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Case report

Paediatric physeal sparing posterior cruciate ligament (PCL) reconstruction with parental donation allograft: Rationale and operative approach

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ABSTRACT

Background: Paediatric PCL injuries are rare but constitute a significant management challenge. We describe a novel approach to the surgical management of an 11-year-old boy who presented with persisting symptomatic instability following 18 months of failed conservative therapy.

Methods: PCL reconstruction was performed using a physeal sparing, all-inside technique under fluoroscopic control. This avoids the potential for iatrogenic growth injury. A parentally donated hamstrings allograft was used to ensure adequate graft size, and reinforced using a non-elastic two millimetre braided suture. Graft reinforcement safeguards against stretching during the early healing phase, but must be removed thereafter to avoid creating a physeal tether.

Results: At three months, clinical examination under anaesthesia showed equivalent PCL laxity in the operated knee compared to the normal contralateral knee. The graft reinforcement tape was incised as planned with no change in laxity assessment. Arthroscopic evaluation demonstrated a quiet joint with a well healed graft and no synovitis. Postoperative long leg radiographs showed no growth deformity against preoperative status.

Conclusion: In paediatric patients with persisting symptomatic instability despite appropriate conservative management, surgical reconstruction of the PCL should be considered. Standard treatment has higher complication rates and poorer graft survival than in an adult cohort. Specific problems include iatrogenic growth plate injury causing growth arrest or angular deformity, inadequate graft size if using hamstrings autograft, and the additional technical challenge of small patient size. Early results from extra-physeal, all-inside PCL reconstruction using a parentally donated allograft are promising and may provide an alternative solution to traditional surgical management.

1. Introduction

Posterior cruciate ligament (PCL) injury is rare and serious injury in the paediatric population. The increase in incidence of ligament injuries has been largely attributed to an increase in sports participation and a better recognition of such injuries. Very little is described in the published literature on the surgical management of paediatric PCL ruptures. The mechanisms of injury are divided into avulsion from the femoral attachment [1–4], tibial attachment avulsion [5–10] and midsubstance tears [11–14]. The few pub-

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lished surgical techniques consist of direct repair [11] or trans-epiphyseal techniques such as in-lay [12] and all-inside approaches [15]. Our case report describes a novel technique using a physeal sparing technique to avoid growth plate injury.

2. Case report

A nine-year-old boy sustained a posterior knee dislocation during a Judo competition (Figure 1). He remained neurovascularly intact and was initially placed in a long-leg cast to maintain the knee in a reduced position. After six weeks in a cast, he was transferred to a knee brace and gentle rehabilitation commenced. A patient specific PCL brace was fashioned and despite prolonged non-surgical management for over a year, he continued to suffer with instability. The patient was unable to return to sport and became socially withdrawn.

Clinical examination at one year after injury demonstrated a reducible posterior sag, with no associated effusion. Posterior drawer at 90 degrees of flexion was positive up to grade 3 with no firm end-point. There was a positive posterior Lachman and a positive reverse pivot shift test. External rotation test was positive at 90°. Collateral ligaments were intact.

Long leg alignment views and plain radiographs were obtained (Figure 2). Magnetic Resonance Imaging (MRI) confirmed the PCL rupture (Figure 3), however, there were no other associated intra-articular injuries. Following detailed discussions with the patient and his parents, it was decided to proceed with a PCL reconstruction.

Due to the age and size of the patient, it was felt that hamstrings autograft may be of insufficient size. At our institution, a Human Tissue Authority licence has been obtained, allowing for the harvest and handling of allograft tissue. The father consented for parental donation of his hamstring tendons for the reconstruction. Standard screening for transmissible diseases was carried out following counselling and consent. The screening protocol included tests for human immunodeficiency virus (HIV), hepatitis B and C, human papillomavirus and cytomegalovirus. As the patient was Tanner stage 2 [16,17], it was felt that a physeal sparing approach should be adopted to avoid growth interference.

3. Surgical technique

Standard preparation for the hamstring graft was performed. Semitendinosus and gracilis were harvested from the parent's knee and stored while the patient was prepared for surgery.

The patient was placed supine with a lateral support and foot bolster. A thigh tourniquet was applied and image intensifier set to allow for intra-operative images. A standard arthroscopy was initially performed to assess the knee. Mild chondral irregularity was noted to the medial femoral condyle, the menisci were intact and no other associated injury was identified.

The parental donation allograft, semitendinosus and gracillis, were whip stitched either end using a non-absorbable 0-suture. These were then folded to make a six strand graft, 90 mm in length and 10 mm in diameter. The graft was compressed down to a size nine millimetres using compression tubes. Two adjustable cortical suspensory fixation devices, Reverse Tension (RT) Tightropes (Arthrex, Naples), were applied either side of the graft ends. The graft was reinforced with a non-elastic two millimetre braided suture and passed independently to the graft through the femoral RT button. The loose ends on the tibial side were kept free of the graft to allow for independent tensioning to act as reinforcement of the construct during the early healing phase. To avoid compromise to growth, a plan was made to release the tape surgically at three months after surgery.

