MENTORS IN ORTHOPEDICS

MANAGEMENT OF ACL INTRA-SUBSTANCE TEARS IN GROWING CHILDREN AND TEENAGERS

https://doi.org/10.71165/1png-goct

AUTHORS

Nikolaos Lepidas - Centre Orthopédique Santy, Lyon, France
Jean-Marie Fayard - Hôpital Privé Jean Mermoz, Lyon, France
Franck Chotel - Université Claude Bernard, Lyon, France

SUMMARY

Background: The incidence of anterior cruciate ligament (ACL) tears in pediatric and adolescent populations has increased significantly, rising approximately 2.3% annually. Management remains controversial due to the competing risks of secondary meniscal or chondral degeneration from knee instability versus potential growth disturbances following surgical reconstruction in skeletally immature patients.

Objective: This article aims to define the clinical indications for surgical intervention and clarify the contemporary role of conservative management in growing children with ACL injuries.

Key Points: Initial assessment requires differentiating physiological joint laxity from symptomatic instability and utilizing MRI to identify concomitant meniscal pathology, despite lower diagnostic specificity in younger children. Conservative management, involving a three-phase neuromuscular rehabilitation protocol, may be appropriate for patients under 12 years (Tanner stage 1) who exhibit perfect stability and no associated lesions. However, longitudinal data indicate that up to 57% of non-operative patients eventually require reconstruction due to secondary instability or meniscal tears. Surgical techniques, categorized as all-epiphyseal or transphyseal, must prioritize tendon grafts, small-diameter tunnels, and physeal-sparing fixation. While reconstruction facilitates a high rate of return to sport (approximately 80–93%), complications include a 4–8.7% risk of growth disturbances and high rates of graft rupture or contralateral injury.

Conclusion: Pediatric ACL management requires individualized strategies based on skeletal maturity and clinical stability. While conservative protocols are viable for select stable patients, surgical reconstruction is indicated for persistent instability or associated meniscal tears to prevent long-term degenerative changes. Combined anterolateral procedures and delayed return to sport may mitigate high graft failure rates.

KEYWORDS

Anterior Cruciate Ligament Reconstruction; Growth Plate; Knee Injuries; Conservative Treatment; Child

INTRODUCTION

Practising sport is a key part of life in the developed world and anterior cruciate ligament (ACL) tear has become a common pathology, even in the paediatric population. In fact, ACL tears account for around 25 to 30% of knee injuries in young athletes[1],[2] . Over the past twenty years, the incidence of these injuries has risen significantly, growing by around 2.3% per year, with a peak noted in teenagers[3]. This rise is based on a number of factors: an increase in the number of young people taking part in sport, specialising in a sport at an early age and the heavy burden of training and competing[4]. The management of growing children who have an ACL tear nonetheless remains a contentious issue, both in terms of the role for conservative and surgical treatments and the timing of management. This controversy is based on two main problems:

On the one hand, the natural course of ACL tears and the repeated episodes of instability provide the conditions for the onset of meniscus and/or cartilage tears and the development of secondary osteoarthritis[5],[6]. In a study by Hagmeijer et al. which looked at 1398 ACL tears, the rate of secondary meniscectomy was 16%. This rate was significantly lower for the group of patients who had surgical ACL reconstruction within 6 months (6%) than in the group who had surgery after 6 months (33%, $p<0.01$) and the group who had non-surgical management (19%, $p<0.01$)[7]. Similarly, Neyret et al. reported an 86% rate of osteoarthritis after meniscectomy due to knee instability over an observation period of 30 years[8].

Conversely, although surgical treatment restores knee stability and means that sporting activities can be resumed, the earliest clinical studies reported a high rate of growth disturbances[9]. Moreover, since many children, especially the very youngest, do not present instability then it is not a foregone conclusion that their meniscal prognosis will be so poor.

The purpose of this article is to define the indications for surgical treatment and clarify the role for conservative treatment today.

INITIAL ASSESSMENT

Specific considerations for examining children

The assessment of a growing child who is suspected to have a torn ACL must be based on a focused interview, a thorough physical examination and a complete imaging investigation. Some findings on the clinical examination that are specific to children could lead to confusion or complicate initial diagnosis. The interview must ask about any episode(s) of instability, a “pop” or “crack” heard during physical activity and any onset of haemarthrosis. On physical examination, children often present with generalised joint laxity that is not pathological. This can translate into genu recurvatum, anterior-posterior knee laxity or even physiological rotatory laxity, even in a healthy knee10. This laxity in translation and rotation resolves with growth 11 and it should not be mistaken for instability. The difference is that laxity is an objective sign found on clinical examination while instability is a symptom experienced by the patient. Furthermore, children often tolerate instability well and painful symptoms are a secondary concern. In our experience, if the pivot shift test is performed and this reproduces the symptoms experienced by the patient, this is clinical evidence that points to instability. It is important not to hold back from

looking for this functional discomfort, repeating the manoeuvre and asking the child if they recognise the sensation.

Additional assessments should include AP and lateral view radiographs of the injured knee to exclude a fracture and one of the elbow or wrist to determine bone age. An MRI should be performed to confirm the diagnosis of ACL tear and to look for any associated meniscus or cartilage damage. It is important to note that MRI imaging presents some features in children that may on occasion be difficult to interpret. The menisci of young children are richly vascular, and this gradually decreases until the adult configuration is reached. This hypervascularisation can sometimes lead to false positives on MRI[12]. Dawkins et al., in a series of 406 patients under 18 years of age who had undergone surgical ACL reconstruction, reported only a 75% sensitivity and 72.1% specificity for the diagnosis of meniscus tears on MRI. Specificity is significantly lower in patients aged ≤ 13 years[13].

