The BASK/BSCOS Steering Committee Report on the Management of Paediatric Soft Tissue Knee Pathology

January 2021

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British Society for Children's Orthopaedic Surgery

BRITISH ASSOCIATION FOR SURGERY OF THE KNEE

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1. Summary Recommendations of the BASK/BSCOS Committee

The committee recommendations aim to advise on standards for children's knee problems by suggesting safe, effective and reproducible guidelines for the United Kingdom. Our BASK/BSCOS survey showed that practice across the country is variable. Only 25% of paediatric orthopaedic surgeons treat ACL injuries whereas 85% of adult knee surgeons will treat ACL injuries in children. 85% of all survey respondents performed fewer than 10 paediatric ACL reconstructions in children in 2018, although this figure is not a suggestion of minimum number of cases. Members of both societies suggested that multi-disciplinary care between adult knee and paediatric surgeons or referral to a high-volume centre would be the best treatment option for the skeletally immature group.

Recommendations:

• This guidance applies to those aged 18 and under. Those aged 16-18 may be in the majority skeletally mature but differences in physiology, complications of surgery and emotional maturity means this guidance applies to all 18 and under but especially those 16 and under.

• There should be a high index of suspicion for ACL injury in a child who presents with a haemarthrosis following a knee injury. Clinical examination findings are difficult to interpret. There should be a low threshold for re-examination of the child in a few weeks or an MRI performed.

•Surgeons should be aware of the limitations of MRI imaging in the diagnosis of ACL and meniscal pathology. An appropriate imaging protocol should be in place for paediatric cases, with appropriate scan reporting provision by specialist musculo-skeletal radiologists.

•All skeletally immature patients undergoing ACL reconstruction should have radiological monitoring for post-operative growth disturbance. This should include weight bearing long leg radiographs performed pre-operatively and repeated at 6 months, one year and then annually thereafter until growth is complete.

• A skeletal age calculation should be performed for all patients with open growth plates planned for ACL reconstruction pre-operatively.

• There should be a pre-agreed referral pathway for cases where growth disturbance is suspected, where the management of growth disturbance sits outside the treating surgeon's scope of practice. Delay in treatment can lead to complex sequelae.

• Transphyseal ACL reconstruction is a safe and effective technique for skeletally immature children although the rates of growth disturbance are likely underestimated, particularly in pre-pubertal children.

• Consider physeal-respecting modifications for the skeletally immature.

•All-epiphyseal and partial- transphyseal techniques are increasingly used but there are few good comparative studies. Growth disturbance does occur, and those performing limited numbers should consider referral to a high-volume centre. The same principle applies for extraphyseal techniques, which have good reported outcomes for the very young.

•For the skeletally immature patient, hamstring or quadriceps tendon autograft are an acceptable option, although care is needed in harvesting the quadriceps tendon. Graft choice should be discussed as part of informed consent. BTB may prove to be a suitable choice for the skeletally mature adolescent but data is currently lacking.

• Lateral extra-articular tenodesis (LET) can be considered a safe option in the paediatric cohort, pending further evidence of the efficacy in reducing re-rupture rates. This is especially so if there is significant pivoting, the patient is hyperlax or if there is genu recurvatum.

• Contemporary ACL repair is unproven in children as of yet and cannot be recommended as a routine treatment for ACL tears. It may have a role in very proximal or distal tears with satisfactory ligamentous tissue. In the absence of a significant body of evidence in support of its use, Paediatric ACL Repair surgery should be conducted following MDT review and as part of an ethics approved prospective study. Use of this technique outside this setting is discouraged. Patients and their carers should be carefully counselled that the gold standard operative treatment for ACL tears is reconstruction.

• Congenital ligament deficiency is rare, often with associated limb deficiencies, and care should be centralised to a limited number of centres within the United Kingdom.

• Non-operative management of ACL rupture in children can be considered, but requires access to a strict and appropriate rehabilitation regime. ACL rupture with associated meniscal or chondral injuries should be managed surgically. The presence of ongoing instability following non-operative treatment should prompt definitive surgical management and should not be deferred until skeletal maturity or a specific age if

symptomatic. Where a treating surgeon is unable to perform the surgery, the patient should be referred to another unit.

• When discussing the risk of re-injury and contralateral rupture for ACL and in the absence of follow up data from the treating surgeon/unit, patients and carers should be quoted a figure of 1 in 4 for combined risk of re-rupture and contralateral ACL rupture.

•The primary goal of all paediatric meniscal surgery is to perform a meniscal repair if at all feasible.

