Anterior cruciate ligament reconstruction: Magnetic resonance imaging and factors influencing outcome

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Abstract  Purpose: This study was conducted to determine the magnetic resonance imaging (MRI) findings in cases of complications following anterior cruciate ligament (ACL) reconstructive surgery, and to correlate these complications with their possible etiological factors based on clinical and radiological criteria.

Methods: The study included 48 symptomatic patients (40 males and 8 females) after arthroscopic ACL reconstruction in the period between 2006 and 2008. Clinical evaluation of the patients was performed using the International Knee Documentation Committee scoring system (IKDC). MRI was performed using 1.5 T dedicated system and a standard imaging protocol. The scans were then reviewed by two senior radiologists for the assessment of integrity of the reconstructed ligament and the presence of related complications. The findings were then analyzed and correlated with the clinical evaluation.
1. Introduction

In recent years the increased number of patients undergoing arthroscopy or surgery of the knee for anterior cruciate ligament (ACL) tears has lead to an increase in the number of patients referred for magnetic resonance imaging (MRI) after surgery because of failure to improve, recurrent symptoms, or new injury (1). A number of arthroscopic techniques have been found to work well in the reconstruction of a torn anterior cruciate ligament (ACL), which is known to provide long-term stability, have the benefit of being minimally invasive and of causing less iatrogenic damage. With the development of these techniques, the choice of graft harvesting site, anatomic positioning, and proper graft fixation have also become important technical factors (2).

In our institution (Razi Hospital), which is a specialized musculoskeletal center in Kuwait, an average of 500 patients per year undergo arthroscopic ACL reconstruction and about 5-7% of those develop postoperative complications and graft failure. All reconstructions were performed by experienced surgeons using the semitendinosus and gracilis tendons autograft. Graft fixation was done in the femur by using endobutton system (Smith and Nephew Endoscopy, Andover, Massachusetts), interference screws or transgraft bioabsorbable pins. The graft fixation in the tibial tunnel was done by using interference screws; (metal) in 27 cases (56.25%) and (bioabsorbable) in 21 cases (43.75%).

Our purpose in this study is to demonstrate the commonest complications encountered after ACL reconstruction and to evaluate the role of MRI in their diagnosis, as well as to correlate those complications with their possible etiological factors based on clinical and radiological assessments.

2. Methods

Our study included 48 patients (40 males and 8 females) who had a complicated unilateral arthroscopically reconstructed ACL in the period between March 2006 and December 2008. The average time interval after the reconstruction was 1 year, where the patients were supposed to finish the rehabilitation and restore their normal activity with good stability, range of motion and no significant pain.

One hundred patients with good post reconstructive outcome (free of symptoms) were followed for 1 year during the same period of time after the reconstruction and were considered as a control group. Patients who never restore normal activity after reconstruction were supposed to be due technical faults or faulty management, while patients who had period free of symptoms with normal activity were supposed to have a new injury or developing complications.

The ages of the patients ranged from 16 to 46 years with a mean age of 31 years. The patients’ main complaints are outlined in (Table 1). Subjects with concomitant meniscal or collateral ligament tears were included in the study, while subjects with concomitant posterior cruciate ligament tear or contralateral knee injury were excluded. All our patients underwent almost the same post-operative rehabilitation protocol. Clinical evaluation of the patients was performed and we used the International Knee Documentation Committee (IKDC) scoring system (3) (Table 2) for all patients.

MRI for the 48 patients was performed with a 1.5 T dedicated system using a transmit-receive extremity coil. The knee was placed in 10-15° external rotation (to orient the ACL with the sagittal imaging plane). The same scanning protocol was used for all patients: axial, sagittal, and coronal T1 weighted spin echo sequences (repetition time of 500 ms, echo time of 20 ms, 22 cm field of view, 4 mm slice thickness with no interslice gap, and a 256 matrix), and sagittal and coronal proton density fat suppressed (PD FAT SAT) fast-spin-echo sequences were used (repetition time of 4000 ms, echo time of