Objectives of initial management

The three main objectives when managing ACL tear in children are:

The two potential treatment options to achieve these goals are conservative treatment, consisting of a programme of functional rehabilitation, or ACL reconstruction and possible meniscus repair.

CONSERVATIVE TREATMENT

Protocol

Unfortunately, in the literature conservative treatment and non-surgical treatment are often confused. Conservative treatment is based on two key aspects: delivery of a thorough and supervised rehabilitation protocol plus regular follow-up in line with a standardised formula.

The rehabilitation protocol includes three main phases and is based on targeted exercises to recover the range of motion of the joint, neuromuscular control and muscle strength[15]:

The first phase (D0-D45) focuses on reabsorption of joint effusion fluid, recovery of the range of motion of the joint, especially in full extension, and gradually waking up the quadriceps as well as control of the weight-bearing knee. Once the knee is under control in weight-bearing and walking is possible, a programme of closed kinetic chain exercises to strengthen the quadriceps can be started.

The aim of the second phase (D45-D90) is to help the patient return to activities of daily living. With this goal in mind, a programme of overall muscle strengthening using open kinetic chain and proprioception exercises is used to regain neuromuscular control in single leg weight-bearing.

The third phase (>D90) consists of readapting to practising sport and is based on plyometrics. The goal is to perform one-legged jumps and direction changes with good proprioceptive control of the injured knee and also the healthy knee.

Regular monitoring of these patients is also crucial because of the ambiguous symptomatology in children. This monitoring may consist of a meticulous clinical examination and an MRI if there is any doubt or any episodes of instability are reported, even if it is just a single event. In our practice, young patients are reassessed at D45/D120/D180 and then on an annual basis to make sure that they are adhering to treatment and tolerating it well.

Sport can be resumed at 4 months. For some, wearing a hinged brace is advisable when playing pivot sports but it only offers relative protection which only has a proprioceptive component. Based on our experience, we prefer to use a simple soft knee support.

In addition, we recommend four to five sessions of maintenance physiotherapy per year, often in September, to adjust any proprioceptive imbalance that has developed, as is likely to occur while a child is growing.

RESULTS

Study	Year	Patients included	Mean age	Mean follow-up (month)	Treatment protocol	Return to sport	Secondary meniscus tears	Persistent damage	Secondary ACL surgery
Streich et al. [36]	2010	12	11	70	Physiotherapy and brace	ND	6 (50%)	ND	7 (58,3%)
Moksnes et al. [18]	2013	40	11	46	Physiotherapy in 4 phases	35 (88%)	8 (19,5%)	8 (20%)	13 (32%)
Moksnes et al. [20]	2013	46	11,8	38	Physiotherapy in 4 phases	42 (91%)	4 (9%)	10 (22%)	10 (22%)
Madelaine et al. [19]	2018	53	12,2	31,5	Physiotherapy in 4 phases	ND	9 (17%)	19 (36%)	21 (40%)
Ekas et al. [22]	2019	47	11	114	Physiotherapy in 4 phases	ND	14 (30%)	ND	27 (57%)

Table 1: List of recent studies evaluating the outcomes of conservative treatment of ACL tears in children and teenagers with open growth plates

Historically, because there was no suitable surgical technique, all growing patients who presented with an ACL tear were treated non-surgically. These treatments in the past did not include any standardised rehabilitation protocol, or when there was one, it focused only on muscle strength. Taking a retrospective view, the results were disappointing. Between 95% and 100% experienced secondary instability[6],[16],[17], often tall children.

Moksnes et al.[18] prospectively monitored the incidence of meniscus and cartilage tears in a group of 40 patients with an average age of 11 years (41 knees with open growth plates) treated non-surgically with a mean follow-up of 3.8 years. Their physiotherapy protocol permitted resuming activities wearing a custom-made knee brace. 13 knees (32%) underwent surgical ACL reconstruction for one of the three following reasons: persistent instability in spite of the physiotherapy protocol, a symptomatic meniscus tear or the reduction achieved was not acceptable for the activity level required. 8 patients (19.5%) needed surgical management because they developed a meniscus tear during follow-up (6 also had ACL reconstructions and 2 had meniscal suture repair only). In 2018, we published a retrospective study that included 53 patients under 18 years of age (Madelaine et al.[19]). In contrast to other studies looking at conservative treatment, there were precise selection criteria: no episodes of instability, or only one, and no meniscus tear warranting consideration for surgery. Ultimately, only 30% of patients managed for ACL tear were enrolled in this conservative protocol. The mean age of patients in the series was 12.2 years and the patients were reviewed over a mean observation period of 31.5 months. All patients initially followed a functional rehabilitation programme and then a gradual return to sporting activities (including pivot sports) without restriction. We reported that 9 patients (17%) presented a secondary meniscus tear and only one patient (2%) needed a secondary meniscectomy. Surgical ACL reconstruction was performed for 21 patients (40%) due to the onset of instability and/or a secondary meniscus tear. Any instability, even if only one single episode, was a

factor for later surgery. These observations prompted us to perform more rigorous patient selection and to offer surgery following the slightest instability even if the physiotherapy protocol had been followed correctly.