• Surgeons performing arthroscopy for meniscal injury should perform a reasonable quantity of regular arthroscopic surgery. They should be able to perform all types of meniscal repair including those techniques for root and ramp lesion repair. The differences in anatomy and size and associated risks of iatrogenic injury should be considered when planning treatment. Meniscectomy should not be a primary treatment where there is any hope of successful repair and is the treatment of last resort in the paediatric and adolescent population.

•Treatment of discoid menisci should not include sub-total meniscectomy as a primary procedure. Saucerisation is the treatment of choice and until evidence clearly identifies a difference, tears and instability should be treated by meniscal repair. Consider referral to a high-volume unit or surgeon if performed infrequently.

• Meniscal Allograft Transplants (MAT) can be considered for post-meniscectomy syndrome or following total or near total meniscectomy. At present treatment should be limited to a few centres with appropriately trained and skilled surgeons and multi-disciplinary post-operative care. Data should be prospectively collected where this type of surgery is carried out.

• Rehabilitation after ACL reconstruction and meniscal surgery should be high quality and managed by appropriately trained physiotherapists with age-specific care. All surgeons should be aware of how paediatric patients are managed after surgery. If these facilities are not available then surgery should not take place. Caution should be displayed in return to performance after ACL reconstruction. Until clear objective measures are available, the committee advises that a minimum time of 1 year for return to pivoting sports should be used, combined with appropriate clinical assessment.

• Injury prevention needs to play a larger role in the paediatric population, and surgeons need to engage with the specialist societies, stakeholders, sports clubs and schools to promote this both on a national and local level. It should also be an essential part of post-operative rehabilitation and a priority for the State.

• Functional outcomes should be recorded by all surgeons performing paediatric ACL reconstruction. Until the National Ligament Registry has a facility for data recording in children, as a minimum the PEDI-IKDC should be used in under 16s. Consideration

should be given, in addition, to recording PEDI-KOOS and HSS Pedi-FABS in over 10s. This is a high-risk cohort with much controversy regarding management and all should participate in the use of patient reported outcome measures to improve the standard of care.

• If a lack of availability of paediatric operating facilities or staffing of beds are an issue, treatment should not be delayed and early referral to a unit with appropriate resources should take place.

• Local arrangements should be available for the transition of patients from the paediatric sector to the adult sector if ongoing care is required. On discharge, an appropriate summary clinical letter should be supplied in the event that later treatment is required, other than at the original treating unit.

• It is the opinion of the committee that where possible, paediatric knee surgical care should be delivered by surgeons combining experience in adult soft tissue knee surgery and paediatric orthopaedic surgery, ideally in the form of an MDT. All surgeons should have good volumes and experience to support good outcomes of care. How this care pathway will look will depend on the available resources and geography of the region in question.

• Paediatric Knee Fellowships need to be established to improve training, research and advancement of skills as the subspecialisation of soft tissue and sports injuries in children becomes established.

2. Introduction

The changing landscape of the NHS has meant wide variability in the management of paediatric soft tissue knee pathology across the United Kingdom. Factors such as the centralisation of paediatric surgical services, sub-specialisation/ loss of general orthopaedic care and increased incidence of pathology have raised concerns from both adult knee surgeons and paediatric orthopaedic surgeons about service provision.

The formation of this group was an initiative of both the British Society for Children's Orthopaedics (BSCOS) and the British Association for Surgery to the Knee (BASK). Members were recruited by the Boards of both societies for equal representation within the committee.

The aim of the working group was, based on the available evidence:

'To achieve the best standards for children's soft tissue knee problems and advise on safe, effective and reproducible guidelines for the United Kingdom'.

The focus of the recommendations is the management of anterior cruciate ligament (ACL) injury and meniscal pathology in patients aged 18 and under. Other pathologies such as tibial eminence fractures are not considered although the principles of care will be similar.

For the purpose of these guidelines, the committee met regularly and worked collaboratively to review literature, gather evidence, learn from practice in other countries across the world and assess practice variability. All topics were discussed at committee meetings with the decision taken by all as to the content of this document. The guidance issued aims to allow surgeons to ensure they are providing the best possible standard of care to the paediatric population, who in view of their age are at higher risk of complications and long term adverse sequelae as compared with an adult population with comparable injuries.

2.1 Incidence of ACL Injury

There is no doubt that the rates of both ACL injury and reconstruction in the paediatric population are increasing and data from multiple countries including registry data confirms this (1-4). The increase is greatest in the adolescent population. The cause of this is multifactorial, and factors such as changes in sports participation, increasing female participation in contact sport, increased body mass index, better diagnosis, higher demands on sporting levels and a trend to operative intervention are all implicated.

