



MR imaging features on follow up of anterior cruciate ligament reconstruction graft and its correlation with subjective scores

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ABSTRACT

Introduction

Anterior cruciate ligament is most common ligament tear in knee joint. MRI is able to assess graft signal intensity and correct tunnel placement in non-invasive way. Previously it has been described as anterior cruciate ligament reconstruction graft has low signal intensity but increased intrasubstance graft signal changes subsequently have been described to develop within the 1st year due to synovial proliferation, vascularization, and "neoligamentization" of graft constructs.

Materials and methods

We did a prospective study of 30 patients with 1.5-T magnetic resonance imaging of the knee who had undergone primary anterior cruciate ligament reconstruction 6 months after surgery, all the subjects were between ages 15 to 60 years were included. The amount of signal intensity changes in graft categorized according to cross sectional area i.e. <25%, 25-50% and >50 %. Graft stability assessed and compared with subjective test i.e. IKDC score and TEGNER score.

Results

Of 30 cases examined increased intrasubstance graft signal intensity was found in 66% (20 of 30) of patients on T2-weighted MR images. Classified amount of intrasubstance signal intensity in graft showed insignificant association between graft signal intensity on T2-weighted images and IKDC score (p-value: 0.824) and TEGNER score (p-value:0.643).

Conclusion

Increased intrasubstance graft signal intensity on T2-weighted images can be seen after ACL reconstruction at follow-up and do not necessarily correlate with functional limitations in patients after ACL repair as progressive vascularization of preligamentous soft tissue with subsequent synovialization and remodeling shows increased signal intensity on intermediate and T2-weighted images..

Keywords: Anterior cruciate ligament reconstruction, graft, IKDC score, increased signal intensity, TEGNER score.

INTRODUCTION

The anterior cruciate ligament is the most frequently injured ligament in the knee [1]. The anterior cruciate ligament (ACL) is the knee joint's primary restraint on anterior translation of the tibia in regard to the femur and a secondary restraint on internal rotation of the tibia. It provides 87% of the total restraining force at 30° of knee flexion and 85% at 90° of flexion [2]. Three major types of ACL injuries are described, Direct Contact: 30% of the cases, Indirect

Contact and Non-Contact: 70% of the cases: by doing a wrong movement. [3] Treatment or reconstruction techniques of ACL-deficient knee joints have improved substantially during the past decades with current reconstructions typically performed arthroscopically and with utilization of autografts or allograft constructs [4,5]. The intra-articular graft undergoes a maturation and remodeling process lasting even beyond 24 months, and consists of 4

steps: The initial avascular necrosis, the revascularization, cellular proliferation, and final remodelling^[vi]. This whole process from tendon graft toward the acquisition of histologic and biomechanical properties similar to the native ACL is known as “ligamentization”. This process could be indirectly monitored through MRI, as it has been proved that poor biomechanical properties and an incomplete graft maturation are related to a hyperintense graft signal on MRI^[vii]. The importance of a patient’s perception of knee recovery, and self-confidence in performing physical tasks after anterior cruciate ligament reconstruction, is reflected by the plethora of subjective rating scales reported in knee outcome studies^[viii, ix, x, xi]

The study was conducted to assess the post-surgical anterior cruciate ligament reconstruction graft through MRI, and to correlate intrasubstance signal intensity within reconstruction graft with subjective scores i.e. IKDC score and TEGNER score. These scores are well-standardized outcome instrument and a valuable measure of symptoms, function, and sport activity.

Materials and Methods:

A prospective study with 1.5-T magnetic resonance imaging of the knee was done in 30 patients who had undergone primary anterior cruciate ligament reconstruction 6 months after surgery, from August 2017 to June 2018. All the subjects were between ages 15 to 60 years were included. Informed consent was obtained in all patients who were part of this study. Exclusion criteria was patients with claustrophobia, cardiac pace maker and MR non compatible implants.

MR imaging was performed with a 1.5 HD XT 16 channel 1.5T GE MRI machine by using a dedicated eight-channel extremity send-receive knee coil, with patients in a supine position and with a fully extended knee. Using following sequences: Sagittal intermediate-weighted (repetition time msec/echo time msec, 2000/21.3) (slice thickness -4 mm), Coronal intermediate-weighted (repetition time msec/echo time msec, 5117/33.9) (slice thickness -4 mm), Axial T2-weighted (repetition time msec/echo time msec, 3500/70) (slice thickness -4 mm).

All these scans were reported by single radiologist to eliminate subject bias. Reader was blinded to

findings of subjective score measurement at MR imaging evaluation.