Some authors have found the age of the child to be a factor that influences the outcome of conservative treatment. For Moksnes et al.[20] conservative treatment could be a viable option for children under the age of 12 as long as there is no meniscus and/or cartilage tear. In our study (Madeleine et al.[19]), none of those in our youngest patient group (Tanner maturity stage 1) needed surgery during the prepubertal phase. It would seem to be quite clear that children in this age range are relatively good candidates for conservative treatment. However, puberty appears to be a sharp turning point after which episodes of instability appear. Dumont et al. found that age over 15 years, weight exceeding 65 kg and a wait of over 150 days between the accident and surgery were significantly associated with an increase in tears to the medial meniscus and cartilage[21] . The same seems to apply as in adults: time appears to be a determining factor in the onset of episodes of instability and secondary tears. In this respect, Ekas et al., who used less restrictive criteria than were applied in our study, reported secondary meniscus tears in 30% and ACL reconstruction in 57% with a mean observation period of 9.5 years[22].

The Moksnes et al. study included 46 children aged < 12 years who were assessed after two years observation. They reported that 85% of their patients had practised a contact pivot sport prior to surgery as against only 50% of patients managed non surgically and 40% of patients who underwent surgical ACL reconstruction[20]. These observations were confirmed in the longer term by Ekas et al. in a group of 44 patients aged < 13 years and after a mean observation period of 8 years. At the last follow-up, 24 patients (55%) had undergone surgical ACL reconstruction and 16 (36%) had undergone meniscal surgery. The patient-reported IKDC score at the final follow-up was 90.6/100 in the non-operated group and 86.3/100 in the operated group. 91% of patients remained active, with 35% of non-operated patients and 33% of operated patients practising a pivot or pivot-contact sport. Only 56% of patients were able to resume their original level of sporting practice[23].

Therefore, in patients with perfect knee stability who adhere to treatment and have no meniscus or cartilage tears, conservative treatment is appropriate and can be offered, at least initially. However, if any instability develops, since the time between the accident and surgery is a factor for developing meniscus and cartilage tears22, it is essential to firstly advise the patient and their parents that they should consult their doctor following any episode of instability, effusion, blockage or pain, and secondly regular and routine follow-up should be set up. Furthermore, we believe that it is preferable for this management to be supervised by a surgeon who will know when the time has come to suggest surgery and, in this way, minimise the risk of a secondary meniscus tear.

SURGICAL TREATMENT

Voices in the literature are unanimous on the need for surgical management in children with a meniscus or cartilage tear and/or persistent symptoms of instability in spite of a functional rehabilitation programme that has been correctly followed. They require surgical management of their ACL tear[15].

For some teams, the technique is chosen on the basis of the child's residual growth potential. To evaluate this, it is crucial to separate out chronological age and bone age and to adopt a more global approach. This should take into account firstly the clinical sexual maturation criteria from the Tanner classification (Figure 1), and secondly radiography of the left hand and/or elbow to determine the child's bone age[14] . It is largely acknowledged that Tanner stage 4, a bone age ≥ 13.5 years in girls and 15.5 years in boys, and the onset of menstruation in girls, are factors pointing to completed bone growth in the knee. This means that it is appropriate to discuss ACL reconstruction using an adult technique.

GIRLS			
	Breast development		Pubic hair
S1	No breast tissue	**P1**	No pubic hair
S2	Palpable breast tissue	**P2**	Sparse, fine hair along the labia majora
S3	Increase in breast size: areola and nipple with rounded contours	**P3**	Pubic hair is darker in colour
S4	Increase in breast size: nipple projects away from the breast	**P4**	Coarser hair, covering the mons pubis
S5	Increase in breast size: areola and nipple with rounded contours	**P5**	Adult pubic hair, extending to the thighs
BOYS			
	Testicles		Pubic hair
T1	<2.5 cm	**P1**	No pubic hair
T2	Testicles increase in size to >2.5 cm; scrotum skin thins	**P2**	Sparse hair on the scrotum
T3	3.0-3.5 cm; penis thickens	**P3**	Pubic hair is darker in colour, spread around the pubis
T4	3.5-4 cm	**P4**	Coarser hair on the pubis
T5	>4 cm; adult size penis	**P5**	Adult pubic hair, extending to the thighs and umbilicus

Figure 1: Tanner classification of pubertal maturation

However, there are many ACL surgical reconstruction techniques for use in the paediatric population. These techniques must follow a few key principles:

- In view of the risk of growth disturbances secondary to grafting of the patellar ligament, it is better to use a tendon graft.
- Small diameter tunnels should be used (< 9 mm)
- No hardware to fix the graft in place should be attached over growth plates
- The shell of perichondrium must be spared especially at the lateral condyle (over the top technique)

To comply with these rules, the two broad categories of technique used are: all-epiphyseal and transphyseal techniques (Figures 2 and 3). The advantage of transphyseal techniques is that vertical, round and oblique tunnels can be created, meaning that the diameter of the tunnel in the growth cartilage can be reduced. With epiphyseal techniques, fixation is done away from the growth cartilage. However, they are more technically demanding to perform.

