated hand resting on the ipsilateral thigh. For IR position, the patient was seated with his arm adducted, shoulder internally rotated, elbow flexed 90°, and his palm on the contralateral elbow. For HC position, the patient was seated with their shoulder internally rotated, and the palm on the contralateral shoulder (Fig. 1). The probe was placed on the IST to visualize its footprint and the main tendon in an appropriate angle that minimizes the anisotropy artifact. The greyscale US images of IST were routinely captured in both long and short axis views for each position, with an angle in which the tendon appeared the most hyperechoic, at the location where the tendon appeared thickest including the conjoined portion.

US IMAGE ANALYSIS

The long and the short axis images captured in the same position were simultaneously assessed in a set. A single patient had total three sets of US images, which were obtained in N, IR and HC position, respectively. Two musculoskeletal radiologists (8 years and 10 years of experience), who were blinded to the patient's information including position, evaluated randomly arranged US image sets of all subjects.

Two readers assigned the grade of tendinosis based on a subjective estimation of tendon thickness and the proportion of low echoic area in the visible range of the tendon on both long and short axis images (11-13). Grades of tendinosis were assigned as follows (Fig. 2); Grade 0 = normal thickness and normal echogenicity of the tendon (Fig. 2A, B), Grade 1 = mild tendon thickening and hypoechoic area occupying up to 25% of the visible tendon (Fig. 2C, D), Grade 2 = moderate tendon thickening with hypoechoic area occupying over 25% and up to 75% of the tendon (Fig. 2E, F), Grade 3 = severe tendon thickening with hypoechoic area occupying more than 75% of the tendon (Fig. 2G, H).

The visible range of the tendon were evaluated on the long axis view and graded as follows

Fig. 1. The three positions used to evaluate infraspinatus tendon on US are provided in the schematic drawings.

