

# Distance Between the Supraspinatus Central Tendon and the Long Head of the Biceps Tendon Can Predict Anterior Rotator Cable Disruption in Rotator Cuff Tear Patients Without Obvious Retraction.

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## Research article

**Keywords:** Rotator cable, rotator cuff tear, shoulder MRI

**Posted Date:** March 2nd, 2021

**DOI:** <https://doi.org/10.21203/rs.3.rs-266978/v1>

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# Abstract

**Background:** Current research shows that the anterior cable plays an essential role in rotator cuff tissue. To determine whether the distance between the supraspinatus central tendon and the long head of the biceps tendon, on a sagittal shoulder MRI scan, can predict anterior cable injury in rotator cuff tear patients before surgery.

**Method:** A retrospective MRI scan was performed and a review of 103 patients with a rotator cuff tear – 50 patients with anterior cable injury and 53 patients without anterior cable injury. The distance between the supraspinatus central tendon and the biceps tendon's long head was measured based on a sagittal MRI scan, and the tear size, degree of tear, and fatty degeneration of supraspinatus was also reviewed. SPSS software was used for statistical analysis of the relevant data. Two Independent Samples t-Test, binary logistics regression and receiver operating curve were also performed to evaluate select parameters.

**Results:** The distance between the supraspinatus central tendon and the long head of the biceps tendon (DTD) was bigger in the anterior cable disrupted group ( $10.05 \pm 2.73$  mm) when compared to the intact anterior cable group ( $7.96 \pm 2.30$  mm) with a significant difference ( $P < 0.01$ ). Moreover, patients in the anterior cable disrupted group were of an older age, and there was a larger tear size and a worsened tear condition ( $P < 0.05$ ). Binary logistics regression t-Test showed that DTD is associated with anterior cable disruption. The receiver operating curve t-Test showed that DTD had an area under the curve of 75%. When setting the cut off value as 9 mm, DTD can predict anterior cable injury with a 74% sensitivity and 73.6% specificity.

**Conclusion:** Compared with intact anterior cable patients, patients with anterior cable injury showed worsened tear condition and a larger distance between the supraspinatus central tendon and the long head of the biceps tendon, based on the oblique sagittal position of the MRI shoulder scan. Therefore, it may be a new tool for helping predict anterior rotator cable disruption in patients without obvious retraction.

**Trial registration:** retrospectively registered

## Background:

The rotator cable was known as the suspension bridge in shoulder force transmission that plays a vital role in force transmission and joint stability [1–3]. Research found that rotator cuff tears involving the anterior rotator cable were easily combined with significantly large tear patterns and more advanced muscle atrophy as well as higher retear rates after repair [4–7]. It was considered that anterior cable disruption led to an imbalance in the shoulder joint couple and increased stress on the crescent tissue, resulting in limited shoulder function and further aggravation of the rotator cuff tissue tears.[2, 5, 8, 9]

Therefore, it is necessary for the doctor to consider whether or not the anterior cable is involved when treating rotator cuff tear patients [10]. Not only for deciding on the appropriate treatment beforehand, but also for determining a better repair strategy. A MRI scan is still the standard method for preoperative evaluation of rotator cuff tissue and anterior cable conditions [11]; however, few studies have investigated the characteristics of anterior cable injuries on a MRI scan.

Recent studies have found obvious posterior displacement of the supraspinatus central tendon on a horizontal shoulder MRI scan with tears involving anterior supraspinatus insertion [12], and this posterior displacement shows a potential value for predicting anterior cable disruption. Research also indicates that the anterior cable has a close relationship with the coracohumeral ligament, which also plays an important role in preventing subluxation of the long head of the biceps tendon (LHBT) [8, 11]. When considering the posterior displacement of the supraspinatus tendon and the anterior shift of the biceps tendon, it is hypothesised that the distance between the supraspinatus central tendon and the long head of the biceps tendon may increase with anterior cable injury, and the distance between the two tendons may help in predicting the anterior supraspinatus disruption.

## **Method:**

### **Study patients:**

A retrospective study was performed to investigate whether the distance between the two tendons differed or not. A review of medical records and shoulder MRI scans of two different groups of patients was performed after receiving institutional review board approval (NO.2021–07). The two groups of patients were the anterior cable injury group, and anterior cable intact group.

The inclusion criteria of the anterior cable injury group patients were that they: (1) underwent a primary rotator repair at our institution between 2018 and 2020; (2) had clear MRI data of shoulder and documented tear pattern and size in the operative report; (3) had no previous history of shoulder surgery or trauma.

