The natural history and treatment of rupture of the anterior cruciate ligament in children and adolescents

A PROSPECTIVE REVIEW

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A total of 60 children and adolescents with rupture of the anterior cruciate ligament (ACL) was seen between 1980 and 1990. Observation of the 23 patients who were treated conservatively revealed that the natural history of the injury resulted in severe instability and poor function of the knee. Associated meniscal tears were present in 15 knees. Three osteochondral fractures occurred and osteoarthritic changes developed in ten knees.

In 1990 therefore we introduced reconstruction of the ACL with a four-strand hamstring graft using an anatomical placement with transphyseal tunnels and anchorage well away from the growth plate. Over a period of nine years, 47 knees underwent reconstruction. The mean follow-up was 49 months (12 to 96). No child suffered physeal damage or leg-length discrepancy. The results were satisfactory in 77% and there was little difference between patients treated before the adolescent growth spurt and those treated during or after this time. These results, however, were not as good as those seen in adults during the same period.

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Between 1980 and 1990, 60 children and adolescents were seen with a confirmed diagnosis of rupture of the anterior cruciate ligament (ACL). We were able to study 33 of these children prospectively over this ten-year period. Since it was thought that reconstruction in the immature patient was likely to damage the epiphyseal growth plates, these children were treated by physiotherapy, rehabilitation, bracing and reduction of activities. As they were keen sportsmen it was often impossible to control their sports activities. Ten of the 33 required a stabilisation procedure during this period due to increasing instability. Apart from associated operations for meniscal or osteochondral damage, the remaining 23 were able to continue with conservative treatment and this group allowed us to observe the natural history of the injury. Nearly half had presented with meniscal tears at the time of diagnosis and a further quarter sustained another meniscal tear during the ten-year period. They were unable to continue with sports and the function of their knee deteriorated progressively. We concluded that rupture of the ACL in children and adolescents was not a benign condition. Episodes of giving-way, pain, swelling and irritability were common. In many, the associated meniscal tear or osteochondral damage had led to degenerative changes at the time of the final review.

In view of the progressive deterioration seen during the period of conservative management, we decided to undertake reconstruction at an earlier stage using hamstring grafts to avoid damage to the growth plate by the bone plug of a bone-patellar-tendon-bone graft. This has already been reported.1,2 In 1990 we began to reconstruct these knees with hamstring grafts positioned in the anatomical site using tunnels which breached the physeal plate as perpendicularly as possible. Over a period of nine years we have treated 47 knees in 45 patients and now report our findings.

Patients and Methods

Untreated group. All 23 patients (16 boys and 7 girls) sustained their knee injury during sports. Their mean age at the time of injury was 12.5 years (11 to 15). The mean period of follow-up was 72 months (36 to 144).

Reconstruction group. In this group there were 45 children and adolescents (32 boys and 13 girls; 47 knees) with rupture of the ACL after a sports injury (Table I). Their mean age was 13 years (11 to 15). In all reconstruction was performed arthroscopically using a four-strand hamstring technique. Two patients had bilateral reconstructions. The technique was the same as that for adults, except that the tibial and femoral anchors were carefully positioned well away from the physes. A titanium stirrup through which the four-stranded graft was looped was used for the tibial anchorage. On the femoral side, the graft was fixed by a titanium screw/claw anchor (Fig. 1). The mean follow-up was 49 months (12 to 96).
An attempt was made to grade the stage of maturation of these children at the time of surgery using a modification of the Tanner\textsuperscript{3} staging for boys and girls (Table II) and the patients were separated into three groups. The prepuberty and puberty groups comprised children before the adolescent growth spurt. They were shorter than their older siblings and their parents, and were in Tanner stages 1, 2 or 3. There were six children in the prepuberty group and 18 in the puberty group. In the adolescent group (Tanner stages 4 and 5) the growth plates are still open, but the patients are undergoing or beyond their final growth spurt. There were 21 patients in this group.

Results

Untreated group. When first seen, all 23 patients had clinical signs of knee instability with a Lachman grade of 2 or 3 and a pivot-shift of grade 2 or 3 (Table III). The mean Lysholm score was 78.6 (54 to 93). The mean Tegner activity level was 6.7 (4 to 9). At a mean follow-up of 72 months knee instability was severe. The mean Lysholm score had fallen to 52.4 (30 to 83) and the mean Tegner activity level to 4.2 (2 to 6). In the early 1980s the International Knee Documentation Committee (IKDC) method of assessment was not available.

At diagnosis, 14 meniscal tears had been detected (8 medial and 6 lateral) and three osteochondral fractures. Nine children had partial tears of the medial collateral ligament, all of which healed without operative treatment. Four subsequently required arthroscopic partial medial meniscectomy and three arthroscopic partial lateral meniscectomy during the observation period.

At the final review, many of these patients were at the end of their second decade. Radiological signs of degenerative changes were seen in ten. All showed a substantial Fairbank sign\textsuperscript{4} on the femoral condyle, three narrowing of the joint space, and four major osteophytes.