Clinical Subjective scores consist of: Tegner score^[xi] and International Knee Documentation Committee 2000 (IKDC) score^[xii, xiii]

MR imaging findings that were evaluated as follows

1. Increased signal intensity of the intraarticular portion of the ACL graft was analyzed on intermediate-weighted and T2-weighted images as present (increase of signal intensity within the substance of the graft) or absent (no increased signal intensity change). If increased intrasubstance signal intensity was present, the location of signal intensity was defined as within the proximal and/or distal half of the tendon graft.
2. When present, the amount of increased intrasubstance graft signal intensity was assessed and subclassified as comprising less than 25%, 25%–50%, or more than 50% of the maximum cross sectional area of the graft on intermediate and T2-weighted acquisitions.

Method of scoring

1. International Knee Documentation Committee 2000 subjective knee form
2. Tegner activity level scale

IKDC score [12,xii]

Patient was asked to fill up International Knee Documentation Committee 2000 Subjective Knee form.

The IKDC subjective knee form consists of 18 questions in the domain of symptoms, functioning during activities of daily living and sports, current function of the knee, and participation in work and sports. The highest possible result is 100

Score interpretation

<50 % severely abnormal,

<51-75% abnormal,

76-89% nearly normal

>90% normal

Interpretation of scores.

Lower score means greater pain and disability.

Tegner activity level scale [11]

1. level 10 (Competitive sports- soccer, football, rugby (national elite)
2. level 9 (Competitive sports- soccer, football, rugby (lower divisions), ice hockey, wrestling, gymnastics, basketball etc)
3. Level 8 (Competitive sports- racquetball, squash or badminton, track and field athletics (jumping, etc.), downhill skiing etc)
4. level 7 (Competitive sports- tennis, running, motorcars speedway, handball Recreational sports- soccer, football, rugby, bandy, ice hockey, basketball, squash, racquetball, running, dancing etc)
5. level 6 (Recreational sports- tennis and badminton, handball, racquetball, down-hill skiing, jogging at least 5 times per week)
6. level 5 (Work- heavy labor (construction, etc.) Competitive sports- cycling, cross-country skiing, Recreational sports- jogging on uneven ground at least twice weekly)
7. level4 (Work- moderately heavy labor (e.g. truck driving, etc.)
8. level 3 (Work- light labor (nursing, etc.)
9. level 2 (Work- light labor Walking on uneven ground possible, but impossible to back pack or hike)
10. level 1 (Work- sedentary (secretarial, etc.)
11. level 0 (Sick leave or disability pension because of hip problems)

Score interpretation

Possible score range: 0–100, where 100 = no symptoms or disability.

Scores are categorized as

Excellent (95–100)

Good (84–94)

Fair (65–83)

Poor (≤ 64)

Statistical analysis:

Data entry was done using Microsoft Excel 2016. Data were analyzed using SPSS version 21.0. The main outcomes for analysis were the number and

proportion of patients with anterior cruciate ligament reconstruction graft the associations of radiological findings i.e. intrasubstance signal intensities with subjective scores i.e. IKDC score and Tegner score , for categorical and continuous variables were obtained by using Chi square test and Unpaired t test/ Paired t test respectively. Correlations were obtained to quantify the relationship between two quantitative variables. All p values were two tailed and significant when values were less than 0.05.

Results:

According to International Knee Documentation Committee 2000 scoring out of 30 patients 4 patients showed normal score(13.33%), 12 patients showed nearly normal score(40%), 14 patients showed nearly normal score(46.66%) and none of the patient showed severely abnormal score.

According to Tegner scoring out of 30 patients 4 patients showed excellent score (13.33%), 13 patients showed good score (43.33%), 13 patients showed fair score (43.3%) and none of the patient showed poor score.

Of 30 cases examined increased intrasubstance graft signal intensity was found in 66% (20 of 30) of patients on T2-weighted MR images. Out of 20 patients 15 patients shows increased intrasubstance signal intensity in <25% of cross sectional area, 3 patient shows increased signal intensity is seen in 25-50 % of cross sectional area and 2 patients shows increased signal intensity in >50% cross sectional area.

On Comparison of increased signal intensity in less than 25% of cross sectional area with IKDC score it was found that 1 patient showed severely abnormal score, 6 patients showed abnormal score, 5 patient showed nearly normal score and 3 patients showed normal score. There was statistically insignificant association between presence of signal intensity less than 25% of cross sectional area and IKDC score (Pearson's Chi-square: 1.512, P-value: 0.836).