The exclusion criteria included were: (1) advanced glenohumeral joint arthritis; (2) large rotator cuff tear with the supraspinatus muscle retracted over the top of the humeral head; (3) extreme internal and external rotation of the humeral head on a shoulder MRI scan. All patient data were collected from the hospital medical record system.

Shoulder MRI scan: A 1.5-or 3.0- T Siemens MRI scanner (Siemens, Erlangen, Germany) was used for a shoulder examination. The patients, shoulder MRI scan included an axial turbo spin-echo (TSE) proton density-weighted image, TSE T1 and TSE T2- weighted images with fat suppression on a parallel or sagittal oblique plane to the supraspinatus tendon.

### **The standards of diagnosis of anterior cable disruption:**

Firstly, operative records were reviewed if it was found that anterior supraspinatus was involved; then, the patient's preoperative MRI scan was evaluated by an experienced senior orthopaedist and a radiologist. A 5mm anterior and posterior area to the intertubercular groove was considered to be the attachment area of the anterior cable [13]. Both the operative records and the MRI scan support would be marked as anterior cable disruption. When it was difficult to determine, the patient would be marked as intact anterior cable. If a disruption was seen on at least one of the parasagittal or coronal sequences, the MRI scan was marked as 'anterior cable disruption'. The intraoperative records were used to evaluate at the same time, both showing that anterior cable disruption was divided into anterior cable injury group.

### **Measurement of humeral rotation and the central tendon of the supraspinatus:**

All measurements were performed by four independent examiners. The four examiners included two fellowship-trained shoulder surgeons (Lifeng Yin and Jiabin Chen), one musculoskeletal radiologist (Xinyu Zhang) and one orthopaedic resident (Wenlong Yan). All measurements were operated on the PACS (picture archiving and communication system) of our hospital. (IDX Image cast, version 10.7; Koninklijke Philips Electronics, Amsterdam, Netherlands)

### **Humeral rotation and radius of the humeral head**

The rotation angle of the humeral head and the radius of the humeral head will be measured on a horizontal plane on the patients' MRI scan by using the PACS tool. A proximal slice, showing an obvious outline of the bicipital groove, was chosen for measuring. Using the tool provided by the PACS system a circle was drawn for measuring the radius, and for locating the central point of the humeral head, which was then used for measuring the rotation angle. The angle between the line from the central point to the bicipital groove and the vertical line was defined as the rotation angle, and it was stipulated that the internal rotation was positive and the external rotation was negative.

### **Measurement of distance between the central tendon and the long head of the biceps tendon (DTD), posterior displacement distance of the central tendon on a horizontal plane (PTD):**

DTD was used to reflect the distance between the supraspinatus tendon and the long head of the biceps tendon. The DTD was defined as the distance between the central points of the long head of the biceps tendon with the anterior edge of the supraspinatus tendon on the oblique sagittal shoulder MRI scan, where the distal coracoid process is about to disappear. First, the T2 fat suppression or the proton density fat suppression sagittal sequence of the MRI scan was reviewed to find the slice where the distal coracoid process nearly disappears (Fig1). Then a line connecting the central point of the LHBT and the anterior edge of the supraspinatus central tendon was made. The DTD was then measured by PACS automatically and the measuring of the distance was repeated twice. The average value was recorded. If the tendon was difficult to be located a more precise slice was selected.

The posterior displacement of the central supraspinatus tendon was defined as the shortest distance from the centre of the bicipital groove to the transferred central tendon line on the horizontal plane of the

MRI, which measurement was based on Updegrave, G. F's method [12]. (Fig. 2)

### **Tear Characteristic and muscle fatty degeneration:**

Additional data regarding the tear size, the degree of the tear and fatty degeneration of the supraspinatus muscles were collected. The tear size was categorised into three degrees: level 1 (<1 cm), level 2 (1 cm–3 cm), level 3 (>3cm) and tear degrade was categorised into two types: partial tear and full thickness tear.

The degrees of supraspinatus muscle atrophy were determined by using Goutallier grading criteria to evaluate the atrophy of supraspinatus. Level 0: no fat infiltration; Level 1: a small amount of fat bands in muscles; Level 2: less fat than muscle; Level 3: fat equivalent to muscle; Level 4: more fat than muscle.

### **Sample size and Statistical methods**

Owing to the fact that there was no previous research for this study to determine the variables, a preliminary experiment was carried out and after analysing with PASS software, it was shown that at least 50 samples were required.