2.2 Changes in Practice for the Paediatric Knee

Changes in the way paediatric services are provided have affected the treatment offered around the UK. Centralisation of services has meant that care previously provided in some

institutions is no longer available, and some surgeons struggle to provide a service where, in the past treatment facilities for children were available.

Historically, orthopaedic departments had a generalist approach to treatment with consultants needing to deal with a range of pathologies. There would commonly have been one or more individuals who would treat children and adults. With time, this has become an infrequent resource as a new generation of sub-specialised consultants has developed with the ability to perform high quality surgery in their area of interest.

Sub-specialisation may improve the standard of care, but also has meant a shift of services to the paediatric sector where ACL reconstruction has infrequently been offered. Many paediatric orthopaedic surgeons will have experience of soft tissue knee surgery as trainees, but only 50 arthroscopic procedures are required for CCT and the ability to perform arthroscopic procedures is directly related to training in and frequency of use of the requisite skills (5).

Members of both BASK and BSCOS had raised concerns about the standards of care for the paediatric knee, and in order to assess the scale of the problem, a survey of members of both Societies took place.

2.3 BASK/ BSCOS Survey

An initial attempt to review HES (Hospital Episode Statistics) data obtained for the purpose of assessment of current practice for ACL and meniscal pathology was abandoned. Unfortunately, miscoding of procedures meant the data obtained was profoundly inaccurate. For example, rates of ACL reconstruction for under 16s were presented from hospitals in which this age group were not treated. Where individual unit data were compared to HES data, miscoding was also identified.

In order to identify current trends, it was decided to submit a survey to Members of BASK and BSCOS. The survey was designed collectively by the members of the steering committee with the aim of establishing what is current practice and the problems faced within both Societies. The survey opened in March 2019 and was advertised to Members of both Societies via email. There was a total of 25 questions, with the survey skipping sections depending on individual responses. A total of 271 responses were received, of which 16 were excluded as non-surgeon members of both Societies. 153 BASK Members completed the survey and 102 BSCOS Members, reflecting the difference in size of the societies. This number represent 41% of the practicing BSCOS membership and 26% of the total BASK membership. A good representative response was received from all regions of the United Kingdom.

A summary of the findings of the survey is listed below:

1. Most but not all ACL reconstruction in children and adolescents are performed by adult orthopaedic knee surgeons.

2. 25% of paediatric orthopaedic surgeons treat ACL injuries compared with 85% of adult orthopaedic knee surgeons.

3. 85% of all respondents performed fewer than 10 paediatric ACL reconstructions in 2018 with only 15% performing more than 10 cases.

4. In respondents performing ACL reconstruction for adult patients, 3% treated fewer than 10 cases in 2018, 67% performing more than 30 cases.

5. 93% of adult orthopaedic knee surgeons treat paediatric meniscal pathology, compared with 57% of paediatric orthopaedic surgeons.

6. 40% of respondents have treated paediatric ACL injuries non-operatively.

7. Transphyseal ACL reconstruction is by far the most prevalent technique of reconstruction.

8. Only 61% of all respondents follow up paediatric ACL cases for more than a year after surgery.

9. Only half of respondents assess skeletal age of patients pre-ACL reconstruction. Of these, over 70% use Tanner staging and not radiological assessment.

10. 14% report seeing at least one case of clinical or radiological growth disturbance.

11. 71% monitor clinically and/or radiologically post ACL reconstruction for growth disturbance.

12. Of those monitoring for growth disturbance, only 56% use long leg mechanical axis views.

13. 95% of paediatric knee cases are treated by paediatrically trained physiotherapists where the treating surgeon is a paediatric orthopaedic surgeon, compared with 52% where the treating surgeon is an adult orthopaedic surgeon.