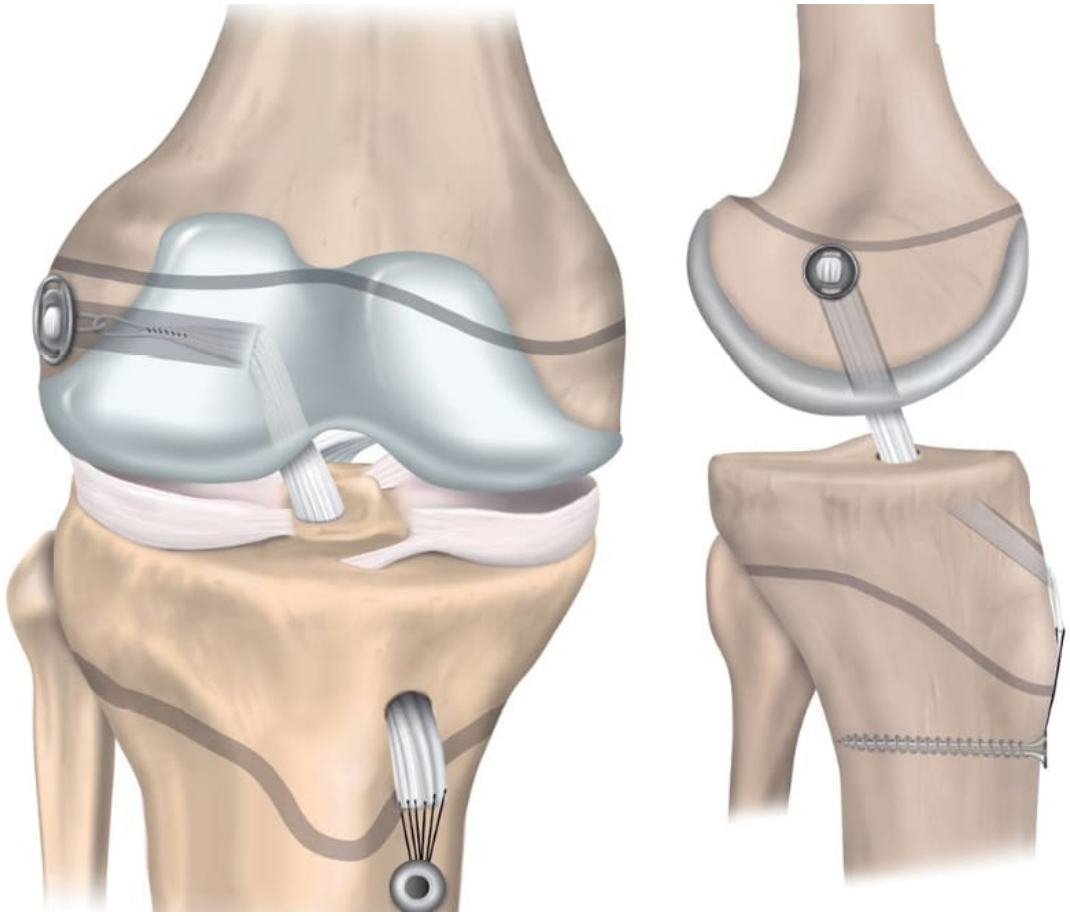

Figure 2: All-epiphyseal technique (from Ardern et al. [34])

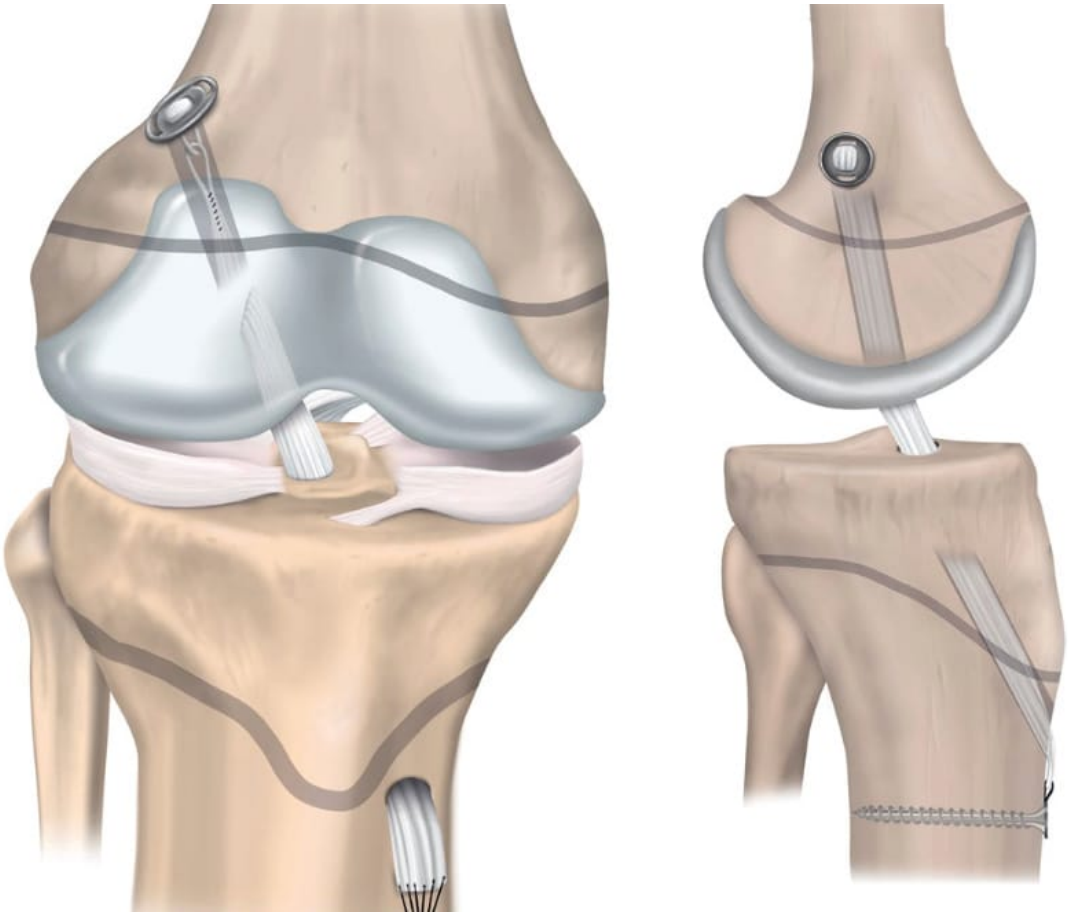

Figure 3: Transphyseal technique (from Ardern et al. [34])