On Comparison of increased signal intensity in 25%-50% of cross sectional area with IKDC (Table 1)score it was found that 1 patient showed severely abnormal score, 1 patients showed abnormal score and 1 patient showed nearly normal score. There was statistically insignificant association between presence of signal intensity 25%-50% of cross

sectional area and IKDC score. (Fisher's exact value: 3.439, P-value: 0.303)

On Comparison of increased signal intensity in more than 50% of cross sectional area with IKDC score it was found that 1 patient showed abnormal score and 1 patient showed nearly normal score. There was statistically insignificant association between presence of signal intensity more than 50% of cross sectional area and IKDC score (Fisher's exact value: 1.465, P-value: 0.999)

So out of 20 patients showing increased signal intensity 2 patients showed severely abnormal score, 8 patients showed abnormal score, 7 patients showed nearly normal score and 2 patients showed normal score however out of 10 patients showing normal signal intensity 6 patients showed abnormal score, 3 patients showed nearly normal score and 1 patient showed normal score. There was statistically insignificant association between presence of signal intensity and IKDC score (Fisher's exact value: 1.453, P-value: 0.824).

On Comparison of increased signal intensity in < 25% of cross sectional area and TEGNER score (Table 2) 2 patients showed excellent score, 6 patients showed good score, 6 patient showed fair score and 1 patient showed poor score. There was statistically insignificant association between presence of signal intensity < 25% of cross sectional area and TEGNER score (Fisher's exact value: 0.587, P-value: 0.999).

On Comparison of increased signal intensity in 25%-50% of cross sectional area and TEGNER score 1 patient showed excellent score, 1 patient showed good score and 1 patient showed poor score. There was statistically insignificant association between presence of signal intensity 25%-50% of cross sectional area and TEGNER score (Fisher's exact value: 5.732, P-value: 0.068)

On Comparison of increased signal intensity in >50% of cross sectional area and TEGNER score 1 patient showed good score and 1 patient showed fair score. There was statistically insignificant association between presence of signal intensity >50% of cross sectional area and TEGNER score (Fisher's exact value: 1.401, P-value: 0.999).

So out of 20 patients showing increased signal intensity with TEGNER score 3 patients showed excellent score, 8 patients showed good score, 7

patients showed fair score and 2 patients showed poor score however out of 10 patients showing normal signal intensity 1 patient showed excellent score, 3 patient showed good score and 6 patient showed fair score. There was statistically insignificant association between presence of signal intensity and TEGNER categories (Fisher's exact value: 1.914, P-value: 0.643).

Discussion:

This prospective study correlated signal intensity changes in anterior cruciate ligament reconstruction graft 6 months after surgery with subjective score i.e IKDC and Tegner score. Earlier the cause of increased signal intensity in graft after surgery was unclear^[xiv] and it was assumed that increased intrasubstance signal intensity within graft is secondary to partial tear or impingement but now it is proven fact that intrasubstance signal intensity within graft is secondary to process of maturation and remodeling of graft process lasting even beyond 24 months, and consists of 4 steps: The initial avascular necrosis, the revascularization, cellular proliferation, and final remodelling^[vi].

Different studies have shown that this 4 steps of maturation of graft and remodelling of graft lasts at least 4 to 6 months however it is possible to define the end of this phase because some changes occur even years after the reconstruction these changes can be demonstrated through an MRI^[xv] so we did our study 6 months after reconstruction surgery.

In our study it was observed that graft signal intensity did not correlate with subjective scores (IKDC score, P-value: 0.824) (Tegner score, P-value: 0.643). Saupé N et al^[xvi]. Also increase in signal intensity did not occur in each graft. Therefore to understand the normal process of graft maturation further study is required.

Majority of the patients in our study were less than 30 years in age i.e. 13 out of 30 (43.33%). This is in consensus with previous study^[xvii] and causes of anterior cruciate ligament tear were mainly fall from height, road traffic accident and while playing.

There are other causes of increased graft signal intensity on short-echo time images that may lead to a false interpretation of a impingement, discontinuous or torn graft^[xviii] as there is variations in the density of the fiber bundles and the mobility of intrasubstance

protons also it has been hypothesized that focal increased ACL graft signal intensity on intermediate-weighted acquisitions to be related to subtle alterations in the collagen structure of the graft caused by instrumentation or mechanical stress^[xviii]. In order to prevent the false interpretation of signal intensity we did study by using short-echo time images and T2 weighted images.

However degenerative changes within graft on long term follow up may show mild intrasubstance signal changes within an ACL graft^[xix].

Conclusion:

In our study we did not found any significant association between intrasubstance signal intensity

within anterior cruciate ligament reconstruction graft among the two third of patients and subjective scores i.e. IKDC score and Tegner score which consists of questions in the domain of symptoms, functioning during activities of daily living and sports, current function of the knee, and participation in work and sports 6 months after surgery. Mild degree of intrasubstance signal intensity may persist at long term follow up due to the process of maturation and remodeling process of graft however the exact cause of intrasubstance signal intensity has not proved by study.