14. Table I -The response by all survey respondents to the question '**What barriers exist in your clinical practice that limit the care of the paediatric knee? Tick all that apply'**

ANSWER CHOICES	RESPONSES	
Inadequate resources to operate on children	20.09%	47
Access to paediatric facilities	20.51%	48
Lack of therapy	15.81%	37
Lack of case volume to establish a safe service	24.36%	57
Centralisation of Paediatric Services have placed a burden on my unit	7.69%	18
Centralisation of Paediatric Services have prevented me caring for a cohort I have historically cared for	10.26%	24
Lack of appropriate training in the paediatric knee	14.10%	33
Concern of criticism of my training and/or volume from others	16.24%	38
I have no barriers	33.76%	79
Other (please specify)	13.25%	31
Total Respondents: 234		

Table I

15. Table II- The response by all survey respondents to the question '**Which of the following models do you feel are a correct way forward for future management of paediatric ACL and meniscal pathology in a Children's Hospital setting? Tick all that apply.'**

ANSWER CHOICES	RESPONSES	
Adult knee surgeon treats these cases	23.93%	56
Paediatric Orthopaedic Surgeon treats these cases	19.23%	45
Multi-disciplinary care and follow up with Adult and Paediatric Orthopaedic Surgeon	61.54%	144
Cases should be referred to a high volume centre	34.19%	80
Other (please specify)	8.12%	19
Total Respondents: 234		

Table II

16. Table III- The response by all survey respondents to the question **'Which of the following models do you feel are a correct way forward for future management of paediatric ACL and meniscal pathology in a District General Hospital setting? Tick all that apply.'**

ANSWER CHOICES	RESPONSES	
Adult knee surgeon treats these cases	29.49%	69
Paediatric Orthopaedic surgeon treats theses cases	10.68%	25
Multi-disciplinary care and follow up with Adult and Paediatric Orthopaedic Surgeon	55.13%	129
Cases should be referred to a high volume centre	40.17%	94
Other (please specify)	14.96%	35
Total Respondents: 234		

Table III

2.4 Worldwide Surveys of Paediatric Knee Surgery

The findings of the European Society of Sports Traumatology, Knee Surgery and Arthroscopy (ESSKA) Paediatric Anterior Cruciate Ligament Monitoring Initiative (PAMI) published in 2016(6), based on a survey of 2,236 members with a response rate of 22%, identified very similar findings to the BASK/BSCOS survey. Of note, clinically significant growth disturbance was reported by 14% despite many not formally monitoring to skeletal maturity, or using appropriate imaging to identify this. Practice was again widely varied with transphyseal hamstring reconstruction being the favoured technique.

A recent survey of the European Paediatric Orthopaedic Society (EPOS) and the Paediatric Orthopaedic Society of North America (POSNA) obtained responses from 25.4% of members, totalling 305 responses. 71% performed fewer than 10 paediatric ACL reconstructions per year, and 60% treated ACL injuries in comparison to 40% for the BASK/BSCOS survey (7). 5.5% reported clinically significant growth disturbance. The trend was towards transphyseal ACL reconstruction although other physeal sparing techniques were utilised more frequently in the paediatric population than in the United Kingdom.

There was a difference in the questions from all of these surveys, but principally the findings were all similar: practice is very widely varied.

A further example of changes to the practice of paediatric orthopaedics comes from the United States where the paediatric sports cases performed by candidates applying for the American Board of Orthopaedic Surgeons part II certification were reviewed between 2004-2014 by the subspecialty carrying out the surgery (8). This has shown an overall increase in the volume of sports cases, but what is most significant is the increase in cases performed by dual paediatric and sports trained surgeons where, over the 10-year period, there was a 919% increase in the cases performed, whilst other single sports and paediatric fellowships saw a drop in number.

2.5 Clinical and Radiological Diagnosis of Meniscal Injury and ACL rupture

Clinical examination of the injured paediatric knee raises specific difficulties. The child is less able to give a clear history of the mechanism of injury, and examination is difficult with clinical tests having low sensitivity (9). Laxity on assessment of the cruciates can be due to physiology as well as ligament rupture. The presence of a haemarthrosis should raise concerns of an intra-articular injury.

Radiographs may identify ligament avulsions and fractures as well as the presence of a lipohaemarthrosis. Of the imaging modalities available, MRI is most useful in identifying cruciate injury and associated injuries to the chondral surfaces, menisci, posterolateral corner and collaterals. The paediatric knee contains vascularity not seen in adult knees, and this can cause difficulty with interpretation particularly with meniscal injury. The sensitivity and specificity of MRI in paediatric ACL injury has been well described at 75-95% but a normal MRI does not exclude injury. Treating clinicians should be aware of direct and indirect features of ACL injury. MRI for meniscal injury has lower sensitivity and specificity. A quarter of patients with a diagnosed ACL rupture will have unrecognised meniscal pathology at arthroscopy (10).

The reporting of the paediatric knee MRI may also present difficulties. Surgeon familiarity with the management of these injuries is important and the same is true of the imaging. Surgeons should ensure their imaging is assessed by an experienced musculoskeletal radiologist.