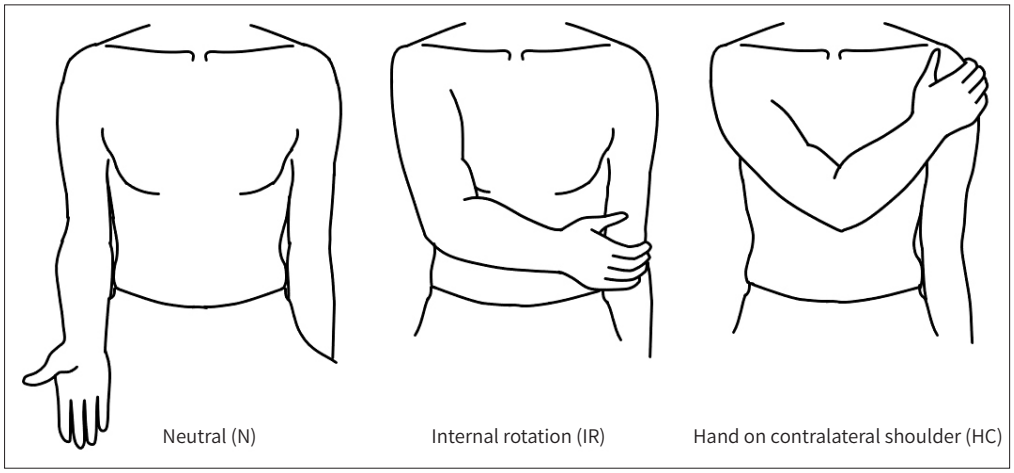

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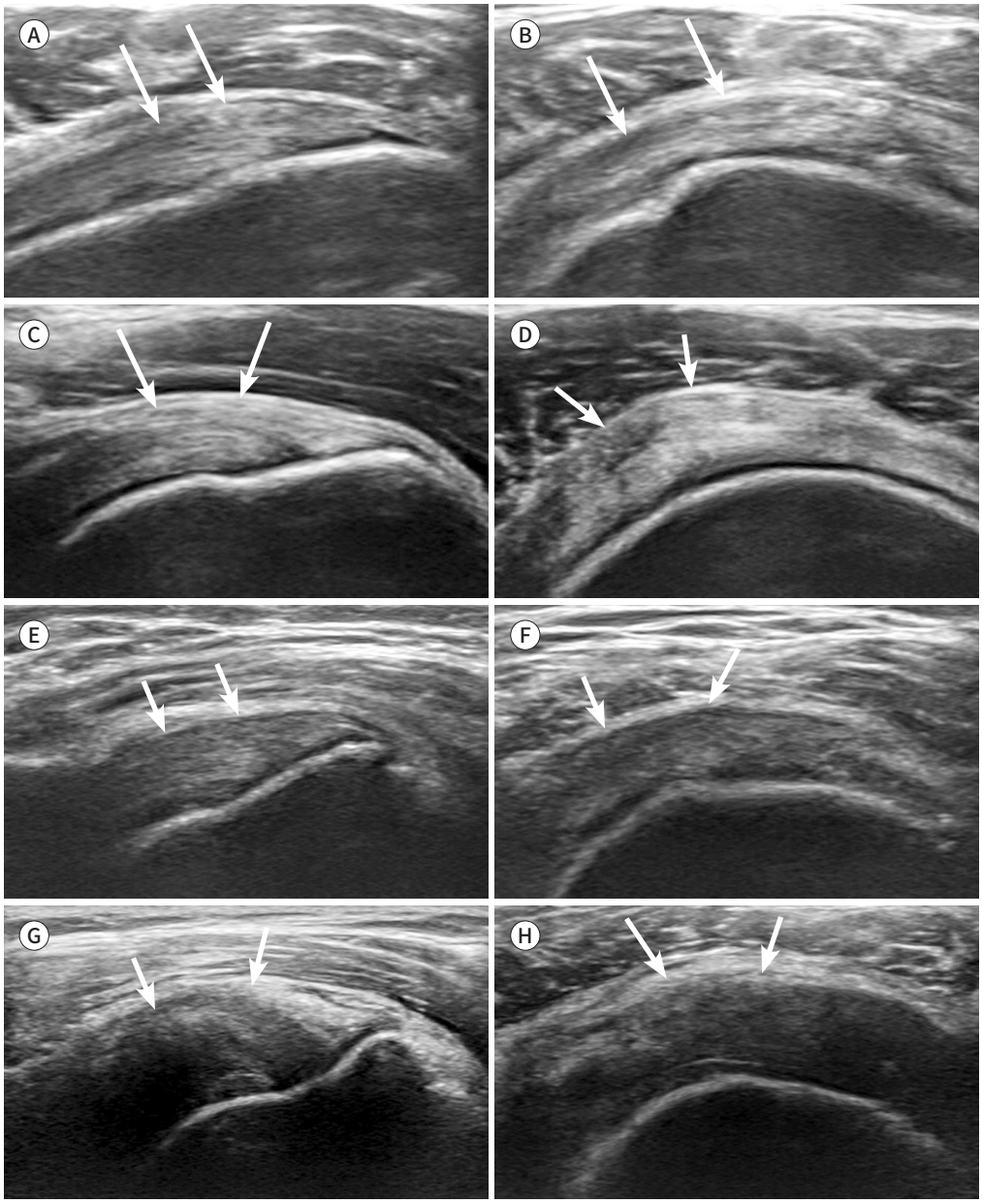
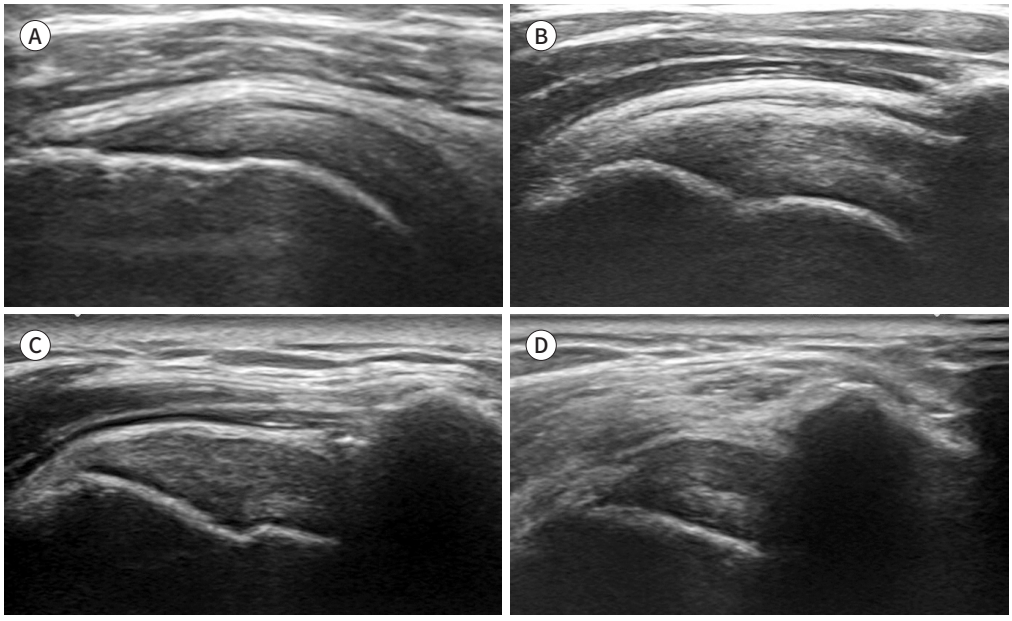
Fig. 2. The representative images of the long and short axes of each grade of tendinosis.
A-H. Tendons (arrows) showing normal thickness and normal echogenicity is considered Grade 0 (A, B). Grade 1 is diagnosed when the tendon (arrows) shows mild thickening and the area of reduced echogenicity occupies up to 25% of the tendon (C, D). Grade 2 is assigned when the tendon (arrows) shows moderate thickening and the area of decreased echogenicity occupies 25%–75% of the tendon (E, F). Grade 3 is diagnosed when there is severe tendon (arrows) thickening and the area of decreased echogenicity occupies > 75% of the tendon (G, H).