RESULTS

The multicentre study conducted by the SFA[24] [Société Française d'Arthroscopie; French Society of Arthroscopy] reported that 80% of patients resumed the same sport but 10.4% had a poor functional outcome (patients with IKDC grades C and D).

A recent systematic review[25] showed a 93.2% rate of return to sport (resuming at pre-surgery level: 77.9%) and a patient-reported IKDC score exceeding 90. In the Moksnes et al. series [20] which included 46 patients who followed conservative treatment there was a 91% rate of resuming sport, but the mean patient-reported IKDC score was 82.9.

COMPLICATIONS

Complications of ACL surgery arise commonly in children. For De Francesco et al. 25, almost one in six operated patients will need surgical revision within three years of ACL reconstruction. Wall et al. reported a secondary complications rate of 48% and a surgical revision rate of 37%[26].

In a series of 193 patients aged < 13 years who had undergone ACL reconstruction, Hansson et al. reported that 45% went on to have secondary surgery with a mean observation period of 6.9 years: 12% for a subsequent tear,

21% for a pathology other than subsequent tear and 12% for a tear of the contralateral knee. The patients that had been given a more restrictive post-operative protocol (immobilisation, gradual recovery of range of motion, resuming sport > 9 months) had a significantly lower rate of revision surgery (8% versus 19%, p= 0.016)[27]. Younger patients aged < 19 years are recognised as being more at risk of onset of a further ACL injury and this must be taken into account in the management of children. In this respect, Dekker et al. reported high rates of both subsequent tear (19%) and contralateral tear (13%). Once again, the authors emphasise that delaying a return to sport was a factor that protected against a further ACL injury[28].

It has today been demonstrated that also reconstructing the anterolateral ligament significantly reduces the risk of subsequent tear in adults[28],[29]. There remains minimal data on this strategy in the paediatric population in the literature, but what there is does appear to also support addition of an extra-articular procedure to the ACL reconstruction. Foissey et al. reported a 2.6% rate of subsequent tear with a mean observation period of 57 months[30]. Similarly, Monaco et al. and Perelli et al.[31],[32] report respective rates of subsequent tear of 14.7% and 15% in patients who underwent isolated ACL reconstruction as against 0% and 6.3% if they also had anterolateral ligament reconstruction. In future, we will be able to select the children who will benefit the most from this type of procedure.

Growth disturbances have historically been the most feared complication. These fall into three different categories: epiphysiodesis, growth acceleration and growth arrest[33] (Figure 4). Growth acceleration appears to be more common in young children. It can result in leg length discrepancies if there is symmetrical growth acceleration, or to deformities in the frontal plane (especially valgus deformities) when growth is asymmetrical. The clinical impact of this kind of complication is usually not as significant as that of an epiphysiodesis but it may mean that surgical revision is needed. For example, Cordasco et al. looked at 23 patients and reported that 26% had leg length discrepancy > 5 mm and 9% exceeding 15 mm[34]. Foissey et al. described two cases out of 39 patients (5%) with growth disturbance exceeding 10 mm. Only one of these needed surgical revision[30]. In a recent meta-analysis that included 45 studies and 1329 patients [35], the rate of repeat tear was 8.7 %, or 115 patients. A total of 58 patients presented growth disturbances, equating to 4%. Moreover, of the patients who presented growth disturbances, only 27.6% needed surgical revision. However, of the patients that had a subsequent tear, 94.6% underwent revision surgery. The authors of this meta-analysis suggest that greater emphasis should be placed on preventing subsequent tears in this population.