Data analysis: SPSS 25.0 was used for most of the statistical analysis. Mean value and standard deviation were used to describe quantitative continuous data, while frequency and percentage were used to describe qualitative data. The humeral rotation, DTD and PTD from the biceps groove, was compared between groups using a two independent T test. Classification and rank variables were compared using the  $\chi^2$  test. Binary logistical regression was also performed to assess the correlation between the DTD, posterior displacement distance, and other tear characteristics with anterior cable disruption. The receiver operating curve was also used for testing the predicting performance of the DTD, PTD, and other rotator cuff tear characteristics.

The data are presented as mean and standard deviation. Statistical significance was set at  $P < 0.05$ .

## **Results:**

103 patients met our requirement, showing a significant difference between age, tear size, muscle atrophy, as well as the DTD between the two groups. The mean age of the patients in the anterior cable injury group was  $60.38 \pm 8.6$  years and  $55.30 \pm 10.85$  years in the control group ( $P < 0.05$ ). There were 22 men and 28 women in the anterior cable injury group, 25 men and 28 women in the anterior intact group, and there were no significant differences between the constitution of the two groups ( $P > 0.05$ ). Table 1 summarises the baseline information and tear characteristics of the two groups.

The mean DTD between the central point of the SS central tendon and the LHBT was increased significantly in the anterior cable injury group ( $10.15 \pm 2.62$  mm) compared to the anterior cable intact group ( $7.96 \pm 2.3$  mm,  $p < 0.01$ ).

However, the mean distance from the bicipital groove was not significant between the anterior cable injury group ( $9.96 \pm 5.35$  mm) and the anterior intact group ( $8.63 \pm 5.02$  mm,  $P = 0.1$ ). The mean rotation angle and the length of the humeral head radius have no significant difference between the anterior cable injury group and the anterior intact group ( $P = 0.14$ ,  $P = 0.31$ ).

The binary logistic regression analysis (Backward Stepwise) showed that except for age, gender and PTD, other parameters play an important role in predicting anterior cable injury (Table 2). The receiver operating curve and calculation of the area under the curve also indicate that the DTD has a good ability in predicting anterior cable injury (AUC = 0.746). 9mm was selected as the cut off value of the DTD in predicting anterior cable injury with 74% sensitivity and 73% specificity (Fig. 3), and the interclass correlation coefficient shows good reliability of measuring the DTD. The intraclass correlation coefficient (ICC) of anterior cable disruption patients was 0.88 and the ICC of the anterior cable intact group was 0.92 with  $P < 0.05$ .

## Discussion:

The findings of this study suggest that when finding that the DTD measure is beyond 9mm in old rotator cuff tear patients without obviously retraction, combined with obvious supraspinatus muscle atrophy, anterior cable disruption may be a strongly suspected base for our data. Moreover, in our study the DTD showed a good performance in predicting anterior cable disruption. However, the posterior displacement distance did not show a good predictive value in this study.

The rotator cuff cable and rotator cuff interval are among the most recent topics of interest in current literature on shoulders [1, 14–17]. Most of the research has been published in the last two decades and our understanding of the importance regarding these anatomical structures has improved with biomechanical studies, which has changed the pre- and intra-operative approaches to shoulder surgery [5, 14, 18].

Most research shows that the anterior cable plays an essential place in shoulder biomechanics [1, 5, 9, 14, 19]. Current research shows that patients with a damaged anterior cable would more easily be associated with symptoms of higher SS muscle atrophy, as well as an increased retear rate after surgery repair, compared to patients without anterior cable disruption [6, 15]. Therefore, it is mandatory to have a good understanding of the anatomy surrounding the rotator cable as well as the close relationship between the insertion of the supraspinatus and infraspinatus tendons and the coracohumeral ligament. However, few studies have focused on the differences in MRI scans of rotator cuff tear patients with anterior cable disruption.

This study shows that the distance between the SS central tendon and the LHBT on the sagittal plane can effectively predict anterior cable disruption. However, few have reported on predicting anterior cable disruption, based on MRI shoulder scans. This distance is referred to as double tendon distance (DTD), as it was measured by two important tendons in MRI shoulder scans.

Based on what is already known, the changes of the DTD may be explained in two directions: the posterior shift of the central tendon of supraspinatus and the anterior shift of the LHBT.

The reason may consist of two parts. On the one hand, with regard to the posterior shift of the SS central tendon, it is theorised that the anterior-most supraspinatus insertion serves as the anterior limb of the rotator cable [2], and a disruption of the anterior cable has a detrimental impact on the SS muscle itself, as well as the anterior-posterior balance [5, 9, 12]. The force from the infraspinatus will easily pull the supraspinatus central tendon backward. Meanwhile, inhomogeneous atrophy of the SS may also lead to this change, due to the pennate muscle fibres beside the supraspinatus central tendon being affected when the anterior part was atrophic [20, 21].