There are no specific guidelines for the reporting of paediatric knee MRIs. A review of imaging methods of the paediatric knee for the Institutions of the steering group found differences between each unit. The principles of imaging are similar to those of adult MRI sequencing with a few exceptions. The standard 4mm slices used in adult MRI may be inadequate for smaller children and miss pathology. Here 3mm slices may be more appropriate. Coronal, sagittal and axial Proton Density Fat-Saturation should be performed, with T1 sagittal images. The increasing availability of 3-Tesla MRI may show an improvement in image quality and diagnosis (11), although 1.5T is standard within most NHS institutions.

2.6 Predicting and Preventing Growth Disturbance

It is a commonly held belief that growth disturbance is rare, but it is highly likely that it is under reported. What constitutes clinically significant growth disturbance has not been defined and the presence of a minor alteration of alignment may have long term adverse effects.

Both shortening and angular deformity in the coronal and sagittal planes can occur, with overgrowth a further possibility following ACL reconstruction in the skeletally immature.

The BASK/BSCOS survey in addition to those of ESSKA and EPOS/POSNA all present higher rates than published in Level III or IV series within the scientific literature (12,13). While a survey of surgeons represents level V evidence, the fact that most are not monitoring with imaging, clinical examination or in terms of follow up suggests that cases of growth disturbance are not being recognised.

Growth disturbance can occur with all techniques of reconstruction, including transphyseal and physeal-sparing methods. Physeal-sparing methods carry the risk of damaging a considerable proportion of the physis even if performed correctly. An MRI follow up study of all-epiphyseal and partial transphyseal reconstruction has identified frequent encroachment onto the tibial epiphysis anteriorly (14). Misplaced tunnels risk significant physeal damage, as they are located in the epiphysis close to the reserve zone of the physis. All-epiphyseal tunnels are also associated with overgrowth, so this technique is not without risk. This may be a consequence of vascular changes from drilling. Transphyseal reconstruction is associated with angular deformities. An MRI follow up study post transphyseal hamstring ACL in skeletally immature patients revealed shortening of the operated limb of 10mm in 24% of cases, and a difference of 2° valgus in the distal femur and also proximal tibia in 82% (15). This change in orientation of the joint line may not affect the overall mechanical axis, and so simple assessment of deformity may not identify this change in alignment. The long term implication of this may be significant in causing abnormal loading, increase in ipsilateral re-rupture rates, meniscal tears and later onset of osteoarthritis (16,17). Unrecognised deformity following ACL reconstruction could in the not too distant future lead to harm and possible litigation.

The steering group undertook a literature search of peer reviewed publications identifying 56 case series on ACL reconstruction in the skeletally immature that defined surgical techniques used and assessed for a postoperative growth disturbance. A transphyseal approach was associated with a 1.22% risk of growth disturbance at the tibial physis (14 cases in 1146 procedures) and a 0.42% risk at the femoral physis (4 cases in 963 procedures). The all-epiphyseal surgical technique was associated with a 0.14% risk of growth disturbance at the tibial physis (1 case in 634 procedures) and a 0.93% risk at the femoral physis (5 cases in 535 procedures). There were no reported cases of growth disturbance in patients undergoing extraphyseal procedures (femoral – 421 cases; tibial - 79 cases).

2.7 Imaging and Assessment for Growth Disturbance

The standard method for assessment of alignment is mechanical axis views using plain X-ray. In all skeletally immature patients undergoing ACL reconstruction it is advisable as a minimum to obtain long-leg weight bearing plain radiographs prior to surgery. If available, use of EOS would be beneficial in reducing radiation dose, and can allow lateral mechanical axis of the treated limb to be assessed. Measurements should focus on recording the mechanical axis of both the distal femur and proximal tibia. Use of the malalignment test (18) and measurement of the mechanical lateral distal femoral angle (mLDFA), mechanical proximal tibial angle (MPTA), anatomical posterior proximal tibial angle (aPPTA) along with mechanical axis deviation (MAD) at the knee are necessary. Without performing this pre-operatively, deformity already present may not be appreciated and changes at an early stage following surgery may not be identified.

Post operatively mechanical axis views should be repeated at 6 months, 1 year and then annually until skeletal maturity post ACL reconstruction. Most physeal bars will be visualised by 2 years, but overgrowth and undergrowth may still continue to produce deformity.

If concerns exist that deformity is developing post-operatively, MRI and/or CT will identify if a physeal bar has developed and allow planning of further treatment.