(Fig. 3); Grade 1 = tendon is visible beyond the rotator crescent (Fig. 3A), Grade 2 = more than half of the crescent is visible but not beyond the crescent (Fig. 3B), Grade 3 = less than half of the crescent and footprint is visible (Fig. 3C), Grade 4 = only footprint is visible (Fig. 3D).

In cases of disagreement between the two readers, they reviewed the images again and the final grade was assigned in consensus. The grade of tendinosis and visible range of the tendon

Fig. 3. The representative images of the visible range of the tendon are provided.
A. The tendon showing its footprint, crescent, and beyond is considered Grade 1.
B. Grade 2 is assigned when the tendon is visible in more than half of the crescent, but not beyond the crescent.
C. Grade 3 is assigned when the tendon is showing its footprint and less than half of the crescent.
D. Grade 4 is assigned when the tendon shows only its footprint.



was re-evaluated by the two radiologists after 2 weeks to assess intra-observer agreement.

For an objective assessment, another musculoskeletal radiologist (5 years of experience) who was also blinded to the patient's position measured the thickness of IST at the thickest part on the short axis image.

STATISTICAL ANALYSIS

The statistical analysis was performed using SPSS version 20 (IBM Corp., Armonk, NY, USA) and a *p*-value of less than 0.05 was considered to be statistically significant. Cohen's kappa statistic was used to assess inter/intra-observer agreement for each gradings. Cohen's kappa results were interpreted as follows: values $\leq$ 0 as indicating no agreement, 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement. Weighted kappa statistics between positions were compared using bootstrapping resampling method with 10000 replicates.