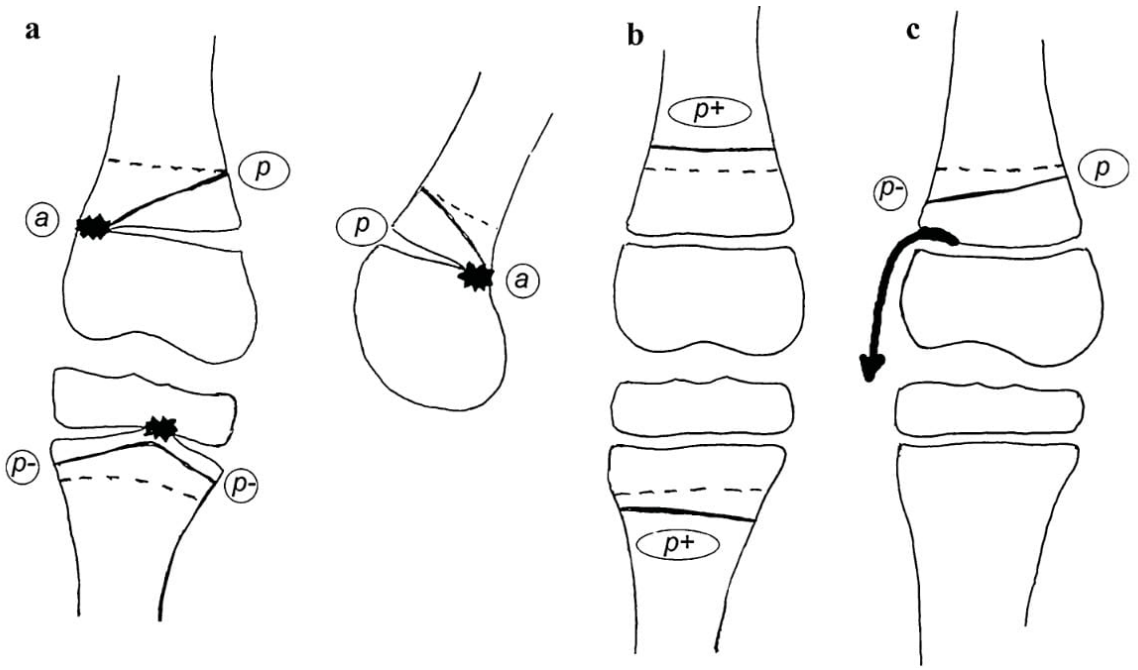

Figure 4: The three types of growth disturbance (from Chotel et al. 33). Type a corresponds to either central (complete arrest) or peripheral (axial deformity) growth arrest, type b is growth acceleration (overgrowth) and type c is growth deceleration due to the implanted tendon exerting pulling forces.

CONCLUSION

The incidence of ACL injuries is growing steadily in children. This is an injury that should never be underestimated because of the potentially serious consequences. Appropriate treatment must be chosen on a case-by-case basis depending on whether or not there is instability, an associated meniscus or cartilage tear, and taking the child's residual growth potential into account. Conservative treatment must include close clinical monitoring and an MRI should be ordered if the slightest doubt persists over the absence of secondary meniscus tears (figure 5). Surgical treatment must use a technique that is appropriate for the child's growth potential. Complications of surgery include, among others, growth disturbances and subsequent tear. The rate and clinical impact of repeat tears are considerably greater than those of growth disturbances, which remain rare. A delayed return to practising sport in conjunction with anterolateral ligament reconstruction may be key factors in the prevention of subsequent ruptures of ACL graft in children.

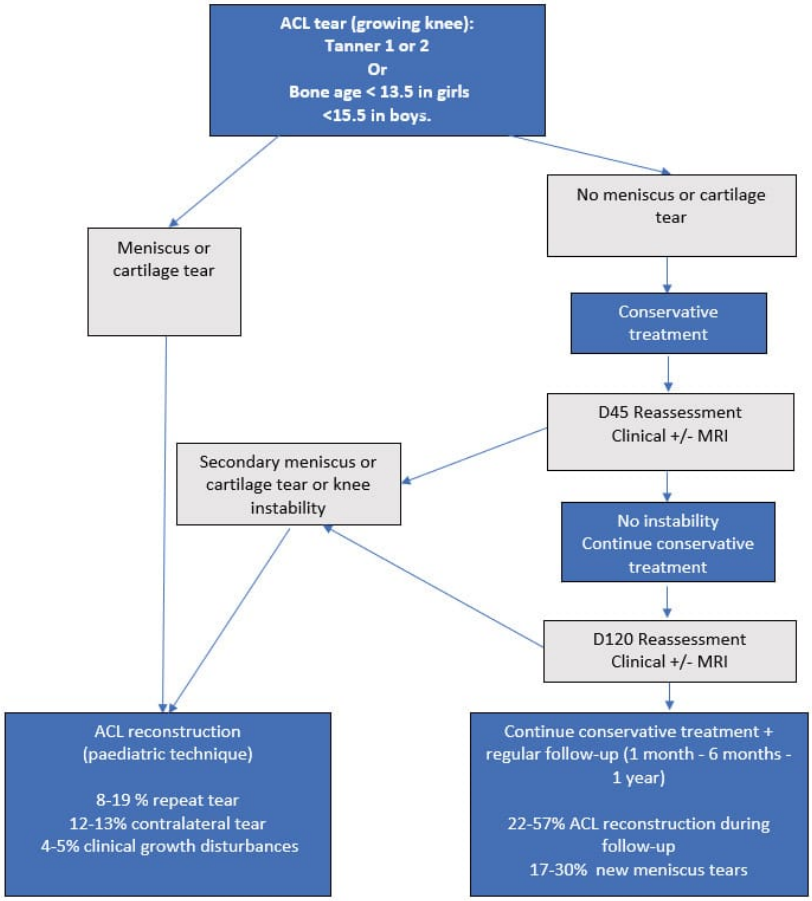

Figure 5: Algorithm for the management of ACL intra-substance tears in children and teenagers with open growth plates.

REFERENCES

1.Swenson DM., Collins CL., Best TM., et al. Epidemiology of Knee Injuries among U.S. High School Athletes, 2005/2006–2010/2011. Medicine & Science in Sports & Exercise 2013;45(3):462–9. Doi: 10.1249/MSS.0b013e318277acca.

2. Shea KG., Pfeiffer R., Wang JH., et al. Anterior Cruciate Ligament Injury in Pediatric and Adolescent Soccer Players: An Analysis of Insurance Data: Journal of Pediatric Orthopaedics 2004:623–8. Doi: 10.1097/00004694-200411000-00005.