Reconstruction group. At diagnosis, all the patients had Lachman and pivot-shift tests of grade 2 or grade 3. At arthroscopy, a grade-3 meniscal tear was seen in 17 (8 lateral and 9 medial) and osteochondral injuries in six. Most of the meniscal tears were repaired by sutures, but seven were trimmed. The results of reconstruction showed marked improvement in the pivot-shift and Lachman tests. Three knees had a grade-3 pivot-shift test and two a grade-2, while 15 had grade-1 and 27 grade-0. Three knees had a grade-3 Lachman test, eight a grade-2, 20 a grade-1 and 16 a grade-0.

The overall IKDC scores at the final review were grade A in 21 knees (45%), grade B in 15 (32%), grade C in eight (17%) and grade D in three (6%). Analysing the 24 children (25 knees) in the prepubertal and pubertal groups alone the results were similar; 13 knees (52%) were grade A, five (20%) grade B, six (24%) grade C and one (4%) grade D.

There were three cases of rerupture in the 47 knees. In all three, the grafts appeared to be vascularised on arthroscopy. One rerupture occurred four months after surgery when the child was pushed down stairs at school. The other two occurred during sports, 15 and 18 months after operation. In both, the medial meniscus was also torn.

Arthroscopy showed that rerupture of the graft in these children had a similar appearance to that in adults.

Table I. Method of injury of the 45 patients (47 knees) in the reconstruction group

<table>
<thead>
<tr>
<th>Method of injury</th>
<th>Number of knees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Football and rugby</td>
<td>25</td>
</tr>
<tr>
<td>Ski-ing</td>
<td>10</td>
</tr>
<tr>
<td>Gymnastic activities</td>
<td>5</td>
</tr>
<tr>
<td>Basketball</td>
<td>4</td>
</tr>
<tr>
<td>Volleyball</td>
<td>1</td>
</tr>
<tr>
<td>Dancing</td>
<td>2</td>
</tr>
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</table>

Table II. Details of the Tanner\textsuperscript{3} staging used to define prepuberty, puberty and adolescence

<table>
<thead>
<tr>
<th>Stage</th>
<th>Boys</th>
<th></th>
<th>Girls</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pubic hair</td>
<td>Penis/testes</td>
<td>Pubic hair</td>
<td>Breasts</td>
</tr>
<tr>
<td>Prepuberty</td>
<td>1</td>
<td>None</td>
<td>Small</td>
<td>None</td>
</tr>
<tr>
<td>Puberty</td>
<td>2</td>
<td>Scanty/slight pigment</td>
<td>Slightly enlarged</td>
<td>Sparse, lightly pigmented</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Darker beginning to curl</td>
<td>Longer, larger</td>
<td>Darker, beginning to curl</td>
</tr>
<tr>
<td>Adolescence</td>
<td>4</td>
<td>Resembles adult but less quantity</td>
<td>Larger glans/dark scrotum</td>
<td>Course, abundant</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Adult. Spread to thighs</td>
<td>Adult size</td>
<td>Feminine triangle. Spread to thighs</td>
</tr>
</tbody>
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\textsuperscript{3}THE NATURAL HISTORY AND TREATMENT OF RUPTURE OF THE ACL IN CHILDREN AND ADOLESCENTS

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previously thought, these patients. The deficiency of the ACL is not benign, as signs of osteoarthritis were seen in a high proportion of meniscal injury and osteochondral damage. Radiological deterioration and bracing. Continued instability led to further deterioration in function. Very few were able to maintain their sporting activities, even after physiotherapy, rehabilitation, and bracing. We were able to observe the natural history of this injury in a group of children who were treated conservatively. They developed progressive instability of the knee and deterioration in function. Very few were able to maintain their sporting activities, even after physiotherapy, rehabilitation, and bracing. Continued instability led to further meniscal injury and osteochondral damage. Radiological signs of osteoarthritis were seen in a high proportion of these patients. The deficiency of the ACL is not benign, as previously thought, and we decided therefore that a more aggressive approach to disruption of the ACL in the skeletally immature patient was indicated. It would appear that early stabilisation of the knee is important to prevent further derangement and later osteoarthritis.

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An anatomical position of the graft appears to be necessary for satisfactory stabilisation of the knee. Non-anatomical positioning without drill holes has been advocated by Brief and Parker, Driz and Cooper, but this type of reconstruction is not thought to be ideal. In one study reconstruction used grafts passing ‘over-the-top’ of the femoral condyles with a tunnel drilled through the tibial physis. Good results were obtained but the number in the study was small. Kim et al described a novel method of internally fixing a hamstring graft into the epiphysis using an interference screw without damage to the epiphyseal growth plate. This, however, may be mechanically unsatisfactory because of the short distance between the surface of the tibial plateau and the physis in the child. Most surgeons in the past have avoided drilling through both physes to produce tunnels for accurate autograft reconstruction because of the potential risk of physeal damage.

The important issue is whether a tunnel of 7 to 9 mm through the physis will produce growth arrest and deformity. Evidence from experimental animals suggests that more than 7% of the physis has to be damaged to produce such arrest. An appropriate tunnel involves much less than 7% of the physis.