A posteromedial portal was established to allow access to the PCL footprint using an outside-in technique. A radiofrequency device was used via the posteromedial portal to identify the tibial footprint with visualisation using a 30-degree arthroscope

Figure 1. Antero-Posterior (AP) and lateral radiographs at initial presentation immediately after Judo injury.

Figure 2. Long alignment, antero-posterior and lateral radiographs after one year.

via the anterolateral portal. For deeper dissection, a curved radiofrequency device was introduced via the anterolateral portal. The curve in this radiofrequency device, allows for posterior retraction of the capsular tissue, while identifying anatomical landmarks on the posterior tibial plateau. Viewing was undertaken from the posteromedial portal at this stage (Figure 4).

To avoid damage to the physis, dissection of the posterior tibia was performed to just distal to the level of the physis. A PCL tibial aimer (Arthrex, Naples) was positioned beyond the physis and the radiofrequency device left in-situ as a retractor to the posterior structures. Owing to the small size of the patient, the aimer sat off the anterior tibia, requiring an assistant to hold in-situ, while the retrograde drilling device (FlipCutter — Arthrex) was passed. A retrograde socket of nine millimetres in diameter and 40 mm in length was created. A passing suture was passed through the tibial socket and retrieved via the anterolateral portal (Figure 4).

A retrograde femoral socket was planned, but due to the small size of the patient was abandoned. Instead, a guide wire was positioned centred on the PCL femoral footprint and under image intensifier guidance, was passed distal to the physis to remain all-epiphyseal. This was enlarged to a 4.5 mm pilot hole for subsequent passage of sutures and fixation device.

A drill was then passed to create a nine millimetre diameter socket 25 mm in length. A passing suture was then retrieved through the socket and taken through the anterolateral portal (Figure 5).

The smooth passage of the sutures was maintained to avoid tissue bridges when passing the six-strand allograft. The graft was placed into the knee via the anterolateral portal in a retrograde fashion using the all-inside technique. The ends of the graft were parachuted into the respective ends of the sockets, initially with 15 mm in the femur to allow for subsequent tensioning. The knee was held in a reduced position, with an anterior drawer at 90 degrees of flexion while tensioning of the tibial RT button was performed. The knee was cycled and re-tensioning of both femoral and tibial RT tightropes was undertaken. The free ends of the non-elastic two millimetre braided suture, were then secured in the tibia using a 4.75 mm bone anchor. Post-operative radiographs confirmed satisfactory reduction of the knee joint and positioning of the RT buttons.

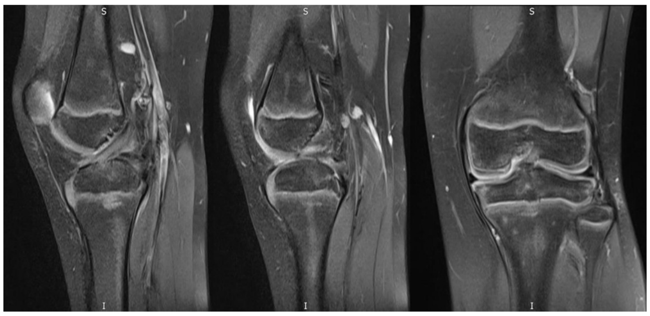

Figure 3. Pre-operative MRI images demonstrating PCL rupture and intact ACL.

Figure 4. Intra-operative image intensifier images for tibial socket preparation.

4. Postoperative care

The patient was placed into a cylinder plaster for the first two weeks. This was exchanged for a dynamic PCL brace allowing prone passive flexion to 90° while non-weightbearing from two weeks to six weeks. Gradual weight-bearing was encouraged from six weeks with institution of active range of movement exercises. Full weight-bearing and a free range of movement were allowed at 12 weeks post-op. Early rehabilitation initially focused on closed chain exercises, moving to open chain activities from four months (one month after the second stage surgery).

As per pre-operative plan, a relook arthroscopy was undertaken at three months and the FiberTape was released. Examination under anaesthesia revealed a stable knee with a range of motion from five degrees of hyper-extension to 120 degrees of flexion. The FiberTape was released and flexion improved to 140° with no detriment to stability. At arthroscopy the PCL reconstruction was noted to be intact with no evidence of synovitis.

Pre-operative scores following the PCL injury were recorded in our physio-research clinic. The Knee injury and Osteoarthritic Outcome Score (KOOS) was 46.5 and Tegner–Lysholm score was 34. At 18 months post-operative, the KOOS was 92.9 and Tegner–Lysholm score was 98.