Generalized estimating equation was used for the univariable analysis to know the effects of patient's position, sex, age and dominancy on the grade of tendinosis, visible range, and the thickness of the IST. And the meaningful variables in the univariable analysis were included in the multivariable analysis.

RESULT

DEMOGRAPHICS

There were 25 male (mean age, 58.2 years; range, 23 to 71 years) and 23 female (mean age,

Table 1. The Agreement for the Grade of Tendinosis and Visible Range of Tendon in the Weighted Kappa Values with 95% Confidence Interval according to the Positions

	Inter-Observer Agreement	Intra-Observer Agreement	
		Reader 1	Reader 2
Grade of tendinosis			
Overall	0.716 (0.645–0.786)	0.838 (0.779–0.895)	0.669 (0.597–0.739)
Neutral	0.729 (0.602–0.856)	0.787 (0.669–0.905)	0.684 (0.550–0.818)
Internal rotation	0.707 (0.573–0.841)	0.827 (0.720–0.935)	0.658 (0.534–0.782)
Hand on contralateral shoulder	0.701 (0.596–0.805)	0.887 (0.806–0.967)	0.661 (0.553–0.769)
Visible range of the tendon			
Overall	0.756 (0.693–0.817)	0.826 (0.766–0.885)	0.767 (0.707–0.825)
Neutral	0.786 (0.698–0.874)	0.825 (0.729–0.920)	0.800 (0.718–0.881)
Internal rotation	0.719 (0.605–0.834)	0.763 (0.641–0.886)	0.700 (0.573–0.826)
Hand on contralateral shoulder	0.750 (0.639–0.860)	0.865 (0.775–0.954)	0.782 (0.683–0.882)

61.3 years; range, 37 to 87 years) among the finally included 48 patients in this study. The examined shoulder was dominant side in 30 patients, non-dominant side in 18 patients, and dominancy was not known in 4 patients. Because sex of the patient did not show significant effect on the outcomes by univariable analysis, multivariable analysis was done for the rest of variables.

AGREEMENTS

The inter-reader/intra-reader agreements for the grade of infraspinatus tendinosis and visible range of the tendon according to the positions are shown in the Table 1. Inter-observer agreements for the grade of tendinosis and visible range of the tendon were substantial in all three positions. And there was no significant difference of inter-observer agreement according to the positions ($p > 0.05$). Intra-observer agreements for the grade of tendinosis and visible range of the tendon were substantial to almost perfect for Reader 1, and substantial for Reader 2. Also, there was no significant difference of intra-observer agreement according to the positions ($p > 0.05$).

GRADE OF TENDINOSIS

The grades of infraspinatus tendinosis in consensus for each position are shown in Fig. 4. The radiologists more frequently assigned lower grade of tendinosis for the images captured in IR position, when compared to those in N or HC position. The statistical analysis also revealed that the grades of tendinosis in HC position were significantly different from those in IR position ($p = 0.004$). The cumulative odds ratio of tendinosis grades in HC position was 2.087 (1.268–3.433 in 95% confidence interval) by multivariable analysis, when compared to those in IR position, which means that tendons evaluated in HC position tended to show higher grade of tendinosis then those evaluated in IR position. However, the grades of tendinosis in N position were not significantly different from those in IR position ($p = 0.146$) or in HC position ($p = 0.370$). Older age and dominancy also showed significant effect on the grade of tendinosis.