### Table 1 Presenting symptoms in the 48 patients included in the study.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>No. of cases</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>48</td>
<td>100</td>
</tr>
<tr>
<td>Instability ± locking</td>
<td>36</td>
<td>75</td>
</tr>
<tr>
<td>Swelling</td>
<td>25</td>
<td>52</td>
</tr>
<tr>
<td>Clicking and stiffness</td>
<td>14</td>
<td>29.16</td>
</tr>
<tr>
<td>Failure to regain full extension</td>
<td>10</td>
<td>20.8</td>
</tr>
</tbody>
</table>

*More than one symptom was encountered in most of the patients, e.g. pain and instability or pain and swelling, etc.*

### Table 2 IKDC scores for the 48 patients with ACL graft complications included in our study.

<table>
<thead>
<tr>
<th>IKDC*</th>
<th>No of cases</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Nearly normal</td>
<td>1</td>
<td>2.08</td>
</tr>
<tr>
<td>Abnormal</td>
<td>33</td>
<td>68.75</td>
</tr>
<tr>
<td>Severely abnormal</td>
<td>14</td>
<td>29.16</td>
</tr>
</tbody>
</table>

*IKDC, The International Knee Documentation Committee scoring system.*
35 ms, 23 cm field of view, 1-3 mm slice thickness “thin section”, and a 256 matrix). An additional sagittal gradient-weighted spin-echo (GRE) sequence was obtained whenever indicated for better assessment of meniscal tears.

Indications for MR imaging after ACL reconstruction include continued joint instability, knee stiffness or pain, a new injury of the knee, and preoperative evaluation for revision of a clinically apparent failed ACL graft.

3. Results

MRI scans were performed to assess the integrity of the ACL graft, presence or absence of graft impingement, cystic degeneration, Cyclops lesion, arthrofibrosis, tunnel widening, and secondary osteoarthritic changes. Associated meniscal or ligamentous injuries were also evaluated.

The depicted clinical signs in our patients’ series were correlated with the MRI findings as shown in (Table 3).

3.1. Graft tear

Graft tear was the commonest cause of graft failure in the included cases (Figs. 1 and 2). All our 34 patients who had a graft tear on MRI scans showed positive tests of torn ACL on clinical examination (anterior drawer, Lachman test (Table 4), and pivot shift test). Of those patients, 20(41.66%) had partial tear, 6(12.5%) had near total tear and 8(16.66%) had complete tear of the ACL graft. These findings were almost matching with the arthroscopic results during revision surgery; as 8 patients (16.66%) showed complete tear and the remaining patients showed variable degrees of partial tear. New injury was experienced in most cases, as 26/34 patients (76.47%) had a history of major twisting trauma after reconstruction. 3/34 patients (8.82%) had history of early aggressive rehabilitation. Other 3/34 patients (8.82%) had history of minor trauma, while the remaining 2/34 patients (5.88%) had residual instability after the reconstruction. In addition, we found that the rate of tear in the grafts fixed by bioabsorbable screws (16/21 patients) 76.19% was higher than that seen in the group where metal fixation screws were used (18/27 patients) 66.66%.

3.2. Graft impingement

The MRI scans revealed graft impingement in 12 patients (25%). Eight patients (16.66%) showed anterior placement of tibial tunnel (partially or completely anterior to the slope

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Table 3  MRI vs. clinical findings among the encountered 48 patients in the study.

<table>
<thead>
<tr>
<th>MRI finding</th>
<th>Clinical findings</th>
<th>No. of cases</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACL graft tear</td>
<td>Instability-pain and locking</td>
<td>34</td>
<td>70.83</td>
</tr>
<tr>
<td>Impingement</td>
<td>Loss of motion and pain</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>Cystic degeneration</td>
<td>Pain</td>
<td>2</td>
<td>4.16</td>
</tr>
<tr>
<td>Cyclops lesion</td>
<td>Loss of full extension and locking</td>
<td>2</td>
<td>4.16</td>
</tr>
<tr>
<td>Tunnel widening</td>
<td>Pain</td>
<td>42</td>
<td>87.5</td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td>Clicking-stiffness and pain</td>
<td>6</td>
<td>12.5</td>
</tr>
</tbody>
</table>

*More than one pathology was encountered in some patients, e.g. graft impingement and tunnel widening or osteoarthritis and tunnel widening.