On the other hand, the anterior-inferior shift of the LHBT. It is speculated that there may be two main reasons contributing to this result. Literature has found that the footprint of the supraspinatus on the greater tuberosity is much smaller and more forward than previously believed, and that it even crosses the intertubercular sulcus and occupies part of the lesser tuberosity [22]. In this situation anterior insertion disruption may easily affect the stabiliser of the LHBT pulley structure that plays an important role in preventing subluxation of the LHBT [8, 11, 23]. Additionally, the upper migration of the humeral head is very common to observe when the glenohumeral joint loses the stable force that is provided by the rotator cuff muscle, especially the supraspinatus [24]. Without the rotator cuff's stability, deltoid and pectoral muscles tend to destabilise the joint superiorly and anteriorly [24]. During the investigation of the MRI shoulder scans, it was observed that, at times, the LHBT looks like a reverse J on the horizontal plane rather than a straight line (Fig. 5), this may support our hypothesis of this change.

Other effects that may contribute to the subluxation of the LHBT were also considered. Due to the the influence of humeral rotation, patients with excessive internal and external rotation were excluded; however, it is still not known whether this affects the DTD measurement [12]. Moreover, there is no strong evidence to prove this study's explanations here, but it is believed that this hypothesis is based on available evidence and logical reasoning.

Previous studies have shown that the supraspinatus central tendon has a constant orientation toward the bicipital groove in normal shoulders, and that the central tendon was usually posteriorly displaced when the tear affected the anterior insertion of the supraspinatus [12, 22, 25]. Gray, et al. reported that this tool may have potential in predicting anterior cable disruption. However, it did not show a significant difference between the two groups as the tear characteristics of the enrolled patients differed between the two researches. In addition, those tendons that were extremely retracted, were excluded. It was indicated that the DTD may have a unique function to aid in predicting anterior cable disruption among milder to medium rotator cuff tear patients. In recent times, the LHBT has become a good autograft for reinforcing rotator cuff tear [26–28]. Increasingly, doctors are using the LHBT as a bridge to reconstruct the anterior cable [15, 26, 29, 30], and in spite of there being follow-up evidence this way may shorten the DTD involuntarily.

This data suggests that the DTD has good ability of predicting values in anterior rotator cable injury in mild to medium rotator cuff tear patients. Binary logistic regression and receiver operating curve both revealed the DTD's potential value in predicting anterior cable disruption. When 9mm was selected as the cutoff value, it showed both sensitivity and specificity greater than 70%. In addition, the DTD index (DTD/radius of the humeral head) was also used to allow it to be more comparable among different patients, which shows that the ratios of the DTD index also have good capacities to predict rotator cable injury (AUC, 0.753) similar as DTD itself.

This study still has some limitations, and the following biases should be considered:

1. This study is a retrospective controlled clinical study with low level of evidence.
2. In this study, patients with extreme internal or external rotation greater than 30°, and patients who had severe rotator cuff tear with a size larger than 3cm or a tendon retracted over the humeral head, were excluded. This will result in limitations for the application of the DTD.
3. No comparison was made between preoperative and postoperative conditions of the supraspinatus central tendon. It still needs to be discussed in the future whether the DTD would reduce after repair.

## **Conclusion:**

The findings of this study sustain the hypothesis that the distance between the supraspinatus central tendon and the LHBT will increase when the anterior cable is injured. Based on the data the double tendon distance (the distance between two tendon central points on a sagittal MRI scan) can help predict anterior cable disruption in certain patients.

## **Abbreviations:**

SS: supraspinatus

LHBT: long head of biceps tendon

DTD: double tendon distance on sagittal plane

PTD: posterior tendon displacement on horizontal plane

MRI: magnetic resonance imaging

ROC: receiver operating curve

ICC: Intraclass correlation coefficient

## **Declarations:**

**Ethics approval and consent to participate:**

Our research was approved by the Ethics Committee of the First Affiliated Hospital of Chongqing Medical University. Number: 2021–07.

### **Consent for publication:**

Not applicable.

### **Availability of data and materials:**

The datasets used and the analysis during the current study are available from the corresponding author on reasonable request.

### **Competing interests:**

The authors declare that they have no competing interests

### **Funding:**

This work was supported by the Medical Research Project of Health and Family Planning Commission in Chongqing (Grant No. 2017ZDXM006) and the General Project of Technology Innovation and Application Development of Chongqing Science and Technology Bureau (Grant No. cstc2019jscx-msxmX0245).