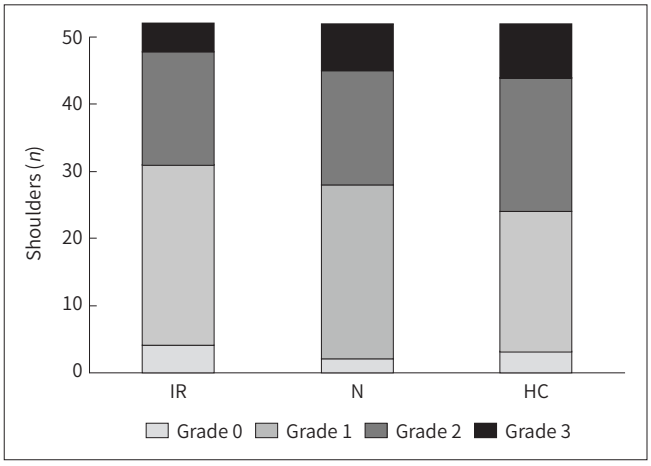


Fig. 4. The grades of tendinosis in a cumulative histogram according to the positions.
HC = hand on contralateral shoulder, IR = internal rotation, N = neutral position

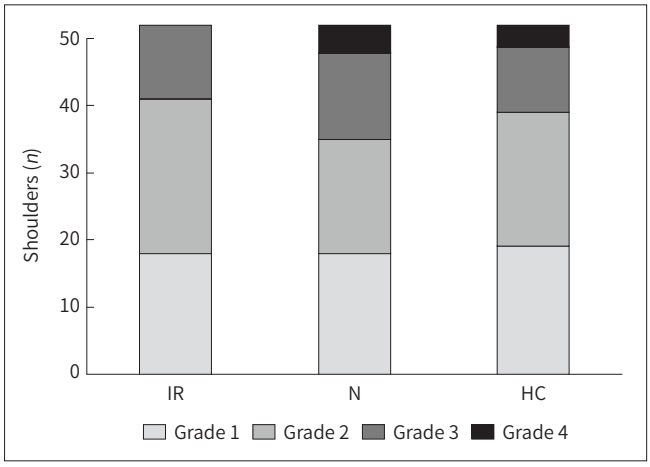


Fig. 5. The visible range of the tendon in a cumulative histogram according to the positions.
HC = hand on contralateral shoulder, IR = internal rotation, N = neutral position

VISIBLE RANGE OF THE TENDON

The visible range of IST in consensus for each position are shown in Fig. 5. There was no patient showing Grade 4 (only footprint is visible) range in IR position, when compared to N position (4 patients) and HC position (3 patients). However, no statistical difference was proven on the visible range of the IST according to positions, assessed by generalized estimation equation ($p = 0.530$).

THICKNESS OF THE TENDON

The thickness of IST showed significant difference according to positions by multivariable analysis. The mean (± standard deviation) thickness of the tendons in N, IR, HC position was 5.56 (± 1.21), 5.89 (± 1.24), 6.23 (± 1.33), respectively. The tendons were thicker in HC position when compared to the tendons in N position ($p < 0.001$), or those in IR position ($p = 0.011$).

DISCUSSION

US has been the most popular modality to evaluate rotator cuff tendons in various clinical settings and this was supported by high accuracy, low cost and safety (1, 14). However, US