Tables and figures:

Table 1: Comparison of percentage of increased signal intensity of cross sectional area with IKDC score.

| IKDC score | PERCENTAGE OF INCREASED SIGNAL INTENSITY OF CROSS SECTIONAL AREA | | | | | |
|-------------------|--|--------|----------------|--------|----------------|--------|
| | <25% | | 25-50% | | >50% | |
| | Present | absent | Present | absent | Present | absent |
| Severely abnormal | 1 | 1 | 1 | 1 | 0 | 2 |
| Abnormal | 6 | 8 | 1 | 13 | 1 | 13 |
| Nearly normal | 5 | 5 | 1 | 9 | 1 | 9 |
| Normal | 3 | 1 | 0 | 4 | 0 | 4 |
| | P-value: 0.836 | | P-value: 0.303 | | P-value: 0.999 | |

Table 2: Comparison of percentage of increased signal intensity of cross sectional area with Tegner score.

| TEGNER score | PERCENTAGE OF INCREASED SIGNAL INTENSITY OF CROSS SECTIONAL AREA | | | | | |
|--------------|--|--------|----------------|--------|----------------|--------|
| | <25% | | 25-50% | | >50% | |
| | Present | absent | Present | absent | Present | absent |
| Excellent | 2 | 2 | 1 | 3 | 0 | 4 |
| Good | 6 | 5 | 1 | 10 | 1 | 10 |
| Fair | 6 | 7 | 0 | 13 | 1 | 12 |
| Poor | 1 | 1 | 1 | 1 | 0 | 2 |
| | P-value: 0.999 | | P-value: 0.068 | | P-value: 0.999 | |



Figure 1a :sagittal intermediate-weighted (2000/21.3) MR Image shows striated increased signal intensity within the ACL graft (white arrow).



Figure 1b :axial T2-weighted (3500/70) MR Image shows increased signal intensity within the ACL graft (white arrow), which comprised between 25-50% of the maximum cross-sectional area of graft.

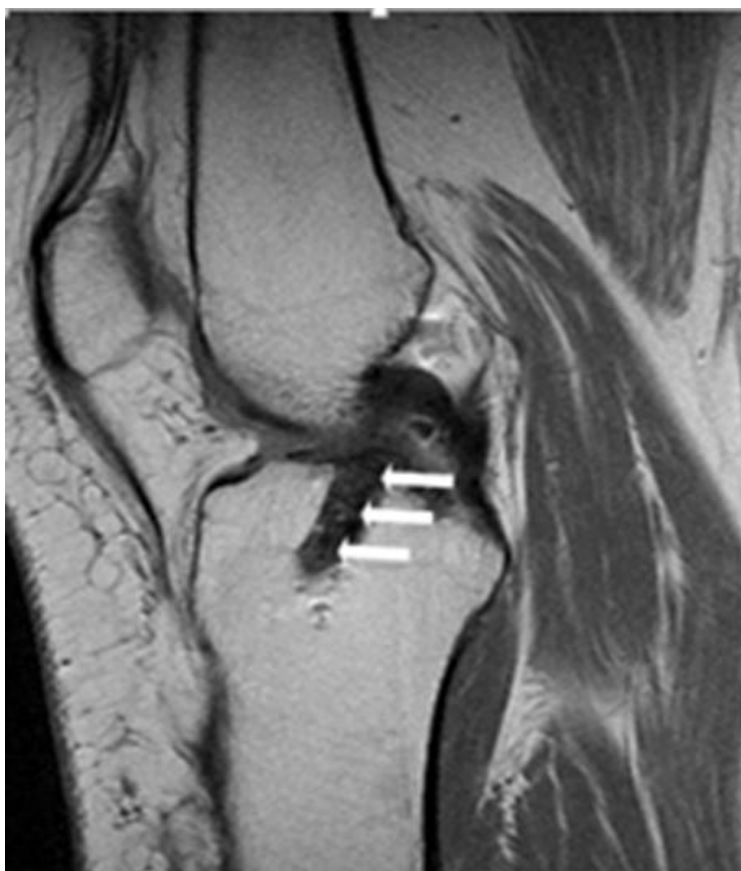


Figure 2a :sagittal intermediate-weighted (2000/21.3) MR Image shows striated increased signal intensity within the ACL graft (white arrow).



Figure 2b: axial T2-weighted (3500/70) MR Image shows increased signal intensity within the ACL graft (white arrow), which comprised more than 50% of the maximum cross-sectional area of graft.

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