2.8 Calculations of Skeletal Age

Skeletal age calculations should be performed for all patients with open growth plates planned for ACL reconstruction pre-operatively. The younger the patient, the greater the risk of growth disturbance occurring with transphyseal reconstruction, and calculation of the skeletal age will allow surgeons to consider physeal sparing techniques.

Tanner staging is a clinical method of assessing maturity popular in publications on paediatric ACL reconstruction. Assessment of Tanner staging involves inspection of secondary sexual characteristics. This represents an intimate examination. Although reliable self-reporting proformas are available the relationship of these assessments to skeletal age is questioned in use for orthopaedic sports medicine (19). In most cases the clinical assessment for Tanner staging is made intra-operatively by which time surgical decision-making has already been carried out and therefore the assessment will not be able to influence treatment options.

The most well recognised technique for skeletal (bone) age assessment is use of the Greulich and Pyle Atlas, a method that uses an AP radiograph of the left hand and wrist to estimate skeletal age (20). The Tanner and Whitehouse (TW3) is also popular but may underestimate bone age in females (21). Modern digital imaging is able to produce a rapid calculation of the estimated bone age of the patient. Techniques also exist for calculating bone age based on age, gender and an AP radiograph of the knee, by measuring the Central Peak Value (CPV). This may be advantageous as most patients will have a radiograph of the knee and it negates the need for imaging the hand (22).

2.9 Management of Growth Disturbance

Treatment of the sequelae of growth disturbance will depend on the nature of the evolving deformity, it's location and future growth potential. Deformity may manifest as overgrowth, undergrowth and angular deformity in the coronal and sagittal planes.

The treatment options include:

- Permanent epiphysiodesis to arrest ipsilateral or contralateral discrepancies from overgrowth or undergrowth.
- Guided growth for treatment of angular deformity.
- Epiphysiolysis for the presence of appropriately sized physeal bars with significant remaining growth.
- Corrective surgery after skeletal maturity.

The management of growth disturbance is beyond the remit of this group but the Committee recommend it is carried out by specialists in deformity correction. In instances of growth disturbance, the surgical management of which falls outside a surgeon's scope of practice, the patient should be referred to a designated regional paediatric surgeon with a deformity practice to provide emergent treatment. This pathway should be put in place at the inception of any children's soft tissue knee reconstruction service.

3. Techniques of ACL Reconstruction

3.1 Transphyseal ACL Reconstruction

Use of this technique in skeletally immature patients is well documented in large case series with excellent outcomes and low incidence of complications (23-32). For the adolescent patient with closed or closing growth plates it remains the technique of choice, particularly as it is essentially the same technique used in adult reconstruction.

With skeletally immature patients, a balance needs to be achieved between the risk of growth disturbance and the benefit of performing an anatomically correct graft, sized appropriately to reduce the high rates of re-rupture seen in this cohort.

It is important to bear in mind that many published case series of transphyseal reconstruction in younger cohorts are 'physeal respecting' procedures, where bone tunnels are filled with the soft tissue grafts, tunnels are not excessive in size, are orientated more vertically and bone blocks (if used) or fixation devices are not placed across the physis using an image intensifier to check positioning. The more oblique a bony tunnel, the more physeal damage occurs. The larger the volume of physis removed in terms of the cross-sectional area, the greater the risk of growth disturbance. Fixation devices close to the perichondral ring can also cause growth disturbance, and are more likely to be seen with more oblique tunnels, such as with anteromedial portal drilling for the femoral tunnel. However, there is no definitive evidence to suggest that such modifications of surgical techniques are actually effective in limiting the risk of growth disturbance. The evidence suggestive of potential benefit comes from animal studies, post transphyseal reconstruction MRI studies and MRI modelling studies (33-36).

The risk in those with considerable remaining growth does however cause concern. There are very limited studies on pre-pubertal children undergoing transphyseal ACL reconstruction (37-40). Whilst good and safe outcomes are shown in pre-pubescent children, the Committee is concerned that the assessment of growth disturbance may be inaccurate in these papers. This is an area that needs further study before the safety of the technique can be assured.

On current published evidence, the transphyseal technique is appropriate for post-pubertal children and adolescents. However, evidence is lacking on the safety and efficacy of this technique in pre-pubertal children (i.e. males with a bone age less than 12 years, girls less than 10). If using this technique on pre-pubertal children, close monitoring of growth disturbance post-operatively with appropriate imaging must be done. This age group may be more safely managed with physeal sparing techniques.