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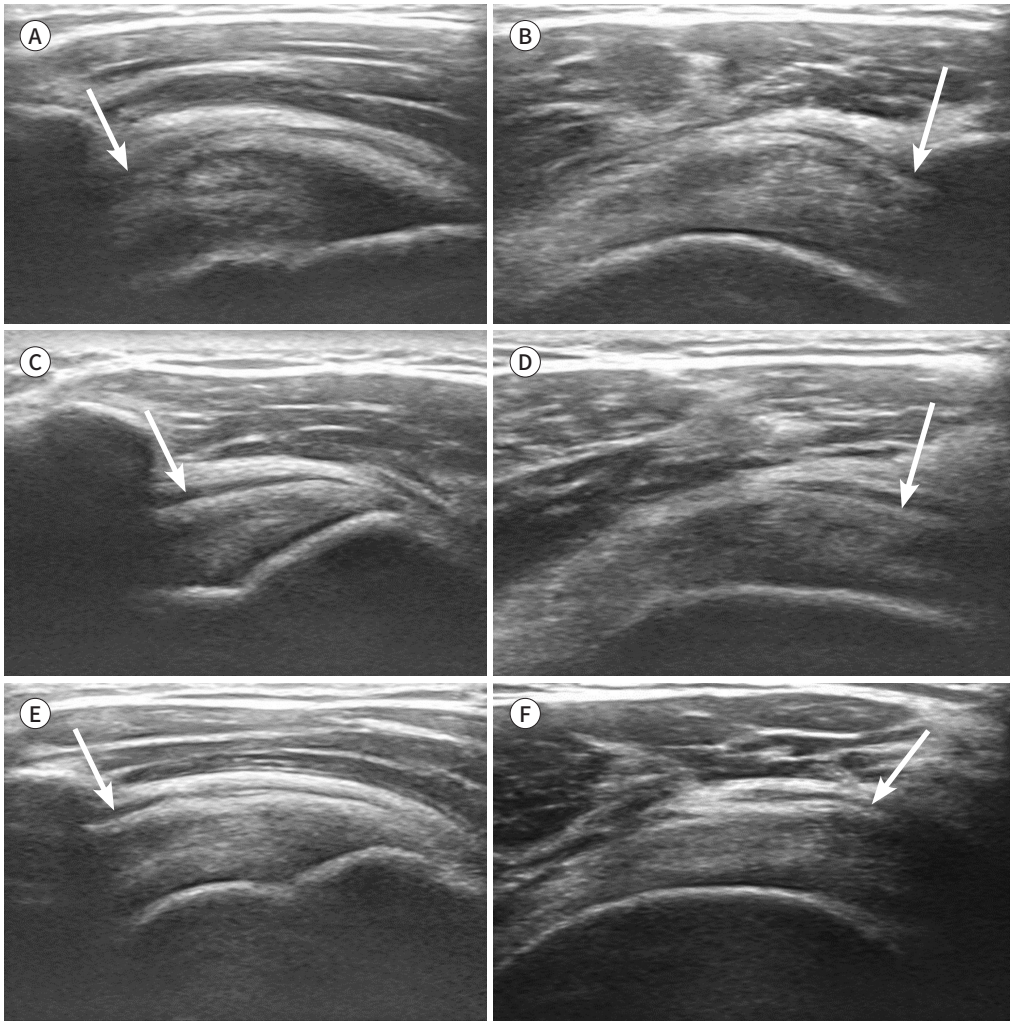
Fig. 6. In a 52-year-old male with infraspinatus tendinopathy, the long and short axes images of the infraspinatus tendon are obtained in the HC position (A, B), the IR position (C, D), and the neutral position (E, F). Note the degree of compression (arrows) on the infraspinatus tendon of the acromion that is different between the positions.
HC = hand on contralateral shoulder, IR = internal rotation



has some limitation in nature that the US beam cannot penetrate bone tissue, by which the patient might need to make a special position to look for the tissues underneath bone (7, 15). To evaluate IST, the main two recommended positions are N position and HC position (5, 6, 10). However, ISTs frequently appear quite different in those two positions in the authors' experience (Fig. 6), and there was no published study related to this topic. Moreover, as one of the authors routinely used IR position additionally to the two main positions, we designed a retrospectively study to know the effect of positions to evaluate IST on US.

Inter-observer agreements for the grade of tendinosis and visible range of the tendon were substantial in all three positions. This result is slightly higher than the study by O'connor et al. (3) in which the inter-observer agreement of supraspinatus tendinosis was reported 0.55 between the experienced radiologists, and the study by Ingwersen et al. (12), who reported inter-observer agreement of grading system of supraspinatus tendinopathy as 0.60. From

those previous studies, the reliability of data on the grade of tendinosis in this study can be proved. And there was no significant difference of interobserver agreement between all three positions.