*bIn each group one or more than one clinical findings could be present, e.g. pain was present in most cases besides other clinical findings like instability, locking, clicking, stiffness, etc.
of the intercondylar notch (Fig. 3). In two patients (4.16%) the impingement was due to osteophytes from the intercondylar notch, and in the remaining two cases (4.16%) the graft was mildly impinged by osteophytes from the tibial plateau and margins of the tibial tunnel (Fig. 2).

**Table 4**  Outcome of the Lachman test in our 48 patients with ACL graft complications.

<table>
<thead>
<tr>
<th>Lachman test</th>
<th>No. of cases</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative results</td>
<td>6</td>
<td>12.5</td>
</tr>
<tr>
<td>Grade I</td>
<td>10</td>
<td>20.83</td>
</tr>
<tr>
<td>Grade II</td>
<td>23</td>
<td>47.9</td>
</tr>
<tr>
<td>Grade III</td>
<td>9</td>
<td>1.75</td>
</tr>
</tbody>
</table>

* A negative test result represents inconclusive results (some patients were guarding on exam), while knees with positive results had an abnormal ligament laxity.

Figure 3  (a and b) Thin sections sagittal proton density fat suppressed MR images showing anterior placement of the tibial tunnel in relation to the projected slope of the intercondylar notch (long line), resulting in marked ACL graft impingement against the anterior inferior margin of the intercondylar roof (white arrow). (c) Sagittal T1WI for the same patient demonstrating the significantly widened tibial tunnel (black arrow).

Figure 4  Sagittal thin section PD fat sat MR image showing cystic degeneration of the graft in a 32-year-old patient demonstrated as elongated cystic formation in an intact graft (white arrow). Adjacent subchondral cysts are also seen (arrowheads).
3.3. Cystic degeneration of the graft

It was diagnosed in two of our patients (4.16%) and both had mild post reconstructive pain (Fig. 4).

3.4. Cyclops lesion

It was also seen in two patients (4.16%) who complained of loss of last (15–30°) degrees of extension (Fig. 5).

3.5. Bone tunnel widening

In all the patients showing bone tunnel enlargement (Fig. 3) the reconstruction was performed a year or more earlier. The mean tibial tunnel antero-posterior (AP) diameter as measured on MRI was largest among the patients with abnormal laxity, while the mean femoral tunnel AP diameter was largest in patients with grafts fixed by endobuttons and bioabsorbable screws. The diameter of the drill used to create the tunnel at the time of surgery was used as the original tunnel width, and was subtracted from the tunnel width determined by MRI at the final follow up to express the difference as a percentage of the original width (Table 5).

3.6. Osteoarthritis

In the six cases (12.5%) exhibiting osteoarthritic changes of the tibiofemoral and/or the patellofemoral joints, the ACL reconstructive surgery was performed more than 18 months earlier. Two of them had an interval time of more than 6 months between the injury and surgery. The remaining four patients had an associated meniscal injury.

Other associated injuries of the knee which were detected in patients with graft failure included: grades 1–2 sprain of the medial collateral ligament in 12 patients (25.0%), complete tear of the medial collateral ligament in three patients (6.25%); who had to have surgical repair of the injured ligaments, and grades 1–2 sprain of the lateral collateral ligament in four patients (8.33%).

New meniscal tears were seen in five patients (10.41%). Three (6.25%) of them involved the posterior horn of the medial meniscus, and two (4.16%) had posterior horn lateral meniscal tear. Only two patients (4.16%) with medial meniscal tear were in need for meniscal repair, while the remaining three patients (6.25%) had small tears and were managed conservatively.