At 18 months post-surgery (Figure 6), long-leg alignment views revealed no growth arrest. There was a slight increase in the valgus alignment of the operated knee compared to the contralateral knee. This may represent medial overgrowth at the distal femur. Lateral radiographs of the knee showed a reduced tibia. Clinical examination demonstrated full range of motion and stable knee with no posterior sag or drawer. His gait pattern had returned to normal. The patient was beginning to participate in contact sports and was able to integrate back into school activities. Long term (annual) clinical follow-up is planned, with repeat radiographs only if clinically indicated.

5. Discussion

Paediatric PCL injuries represent a significant surgical management conundrum. Growth disturbance following transphyseal anterior cruciate ligament (ACL) reconstructive surgery has been well documented [18–20]. Techniques have been developed to perform all epiphyseal surgery to avoid violation of the physis. In a meta-analysis by Frosch et al., a 1.8% incidence of leg length discrepancy or limb axis deviation was reported after operative treatment of ACL ruptures in a skeletally immature cohort of 935 patients [21]. All epiphyseal techniques in ACL reconstruction have allowed surgeons to avoid violating the physis, but are not without their complications. Koch et al. reported on outcomes of 12 patients undergoing all-epiphyseal ACL reconstructions. Two patients developed overgrowth over one centimetre and four had minor overgrowth of less than one centimetre [19]. It is thought that this is due to mechanical stimulation of the zone of proliferation at the epiphysis. A similar observation is made in physes which have experienced trauma, resulting in an overgrowth and limb malformation [22,23]. At 18 months of follow-up, we also observed medial overgrowth resulting in a slight increase in valgus alignment compared to the contralateral lower limb. The alignment of the patient will be monitored until skeletal maturity.

Figure 5. Intra-operative image intensifier images of femoral socket preparation and graft fixation.

Figure 6. Post-operative long alignment radiographs at two years.

Extra-articular physeal sparing techniques have been described in the past when arthroscopic techniques had not yet become established. The extra-articular Macintosh procedure used the Iliotibial band as a check-rein to anterior instability and anterolateral rotatory instability with good effect [24–27]. Our method of a physeal sparing tibial tunnel combined with an all-epiphyseal approach on the femur in a PCL reconstruction is the first of its kind.

PCL injury in a paediatric population is a rare injury. To date, very few publications exist on the surgical management of PCL ruptures [12,28,29]. These injuries are well documented to lead to medial and patellofemoral arthrosis [30]. Of note, this patient already had signs of chondral wear to the medial femoral condyle, suggesting that continued non-operative management would likely result in early onset arthritis.

In addition, this patient had suffered significant social withdrawal necessitating professional input due to his inability to participate in sporting activities with his peers. Surgical reconstruction has provided him with the opportunity to reintegrate into his social groups as well as school activities.

Parental hamstring allograft has demonstrated excellent outcomes in ACL reconstruction surgery [31]. Benefits in using parental allograft include preservation of the child's hamstrings for future use and reduced morbidity following reconstructive surgery. Shah et al. demonstrated good outcomes in the use of parental allograft for PCL reconstruction using an extra-epiphyseal tibial tunnel and transphyseal femoral tunnel technique. Cadaveric allografts have been associated with a higher failure rates of between 13% and 44% in an adult population [32,33], which would not be suitable for a paediatric population, where re-rupture rates are generally higher. MRI studies have demonstrated increase in graft length but not in diameter as the child grows in ACL reconstruction [34]. Using parentally donated hamstring allograft compensates for this lack of diameter and negates the increased risks of re-rupture seen in smaller hamstring grafts in younger patients [35].

Appropriate counselling and consent must be performed prior to proceeding with screening protocol for parental allograft donation. The implications for positive blood screening can be devastating for those concerned and support measures need to be in place in such instances.

There is little published on the outcome of paediatric PCL reconstruction due to the rare occurrence of such a procedure. In a case report by Accadbled et al., an 11 year old child underwent all inside PCL reconstruction. While no formal scores were recorded, the child returned to pre-injury sports level and remained asymptomatic at two years [15]. Similarly, Warme and Mickelson reported on a 10 year old who underwent PCL reconstruction using a tibial inlay technique, reported no physeal growth arrest and a return to pre-morbid sporting ability [36]. Good outcomes can also be achieved with non-operative methods as reported by Scott and Murray, for intra-substance PCL injuries [14]. The decision to proceed with surgical intervention must be made after a prolonged rehabilitation and failed conservative measures.

Our technique utilises the principles of graft reinforcement as a temporary internal brace. We have reported on a similar technique in the past with ACL repair with good patient reported outcomes [37]. The reinforcement acts as a secondary stabiliser as the graft integrates into the bony tunnels [38]. In our experience, in the paediatric population, the FiberTape must then be released to avoid the consequences of secondary growth disturbance. We recommend a minimum follow-up of two years to look for angular deformity and leg length discrepancy, ideally this should be continued till physeal closure.

6. Conclusion

Although technically demanding, paediatric PCL reconstruction using physeal sparing arthroscopic techniques is feasible. The additional use of parentally donated hamstring allograft ensures adequate graft size can be achieved without the higher risk of failure associated with frozen allograft use.

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