3.2 Physeal Sparing ACL Reconstruction

3.2.1 All-epiphyseal

This technique allows anatomical tunnel placement without crossing the physis and aims to prevent growth disturbance. It theoretically avoids tension across the physis which may cause growth inhibition. Indications are for patients with significant growth potential, such as the pre-pubertal age group where the epiphyses are large enough to accommodate a suitably sized socket. This is an 'all-inside' surgical technique that requires appropriate jigs and for most available systems retrograde reamers. Intra-operative fluoroscopy should always be used to ensure the physis is not damaged. It is a technically demanding procedure with a steep learning curve. Early studies of the technique had high complication rates. Larger level IV series have shown that the technique is successful in terms of long term functional outcomes, re-rupture rates and incidence of growth disturbance in comparison to transphyseal reconstruction (14,41-47). The small size of the epiphysis is at risk with misplaced drilling of both femoral and tibial tunnels. Overgrowth is a reported phenomenon, likely due to hypervascularity from drilling close to the physis. Without a high volume paediatric ACL practice, surgeons should not perform this procedure and cases should be referred to a high-volume surgeon/unit, especially if that resource is geographically close. The age group in which this procedure is indicated is that with the highest risk of growth disturbance.

3.2.2 Partial Transphyseal

This commonly involves an epiphyseal femoral tunnel with a transphyseal tibial tunnel although there are many variations. This approach reflects concern that there is a greater potential for growth disturbance in the distal femur in terms of ultimate limb length with the eccentric and oblique tunnel seen with a transphyseal technique makes growth disturbance a possible higher risk. In contrast, the presence of a more reliably vertical tunnel in the centre of the tibia means this physis is at less risk (48). Some have described techniques involving a transphyseal femoral tunnel and all epiphyseal tibial tunnel (49).

This hybrid technique is therefore advocated by some for early adolescence. Technically it is easier to perform than an all-epiphyseal technique. There is very little published on this technique, but notably where data is available growth disturbance may still be a significant problem (49-50).

3.2.3 Extraphyseal

The technique of extraphyseal reconstruction is based on historical procedures that pre-date arthroscopic ACL reconstruction and is the paediatric variant of the 'over the top' technique. The procedure utilises a strip of iliotibial band and is a non-anatomic, intra-articular reconstruction combined with an extra-articular tenodesis of which the Micheli modification of the Modified McKintosh is the best described technique (51). The advantage is the absence of fixation or drilling in the epiphysis or the physis. Growth disturbance rates (0%) and re-

rupture rates (6.6%-13%) are very low at medium and long term follow up with good functional outcomes (52,53). This may be in part due to the use of an extra-articular tenodesis as part of the procedure. The comparison of physeal sparing techniques with transphyseal techniques in various systematic reviews include extraphyseal techniques. This may explain why outcomes are comparable based on the complication rates seen with all-epiphyseal techniques (54).

Concerns with this method of reconstruction are the non-anatomical intra-articular reconstruction as the graft passes close to the ACL femoral footprint as it passes behind the lateral femoral condyle into the knee. This may lead to instability and ongoing risk to the menisci (53). In addition, harvest of the iliotibial band can lead in half the patients to thigh asymmetry, although this is cosmetic and rarely symptomatic. It does avoid donor site morbidity associated with both quadriceps and hamstring autografts (55,56). It remains an excellent option for the younger child, who ideally should be managed in a high volume paediatric practice.

3.3 Graft Choice

The same graft choices exist in paediatric ACL reconstruction in with adult treatment but with some minor differences. As part of informed consent, graft choice should be discussed with patients and their parents. The issue of donor site morbidity and functional deficits related to autograft harvest should be considered.

The predominant graft used, more so than in adult cohorts, is hamstring autograft (57,58). Outcomes are good, but as in the adult literature, including registry data and meta-analyses (59,60), there is a possibility of a lower re-rupture rate with the use of bone-patellar tendon-bone (BTB). In one of the largest series of paediatric ACL reconstruction with over 500 cases (61), BTB had half the re-rupture rate in comparison with hamstring autograft. This can be partly explained by age bias as BTB autograft is a relative contra-indication in the skeletally immature patient. Harvesting of a bone block risks anterior tibial growth arrest as well as leading to physeal bar formation, so it is rarely performed. Good outcomes have been described in adolescents with open growth plates by placing the bone blocks in the metaphysis of the femur and tibia, but this practice cannot be recommended (62). In patients who have completed skeletal growth, surgeons can use BTB grafts and with time this may prove to be a better graft in reducing re-rupture rates. The risk of arthrofibrosis with BTB may be higher than with hamstring grafts (63).