### **Author's contributions:**

LFY and CJX collected and analysed the data. JZ and WLY contributed to the research design and quality control. LFY was a major contributor in writing the manuscript. HZ and MKG helped with writing this article and the checking of language. All the authors read and approved the final manuscript.

### **Acknowledgements:**

We are grateful to all the professors and friends who support this research.

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## Tables:

Table 1  
Patient demographics and mean outcomes.

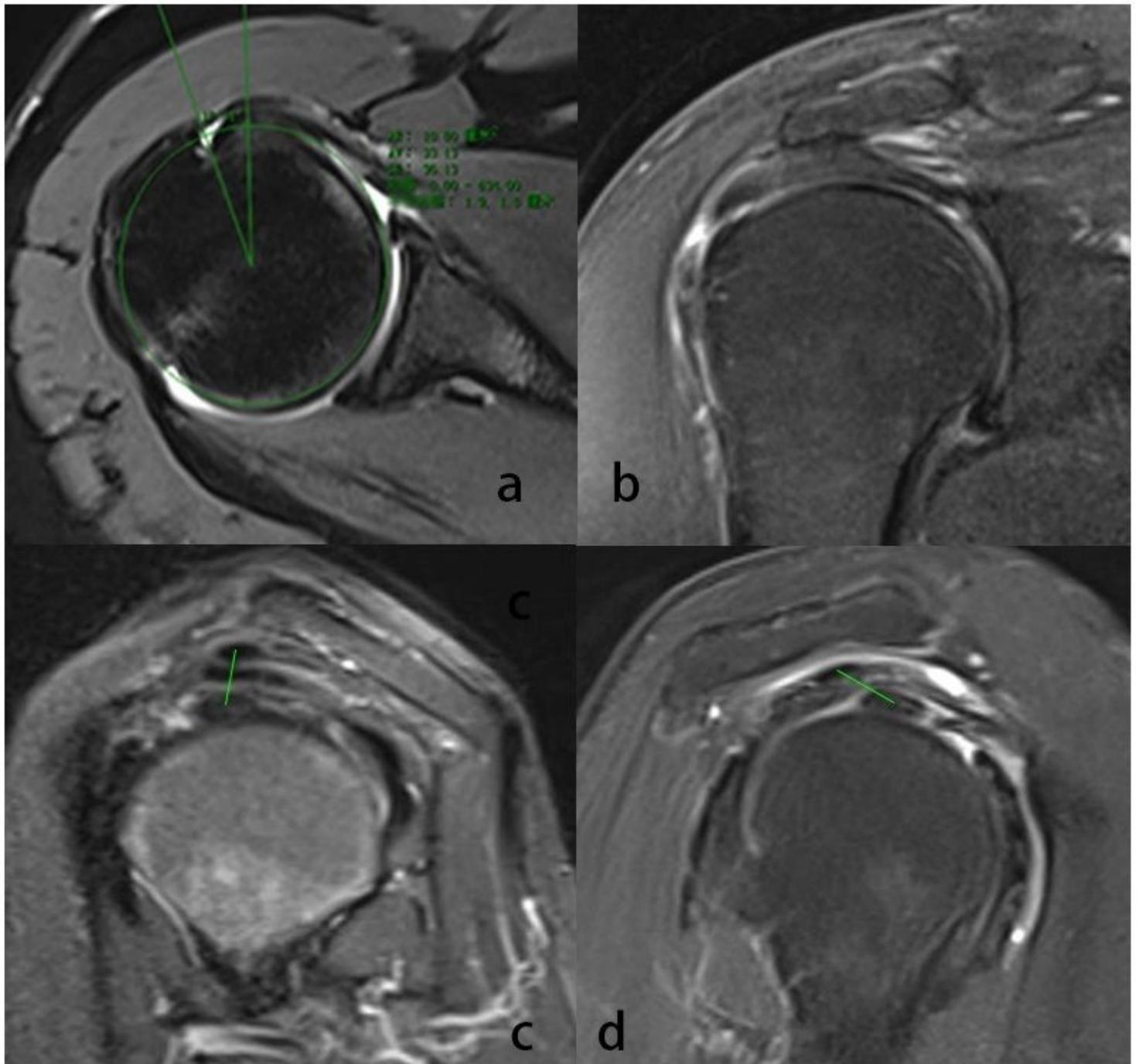
Characteristics	classification	cable intact	cable disrupted	P
Age(years)		55.3 ± 10.8	60.4 ± 8.6	< 0.05
Gender(n)	Man	25	22	> 0.05
	Woman	28	28	
Tear size (n, %)	< 1cm	50(94%)	32(64%)	< 0.05
	1-3cm	3(6%)	15(30%)	
	> 3cm	0	3(6%)	
Tear degree (n, %)	Partial	42(79%)	16(32%)	< 0.05
	Full-thickness	11(21%)	34(68%)	
SS atrophy	Grade 0	15	6	< 0.05
	Grade 1	35	25	
	Grade 2	3	19	
DTD(mm)		7.96 ± 2.30	10.05 ± 2.73	< 0.05
PTD (mm)		8.63 ± 5.02	9.97 ± 5.36	> 0.05
Rotation angle(°)		5.04 ± 18.52	10.13 ± 15.55	> 0.05
Head radius(mm)		21.91 ± 1.85	21.55 ± 1.79	> 0.05
There was a statistically significant difference (p < 0.05) among two groups.				