3. Beck NA., Lawrence JTR., Nordin JD., et al. ACL Tears in School-Aged Children and Adolescents Over 20 Years. Pediatrics 2017;139(3):e20161877. Doi: 10.1542/peds.2016-1877.

4. Popkin CA., Wright ML., Pennock AT., et al. Trends in Management and Complications of Anterior Cruciate Ligament Injuries in Pediatric Patients: A Survey of the PRiSM Society. Journal of Pediatric Orthopaedics 2018;38(2):e61–5. Doi: 10.1097/BPO.0000000000001098.

5. Kannus P., Jarvinen M. Knee ligament injuries in adolescents. Eight year follow-up of conservative management. The Journal of Bone and Joint Surgery British Volume 1988;70-B(5):772–6. Doi: 10.1302/0301-620X.70B5.3192578.

6. Graf BK., Lange RH., Fujisaki CK., et al. Anterior cruciate ligament tears in skeletally immature patients: Meniscal pathology at presentation and after attempted conservative treatment. Arthroscopy: The Journal of Arthroscopic & Related Surgery 1992;8(2):229–33. Doi: 10.1016/0749-8063(92)90041-9.

7. Hagmeijer MH., Hevesi M., Desai VS., et al. Secondary Meniscal Tears in Patients With Anterior Cruciate Ligament Injury: Relationship Among Operative Management, Osteoarthritis, and Arthroplasty at 18-Year Mean Follow-up. Am J Sports Med 2019;47(7):1583–90. Doi: 10.1177/0363546519844481.

8. Neyret P., Donell S., Dejour H. Results of partial meniscectomy related to the state of the anterior cruciate ligament. Review at 20 to 35 years. The Journal of Bone and Joint Surgery British Volume 1993;75-B(1):36–40. Doi: 10.1302/0301-620X.75B1.8421030.

9. Larsen MW., Garrett WE., DeLee JC., et al. Surgical Management of Anterior Cruciate Ligament Injuries in Patients With Open Physes: Journal of the American Academy of Orthopaedic Surgeons 2006;14(13):736–44. Doi: 10.5435/00124635-200612000-00005.

10. Wilson P, Ellis H., Chung J. Pediatric anterior cruciate ligament injuries. Tachdjian's Pediatric Orthopaedics : From the Texas Scottish Rite Hospital for Children. 6th ed. Amsterdam: Elsevier; 2021.

11. Baxter MP. Assessment of Normal Pediatric Knee Ligament Laxity Using the Genucom: Journal of Pediatric Orthopaedics 1988;8(5):546–50. Doi: 10.1097/01241398-198809000-00010.

12. King SJ. Magnetic resonance imaging of knee injuries in children. Eur Radiol 1997;7(8):1245–51. Doi: 10.1007/s003300050284.

13. Dawkins BJ., Kolin DA., Park J., et al. Sensitivity and Specificity of MRI in Diagnosing Concomitant Meniscal Injuries With Pediatric and Adolescent Acute ACL Tears. Orthopaedic Journal of Sports Medicine 2022;10(3):232596712210793. Doi: 10.1177/2325967121079338.

14. Ardern CL., Ekås G., Grindem H., et al. 2018 International Olympic Committee consensus statement on prevention, diagnosis and management of paediatric anterior cruciate ligament (ACL) injuries. Knee Surg Sports Traumatol Arthrosc 2018;26(4):989–1010. Doi: 10.1007/s00167-018-4865-y.

15. Moksnes H., Engebretsen L., Risberg MA. Management of Anterior Cruciate Ligament Injuries in Skeletally Immature Individuals. J Orthop Sports Phys Ther 2012;42(3):172–83. Doi: 10.2519/jospt.2012.3608.

16. Mizuta H., Kubota K., Shiraishi M., et al. The conservative treatment of complete tears of the anterior cruciate ligament in skeletally immature patients. J Bone Joint Surg Br 1995;77(6):890–4.

17. McCarroll JR., Rettig AC., Shelbourne KD. Anterior cruciate ligament injuries in the young athlete with open physes. Am J Sports Med 1988;16(1):44–7. Doi: 10.1177/036354658801600107.

18. Moksnes H., Engebretsen L., Risberg MA. Prevalence and Incidence of New Meniscus and Cartilage Injuries After a Nonoperative Treatment Algorithm for ACL Tears in Skeletally Immature Children: A Prospective MRI Study. Am J Sports Med 2013;41(8):1771–9. Doi: 10.1177/0363546513491092.

19. Madelaine A., Fournier G., Sappey-Marinier E., et al. Conservative management of anterior cruciate ligament injury in paediatric population: About 53 patients. Orthopaedics & Traumatology: Surgery & Research 2018;104(8):S169–73. Doi: 10.1016/j.otsr.2018.09.001.

20. Moksnes H., Engebretsen L., Eitzen I., et al. Functional outcomes following a non-operative treatment algorithm for anterior cruciate ligament injuries in skeletally immature children 12 years and younger. A prospective cohort with 2 years follow-up. Br J Sports Med 2013;47(8):488–94. Doi: 10.1136/bjsports-2012-092066.

21. Dumont GD., Hogue GD., Padalecki JR., et al. Meniscal and Chondral Injuries Associated With Pediatric Anterior Cruciate Ligament Tears: Relationship of Treatment Time and Patient-Specific Factors. Am J Sports Med 2012;40(9):2128–33. Doi: 10.1177/0363546512449994.