There are only two reports which have described physeal damage to a child’s knee after reconstruction of the ACL. Lipscomb and Anderson described a series of adolescent patients who had reconstruction using semitendinous grafts with both femoral and tibial tunnels. There was one case of growth arrest, which was probably produced by the staple used for fixation. Koman and Sanders described a boy with open physis in whom reconstruction with a hamstring graft had been undertaken. The tunnels were packed with bone and the radiograph clearly shows that the femoral fixation device passes through the physis.

In a recent survey by Kocher et al the ACL Study Group and members of the Herodicus Society were circulated. There were 15 reported cases of disturbance of growth. In three of these there was a bone plug of a patellar tendon graft across the physis and in five a fixation device crossed the growth plate.

McCarroll, Rettig and Shelbourne described a series of 24 young athletes with open physes in whom a bone-patellar-tendon-bone graft had been inserted with the usual tunnels. No arrest of growth occurred, but this group was near maturity and little physeal growth remained. Andrews, Noyes and Barber-Westin described eight children with a mean age of 13.6 years in whom alligrafts had been inserted through a 7 mm drill hole. They noted no leg-length discrepancy at skeletal maturity.

In view of the rarity of physeal damage reported in the literature in 1990, the senior author (PMA) began reconstruction of the ACL in children with open physes using a four-strand hamstring graft. All were assessed for subsequent growth disturbance, clinically and radiologically, and none was detected.

In our series of 47 knees the results were satisfactory in 75% and unsatisfactory in 25%. The final results, assessed by the IKDC scoring system, are poorer than those in adults. Children often have lax joints and this can present a problem in some reconstructions. Irrepressibly sports-active children frequently return to high activities against advice as soon as they are released from hospital. This may be the cause of many grade-C laxities. The higher incidence of rerupture is also a problem in the immature and may be a manifestation of childhood sporting exuberance. One 13-year-old child in our series had a rerupture of the ACL when pushed down stairs at school, but the others occurred while playing sport more than one year after reconstruction. Rerupture was the cause of the grade-D results.

The Tanner grading was used in a modified form to differentiate pubescent, pubescent and adolescent groups. However, the IKDC grading for pubescent and

### Table III. Details of the pivot-shift test and Lachman test grading systems. The numbers in parentheses refer to the number of patients

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<thead>
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<th>Pivot-shift test</th>
<th>Lachman test</th>
</tr>
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<tbody>
<tr>
<td>Grade 0 Normal (0)</td>
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</tr>
<tr>
<td>Grade 1 Glide, no jerk (0)</td>
<td>Grade 1 Equivalent of 3 to 5 mm (0)</td>
</tr>
<tr>
<td>Grade 2 Mild jerk (7)</td>
<td>Grade 2 Equivalent of 6 to 10 mm (10)</td>
</tr>
<tr>
<td>Grade 3 Major jerk (16)</td>
<td>Grade 3 Equivalent &gt;10 mm (13)</td>
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**Discussion**

Children and teenagers are participating in increasing numbers in competitive and recreational sports at a high level. With the evolution of the ‘young athlete’, there has been a rise in sporting injuries in this age group. Knee complaints are common and there has been an increase in non-osseous disruption of the ACL. Stanitski, Harvell and Fu found that sports injuries were the cause of 70% of acute haemarthroses in children. Tears of the ACL accounted for 63% of these injuries. Awareness of this problem and improvements in diagnosis has led to an increasing number of children and adolescents being treated for deficiency of the ACL while they are still growing. The injury may avulse a fragment of the tibia requiring reduction and sometimes internal fixation to ensure stability of the knee. However, the management of intrasubstance non-osseous tears of the ACL remains a contentious subject.

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The Tanner grading was used in a modified form to differentiate pubescent, pubescent and adolescent groups. However, the IKDC grading for pubescent and
pubescent children differed little from that for reconstruction in the whole group.

It was thought to be important to use hamstring tendon for reconstruction rather than patellar tendon. The bone plugs of patellar tendon grafts straddle the physes and could damage the growth plate.

The harvesting technique was exactly as that undertaken in the adult. It was interesting to note that the hamstring tendons were surprisingly large in proportion to the size of the child. Exact placement of the graft was undertaken using an arthroscopic technique. The tunnels were drilled to the exact size of the compressed four-strand graft using sizing tubes for measurement and were tightly filled by the graft.

It is presumed that the graft increases in size because it is vascularised and the knee is never ‘captured’ after operation with increasing flexion contracture because of a reconstruction which is too tight. The fixation anchors grow away from the physes particularly on the femoral side (Fig. 2).

The intercondylar notch in this group of children was in proportion to the size of the femoral condyles and no notchplasty was required. This is of interest when compared with children with congenital deficiency of the ACL in whom the notch is small and rudimentary. No child with congenital deficiency was included in this series.

The rehabilitation programme was slower than that undertaken in the adult since the children usually tried to return to full activity too quickly. Early extension was encouraged to zero, but not beyond. Only those children with marked genu recurvatum were braced with extension limited to -5°.

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References