Table 2

Binary logistics regression.

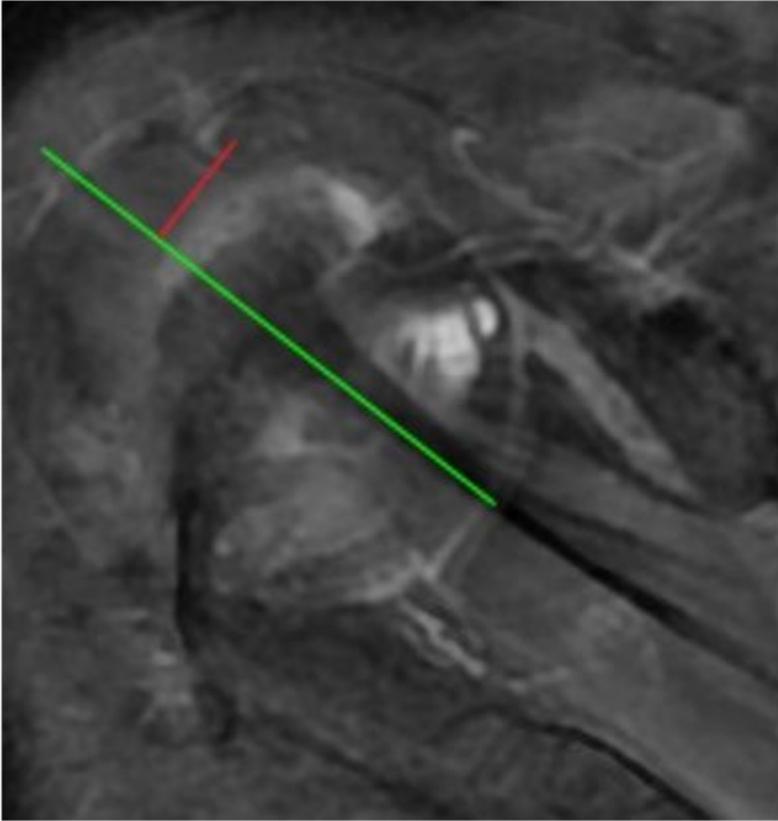
Variables not in the Equation				
			Score	Sig.
Step 2 <sup>a</sup>	Variables	Gender	.050	.823
	Overall Statistics		.050	.823
Step 3 <sup>b</sup>	Variables	⊠PTD)distance from bicep groove/mm	.722	.396
		Gender	.087	.768
	Overall Statistics		.774	.679
Step 4 <sup>c</sup>	Variables	⊠PTD)distance from bicep groove/mm	.644	.422
		Years	.705	.401
		Gender	.047	.829
	Overall Statistics		1.489	.685