4. Discussion

Arthroscopic reconstruction of the anterior cruciate ligament is a frequently performed procedure generally with good results. However, complications of the surgical procedure are not infrequent (4). The causes of such complications can be divided into three categories: technical, biologic, and external. Technical causes include: non-anatomic tunnel placement, hardware failure, inadequate notchoplasty, improper tensioning and graft fixation, and insufficient graft material. Biologic causes include: failed ligamentization (for those grafts which were not originally ligaments), infection, arthrofibrosis and infrapatellar contracture syndrome. External causes for failure...
The menisci and articular cartilages (7). MRI is the most valuable imaging method for postoperative evaluation of the knee. It is noninvasive and has multiplanar imaging capabilities that are useful for assessing tunnel positioning and other structures of the knee. It offers the added benefit of direct visualization of the graft with excellent soft tissue contrast (6). Indications for post operative MRI include persistent knee instability, extension lag, new injury of the knee and preoperative evaluation for revision of failed ACL grafts, since it provides information on the size and position of the tibial and femoral tunnels as well as the condition of the menisci and articular cartilages (7).

Many authors (8–10) emphasized the ability of MR imaging in the detection of complications of ACL reconstruction. Also, comparative studies have been done on specific topics including the impact of different types of grafts (11) and fixation screws (12) used in graft reconstruction on the outcome of the reconstructed ACL. Studies on the effect of tunnel enlargement on graft integrity and knee stability have been published as well (13).

By analyzing the MRI examinations for the presented cases of graft failure and correlating the findings with surgical and clinical data including thorough history taking, we found the causes of graft failure and their possible underlying etiological and predisposing factors as follows:

4.1. Graft tear

As MRI provides direct visualization of the graft fibers, we considered the graft to be disrupted completely when there was absence of intact fibers, or partially torn when some fibers remain intact in the dedicated thin section sagittal and coronal scans.

Knee instability in patients with graft tear was evident on clinical examination and by functional scoring. This is in agreement with Collins et al. (14), who stated that graft failure manifested clinically as knee instability. Also coinciding with our study, Jomha et al. (15), reported that significant traumatic injury was found to be the most common cause of graft rupture and re-operation, now that many of the technical problems of the surgery have been perfected, while early aggressive rehabilitation may be a predisposing factor for graft failure.

4.2. Graft impingement

Graft impingement was the second most common cause of graft failure in many series (2,4). This was matching with our results as graft impingement was encountered in 12 patients (25.0%) of our series which constituted the second cause of graft failure.

As in agreement with Papakonstantinou et al. (4), the cause of graft impingement in our series was mostly due to technical fault especially when the tibial tunnel was placed partially or completely anterior to the projected slope of the intercondylar roof in the extended knee and was shown in the plain X-rays and sagittal MRI studies of the patients. This caused the distal half of the roof to impinge the anterior surface of the graft during knee extension resulting in loss of terminal knee extension and a likelihood of graft rupture. The intra-articular portion of the impinged graft showed abnormal morphology with increased signal intensity on T1 and T2 weighted images; usually involving the distal two thirds of the graft.

Other causes of graft impingement in our study included osteophytes from the intercondylar notch (notch stenosis) and osteophytes from the tibial plateau and margins of the tibial tunnel which was indicative for roofoplasty and lateral notchoplasty.

4.3. Cystic degeneration of the graft

This appeared on MRI as elongated cystic lesion between the intact graft fibers. It was seen 2 years after ACL reconstruction in the two patients with this diagnosis. Both patients complained of pain and one of them had mild limitation of movement. However, no instability was detected in either patients. On MRI the graft appeared intact with some fibers seen splayed apart around loculated fluid intensity and significant tunnel enlargement was noted in both cases. This is in agreement with Papakonstantinou et al. (4) who stated that cystic degeneration of the ACL graft is a late complication that is usually accompanied by enlargement of the bone tunnel and is not associated with graft failure or knee instability. No evident cause or predisposing factor for such complication was identified, however, it has been suggested that hamstring autograft and fixation of the graft with endobuttons (soft tissue graft with insecure fixation) may predispose to cystic degeneration (16).