22. Ekås GR., Laane MM., Larmo A., et al. Knee Pathology in Young Adults After Pediatric Anterior Cruciate Ligament Injury: A Prospective Case Series of 47 Patients With a Mean 9.5-Year Follow-up. Am J Sports Med 2019;47(7):1557–66. Doi: 10.1177/0363546519837935.

23. Ekås GR., Moksnes H., Grindem H., et al. Coping With Anterior Cruciate Ligament Injury From Childhood to Maturation: A Prospective Case Series of 44 Patients With Mean 8 Years' Follow-up. Am J Sports Med 2019;47(1):22–30. Doi: 10.1177/0363546518810750.

24. Geffroy L., Lefevre N., Thevenin-Lemoine C., et al. Return to sport and re-tears after anterior cruciate ligament reconstruction in children and adolescents. Orthopaedics & Traumatology: Surgery & Research 2018;104(8):S183–8. Doi: 10.1016/j.otsr.2018.09.006.

25. Gupta A., Tejpal T., Shanmugaraj A., et al. All-epiphyseal anterior cruciate ligament reconstruction produces good functional outcomes and low complication rates in pediatric patients: a systematic review. Knee Surg Sports Traumatol Arthrosc 2020;28(8):2444–52. Doi: 10.1007/s00167-020-06085-3.

26. Wall EJ., Ghattas PJ., Eismann EA., et al. Outcomes and Complications After All-Epiphyseal Anterior Cruciate Ligament Reconstruction in Skeletally Immature Patients. Orthopaedic Journal of Sports Medicine 2017;5(3):232596711769360. Doi: 10.1177/2325967117693604.

27. Hansson F, Moström EB, Forssblad M, Stålman A, Janarv PM. Long-term evaluation of pediatric ACL reconstruction: high risk of further surgery but a restrictive postoperative management was related to a lower revision rate. Arch Orthop Trauma Surg. 2022 Aug;142(8):1951-1961. doi: 10.1007/s00402-021-04135-0. Epub 2021 Aug 30. PMID: 34459955; PMCID: PMC9296415.

28. Dekker TJ., Godin JA., Dale KM., et al. Return to Sport After Pediatric Anterior Cruciate Ligament Reconstruction and Its Effect on Subsequent Anterior Cruciate Ligament Injury. The Journal of Bone and Joint Surgery 2017;99(11):897–904. Doi: 10.2106/JBJS.16.00758.

29. Sonnery-Cottet B., Saithna A., Cavalier M., et al. Anterolateral Ligament Reconstruction Is Associated With Significantly Reduced ACL Graft Rupture Rates at a Minimum Follow-up of 2 Years: A Prospective Comparative Study of 502 Patients From the SANTI Study Group. Am J Sports Med 2017;45(7):1547–57. Doi: 10.1177/0363546516686057.

30. Getgood AMJ., Bryant DM., Litchfield R., et al. Lateral Extra-articular Tenodesis Reduces Failure of Hamstring Tendon Autograft Anterior Cruciate Ligament Reconstruction: 2-Year Outcomes From the STABILITY Study Randomized Clinical Trial. Am J Sports Med 2020;48(2):285–97. Doi: 10.1177/0363546519896333.

31. Foissey C., Thaunat M., Caron E., et al. Combining Anterior Cruciate Ligament Reconstruction With Lateral Extra-Articular Procedures in Skeletally Immature Patients Is Safe and Associated With a Low Failure Rate. Arthroscopy, Sports Medicine, and Rehabilitation 2022;4(6):e1941–51. Doi: 10.1016/j.asmr.2022.08.002.

32. Monaco E., Carrozzo A., Saithna A., et al. Isolated ACL Reconstruction Versus ACL Reconstruction Combined With Lateral Extra-articular Tenodesis: A Comparative Study of Clinical Outcomes in Adolescent Patients. Am J Sports Med 2022;50(12):3244–55. Doi: 10.1177/03635465221118377.

33. Perelli S., Costa GG., Terron VM., et al. Combined Anterior Cruciate Ligament Reconstruction and Modified Lemaire Lateral Extra-articular Tenodesis Better Restores Knee Stability and Reduces Failure Rates Than Isolated Anterior Cruciate Ligament Reconstruction in Skeletally Immature Patients. Am J Sports Med 2022;50(14):3778–85. Doi: 10.1177/03635465221128926.

34. Chotel F., Henry J., Seil R., et al. Growth disturbances without growth arrest after ACL reconstruction in children. Knee Surg Sports Traumatol Arthrosc 2010;18(11):1496–500. Doi: 10.1007/s00167-010-1069-5.

35. Cordasco FA., Mayer SW., Green DW. All-Inside, All-Epiphyseal Anterior Cruciate Ligament Reconstruction in Skeletally Immature Athletes: Return to Sport, Incidence of Second Surgery, and 2-Year Clinical Outcomes. Am J Sports Med 2017;45(4):856–63. Doi: 10.1177/0363546516677723.

36. Wong SE., Feeley BT., Pandya NK. Complications After Pediatric ACL Reconstruction: A Meta-analysis. Journal of Pediatric Orthopaedics 2019;39(8):e566–71. Doi: 10.1097/BPO.0000000000001075.

37. Streich NA., Barié A., Gotterbarm T., et al. Transphyseal reconstruction of the anterior cruciate ligament in prepubescent athletes. Knee Surg Sports Traumatol Arthrosc 2010;18(11):1481–6. Doi: 10.1007/s00167-010-1057-9.