## Figures



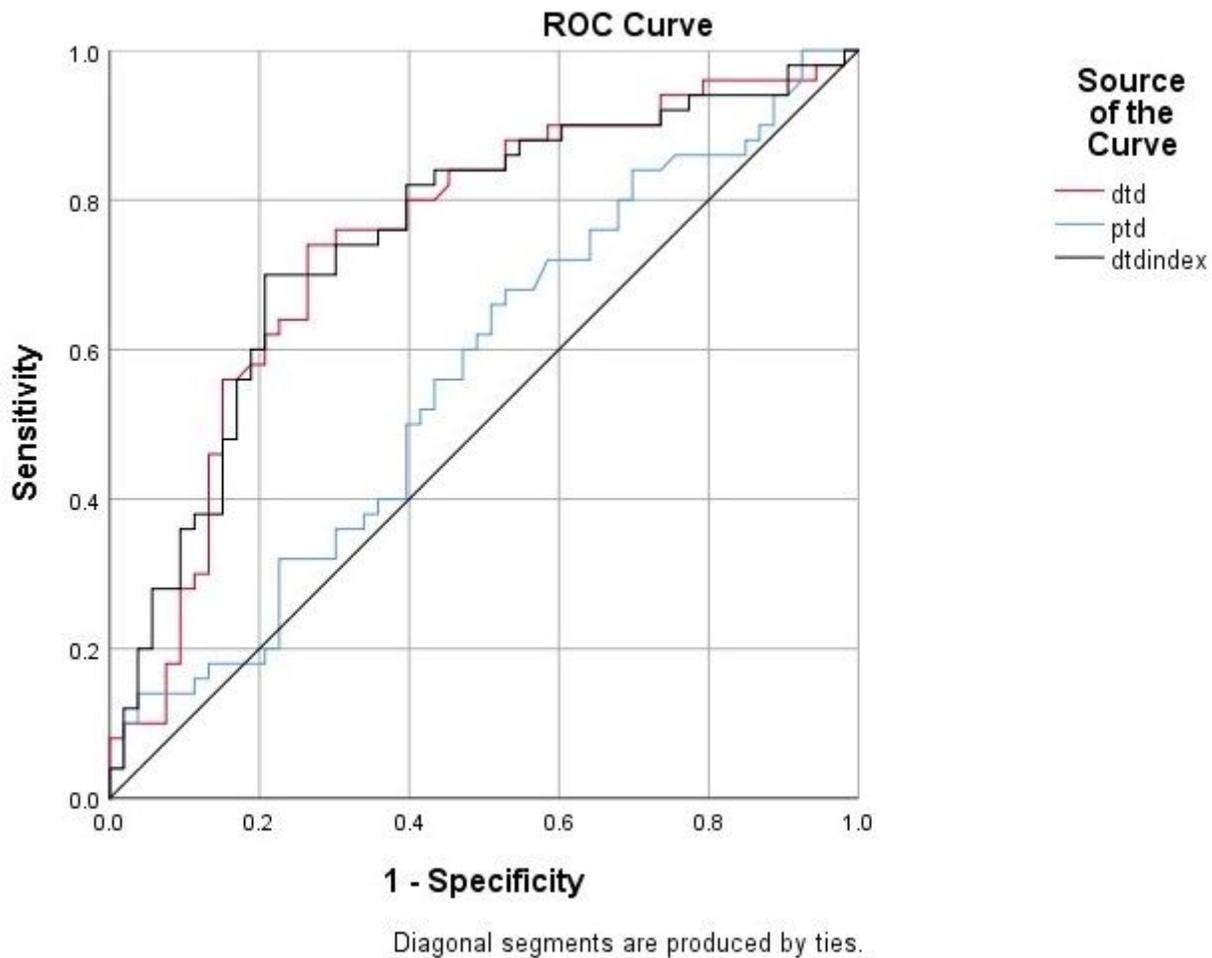
**Figure 1**

a. measurement of humeral rotation angle and head radius; b. anterior cable disruption without obviously retraction; c. DTD in patients without anterior cable disruption; d. DTD in patients with anterior cable disruption.



**Figure 2**

picture of measuring PTD. The green line was the extension line of the supraspinatus central tendon and the red line is the distance from the biceps tendon groove to its vertical line



**Figure 3**

picture of ROC curve. The receiver operating curve and calculation of the area under the curve also indicate that the DTD (red line) has a good ability in predicting anterior cable injury (AUC = 0.746). DTD/radius also has a good ability [black line]. PTD showed low power in predicting [blue line].