4.4. Cyclops lesion

Cyclops lesion is a fibroproliferative scar nodule that develops after ACL reconstruction using all types of grafts. It can be caused by a residual ACL stump, residual bony or cartilage debris, and hypertrophy of graft fibers (17).

It is most commonly located anterolateral to the tibial tunnel. It appears as a well circumscribed nodule of intermediate to low signal intensity on T1WI in the intercondylar notch just anterior to the tibial insertion of the graft and posterior to the infrapatellar pad of fat, and as a head-like fibrous lesion with a reddish-blue areas of discoloration at arthroscopy (18).

With extension, painful impingement occurs between the nodule and the intercondylar notch, blocking terminal extension (19).

This is consistent with our results, where both our patients had presented with loss of terminal extension of the knee making it the second most common cause of postoperative loss of terminal extension.

In recent years the incidence of this complication is noted to be relatively low compared to the early days when ACL reconstruction was first performed, presumably due to the developed techniques and skills of the surgeons with less manipulations and invasiveness of the technique, and consequently less fibrous tissue and inflammatory reaction around thegrafted ACL (18).

4.5. Bone tunnel widening and fixation screws

Herseki et al. (13) considered that bone tunnel enlargement was only a radiological finding and did not affect the clinical results of ACL surgery. Also expansions of the femoral tunnel up to 77% and tibial tunnel up to 42% have been reported and
appears to occur universally after ACL reconstruction with autogenous hamstring tendons (20). Emond et al. (21) reported that bioabsorbable screws and metal screws have similar fixation strengths, and that there is no significant difference in outcomes between these screw types for ACL reconstruction, although bioabsorbable screws may be associated with an increased inflammatory response, an increased risk of screw breakage, incomplete screw absorption, or tunnel widening.

However, in our study there was a significant widening of the mean tibial tunnel AP diameter in patients with abnormal laxity, and the mean femoral tunnel AP diameter was largest in patients with grafts fixed by bioabsorbable screws. This is in agreement with the work of Moisala et al. (12) who stated that the tunnel widening in the tibia was associated with knee laxity. He also reported a graft failure rate of about 23% among patients with bioabsorbable screws and 6% in those where metal screws were used. The exact cause of bone tunnel enlargement is not yet known, however, it may be due to accumulation of peri-ligamentous tissue around the graft or graft movement within the tunnel, especially when the graft fixation is away from the joint line which may allow for increased graft-tunnel motion (22).

After all, tunnel expansion remains a treatment challenge in patients who require a revision ACL reconstruction (23).

4.6. Osteoarthritis

Long term squeal of ACL reconstruction have not yet been defined and some believe that such ligament reconstruction does not protect the knee joint from osteoarthritis as it can cause degenerative changes by altering the natural symmetry of the knee, causing compression of articular cartilage and changes in joint biomechanics (24).

In the current study, osteoarthritic changes and therefore poor outcome after ACL reconstruction was noted mostly in patients with long interval time (more than 6 months) between the injury and reconstruction, as well as among those who had other associated injuries like meniscal or collateral ligament tears. This is in agreement with Seon et al. (25), who reported that significant independent predictors of osteoarthritis were accompanying meniscal injury, an interval more than 6 months from injury to reconstruction, and age more than 25 years at reconstruction.

5. Conclusion

MRI is the most valuable imaging modality for postoperative evaluation of the knee. It is useful to evaluate tunnel positioning, graft integrity, and other soft tissue structures of the knee. A new traumatic injury was found to be the most common cause of graft failure or re-tear. Other causes include early aggressive rehabilitation, graft impingement mostly due to technical faults (like anterior placement of the tibial tunnel), Cyclops lesion, cystic degeneration of the graft, and early osteoarthritis.

It is noted that the bioabsorbable femoral screws and endobuttons used for graft fixation were associated with relatively higher incidence of femoral tunnel widening and graft failure than the metal screws. Also cases of tibial tunnel widening were associated with significant knee laxity. However, we believe that there is still a need for long term follow up of the reconstructed ACL patients on a wide scale for better evaluation of the different factors influencing the outcome of the ACL graft.

References