The grades of infraspinatus tendinosis were higher in HC position, when compared to those in IR position with statistical significance. The thickness of the tendon was also different between all three positions, but the grades of tendinosis in N position was not statistically different from those in IR position or HC position in this study, including small number of subjects. Nevertheless, HC position was proven to make the tendinosis of IST overestimated on US. The visible range of the tendon was not statistically different according to the positions. Therefore, this study suggests that N position or IR position can be recommended to evaluate IST on US, because instant change of the tendinosis grade according to the position is not logical.

There are some limitations in this study. First, only small number of the patients were available for this study. Second, this was a retrospective study using captured US images for qualitative assessments. Since US evaluation cannot be free from anisotropy artifacts, captured images can be affected by them and be misinterpreted. But, we measured the thickness of IST as a quantitative assessment to overcome this limitation. Third, there was no confirmative reference to compare the grade of tendinosis or thickness of the tendon with US evaluation. However, since instant increase of the tendinosis grade according to the patient's position does not make sense, we thought the position showing the lower grade of tendinosis and providing sufficient sonic window would be the better position to evaluate IST on US.

The patient positioning significantly affected the grade of tendinosis and the thickness of IST. The grade of tendinosis was significantly lower and the thickness of tendon was significantly smaller in IR position, when compared to HC position. The visible range of the IST was not significantly different according to the positions. IR position is a feasible option to assess IST on US.

Author Contributions

Conceptualization, C.J.W., S.S.; data curation, C.J.W., L.J., K.D.H., P.J., O.S.; formal analysis, C.J.W., O.S., S.S.; investigation, C.J.W., K.D.H.; methodology, K.D.H., O.S.; project administration, C.J.W.; resources, C.J.W.; software, O.S.; supervision, C.J.W., S.S.; validation, C.J.W., P.J., O.S., S.S.; visualization, L.J., C.J.W.; writing—original draft, C.J.W., L.J.; and writing—review & editing, C.J.W., K.D.H., P.J., O.S., S.S.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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초음파 영상에서 극하근 힘줄병의 단계와 관찰가능 범위에 환자의 자세가 미치는 영향

채지원[1,2] · 이주호[3] · 김동현[1,2] · 박진아[1,2] · 오소희[4] · 신수미[1,2]*

목적 환자의 자세가 극하근의 힘줄병의 단계, 두께와 관찰가능 범위에 영향을 주는지 알아보고자 하였으며, 이로써 내전자세에서 초음파로 극하근을 평가하는 것이 가능한지 알고자 하였다.

대상과 방법 이 연구는 극하근을 세 가지 다른 자세(중립자세, 내전자세, 반대쪽 어깨에 손을 얹은 자세)로 평가한 48명의 환자의 52개의 어깨를 대상으로 하였다. 두 명의 영상의학과 전문의가 후향적으로 극하근의 힘줄병의 단계를 grade 0에서 grade 3까지, 관찰가능 범위를 grade 1에서 grade 4까지 판정하였다. 극하근의 두께는 다른 영상의학과 전문의가 단축 영상에서 측정하였다. 일반화추정방정식을 통계적 기법으로 사용하였다.

결과 반대쪽 어깨에 손을 얹은 자세에서 힘줄병의 단계는 내전자세보다 누적승산비가 2.087 (p = 0.004, 95% 신뢰구간: 1.268–3.433)로 더 높았으나, 중립자세에서 힘줄병은 단계는 내전자세(p = 0.146)와 반대쪽 어깨에 손을 얹은 자세(p = 0.370)와 유의한 차이가 없었다. 극하근의 두께(p < 0.001)는 자세에 따라 유의한 차이가 있었으나, 관찰가능 범위(p = 0.530)는 유의한 차이가 없었다.

결론 환자의 자세는 극하근의 힘줄병의 단계와 두께에는 영향을 주었지만 관찰가능 범위에는 영향을 주지 않았다. 내전자세에서도 초음파로 극하근을 평가하는 것이 가능하다.

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