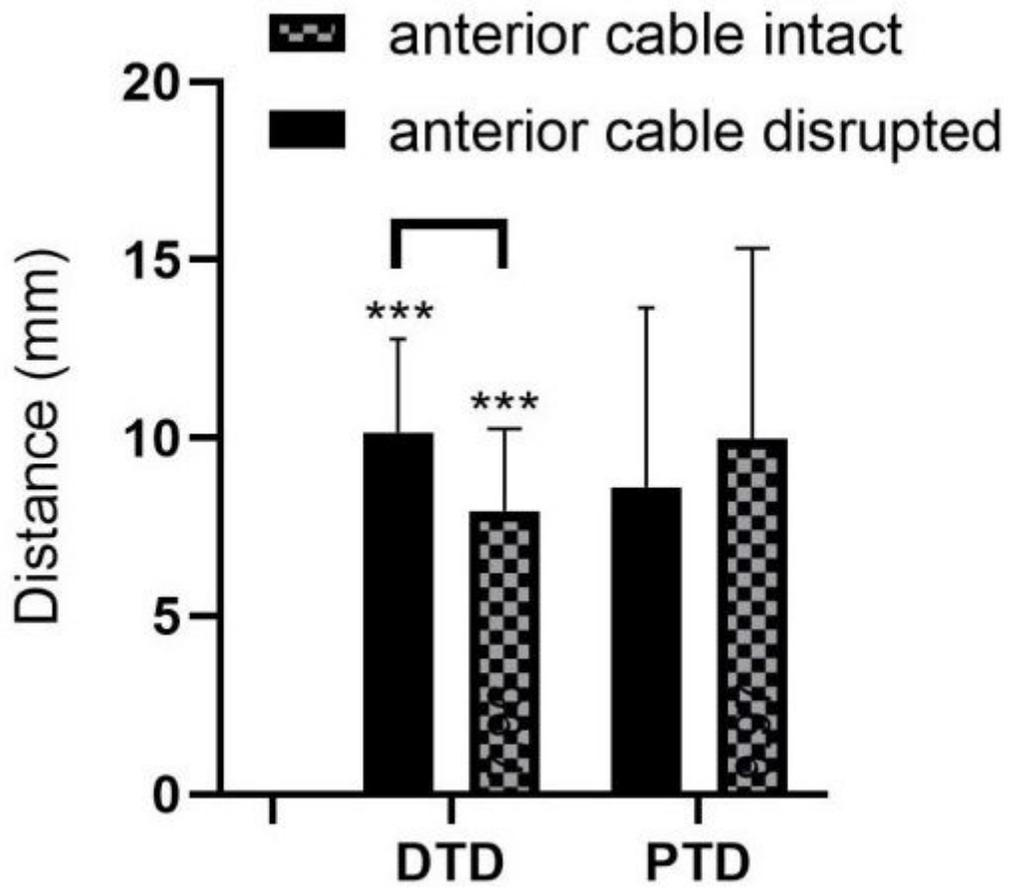
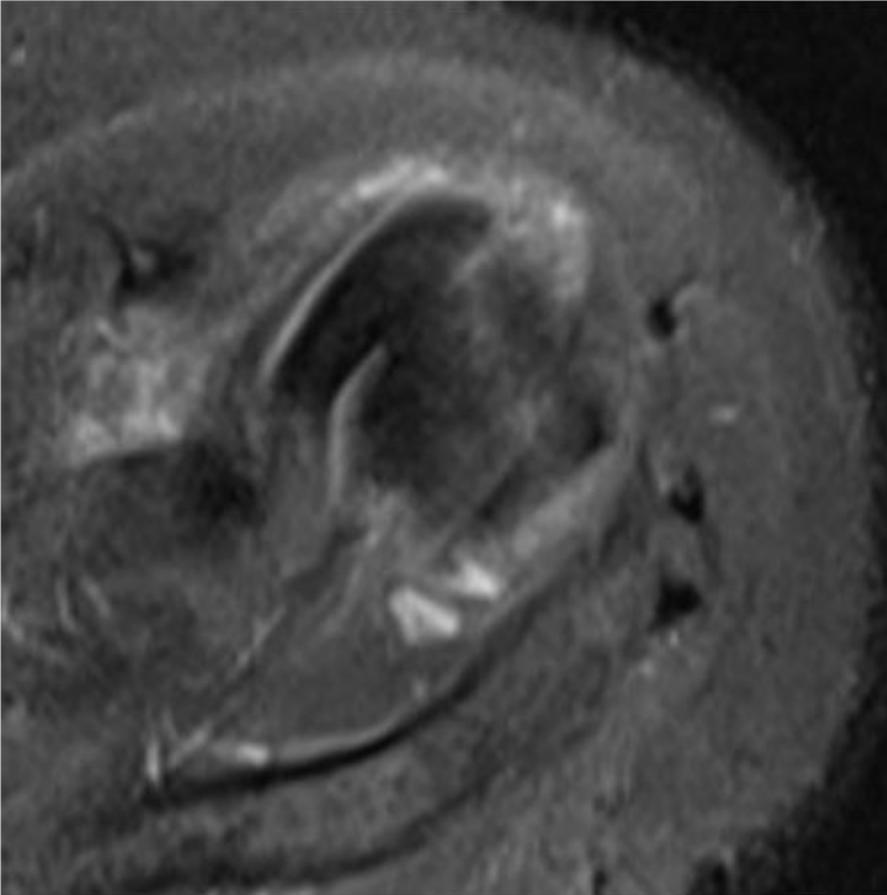


Figure 4

The two measures results were compared among two groups of patients.



**Figure 5**

The long head biceps tendon appears J-shaped in patients with anterior cable injury.

## **Supplementary Files**

This is a list of supplementary files associated with this preprint. Click to download.

- [additionalfile2.rar](#)
- [dataforcable.xlsx](#)