Quadriceps tendon autograft has become more popular over the last decade in all age groups (64,65). There are no randomised comparative studies, but as yet, its use in the skeletally immature does not seem inferior to hamstring autograft (66). Failure rates in adults may be higher from registry data (67). Harvesting the quadriceps tendon requires some consideration of technique (68) due to size and the risk of retraction of the rectus femoris if harvest is continued too far proximally.

Allograft is infrequently used in children and adolescents. The higher failure rates seen with high dose irradiated grafts in adult populations have not yet been proven in the skeletally immature patients partly due to low numbers of published cases, although published failure rates are high (70-73). Living parental donor hamstring allograft is another option that can be

considered (74,75). There are ethical considerations with this in terms of consent, and logistical issues in attempting the safe performance of dual or staged procedures, particularly in the paediatric sector. If allograft use is being considered, careful discussion of the theoretical and actual risks should take place. For primary ACL reconstruction in children allograft is not recommended over autograft based on current evidence and should not be used as first graft choice.

In summary, hamstring autograft is safe and effective for the paediatric cohort, but BTB may be a better option for the skeletally mature adolescent. More studies are needed to compare these two techniques in children, but both are acceptable methods. For the skeletally immature patient, hamstring or quadriceps tendon autograft is an option, but with any graft choice it is worth bearing in mind that the high re-rupture rates seen in children are multi-factorial and comparative evidence on graft choice limited.

3.4 Lateral Extra-articular Tenodesis (LET)

The high risk of re-rupture in children and adolescents with primary ACL reconstruction has prompted some to suggest the routine addition of an extra-articular procedure to reduce rotational instability. There is a good body of evidence to suggest the potential benefits in terms of re-rupture rates in patients of a young age with two or more of the following risk factors (76-77):

- A high-grade pivot
- Generalised ligamentous laxity
- Genu recurvatum >10°
- Participation in pivoting sports

Routine use outside of these indications is not as yet, evidence based. This is however not a new procedure in children, where extraphyseal reconstruction has combined a lateral tenodesis with a non-anatomical intra-articular reconstruction with good outcomes. Use in a young cohort who struggle with neuromuscular control and stability after ACL reconstruction may prove to be a good choice.

There have been concerns raised regarding over constraint without evidence to date (78). Short term rehabilitation may be longer and complicated post-operatively by pain, risking arthrofibrosis. In the skeletally immature there is a case to consider avoiding the use of screws or staples and using intra-operative fluoroscopy.

3.5 ACL Repair

The potential for paediatric patients to benefit from their enhanced biological healing with acute ACL repair may be significant. Most of the blood supply of the paediatric ACL passes mainly in the interval between the ACL and PCL, ascending for the middle and proximal parts, and descending for the distal third. The osseous footprints are relatively avascular. Historically, ACL repair was associated with high failure rates, leading to the development of

reconstruction (79). Proximal or distal avulsions maintain the blood supply and therefore possibly retaining the healing potential, suggesting that repair may be an option for this type of tear in the paediatric cohort (80). A resurgent interest is based on a small number of level III and IV studies showing low short term re-rupture rates with varied clinical outcomes (81,82). A recent case series from the UK of ACL repair with synthetic augmentation in patients with a mean age of 12.9 showed no re-ruptures of proximal tears, although follow up was only to 2 years (83). A similar study with a different surgical technique comparing repair of proximal tears to reconstruction at 3.2 years mean follow up identified a cumulative failure rate 10 times higher (84).

Of interest is the Bridge Enhanced Anterior Cruciate Ligament Repair (BEAR) study, assessing a biological repair technique utilising a bovine collagen matrix with extracellular protein. This represented a prospective randomised controlled trial with two years follow up of a cohort of 100 participants with a median age of 17, 65 undergoing biological repair vs 35 with ACL reconstruction. 14% vs 6% re-ruptured, although not statistically significant (85). All of the BEAR participants had >50% of tibial remnant ACL present.

At present, surgeons should be cautious about offering this treatment- which goes against higher level evidence published historically unless it is as part of a formal study. In addition, it certainly should pass through the hospital clinical effectiveness and audit committee before being attempted. There is still no clear evidence of the ideal time window for treatment. In the absence of a significant body of evidence in support of its use, Paediatric ACL Repair surgery should be conducted following MDT review and as part of an ethics approved prospective study. Use of this technique outside this setting is discouraged.

3.6 Congenital Ligament Deficiency

Aplasia or hypoplasia of the cruciates are rare and often associated with limb deficiencies. Only small case series are available to guide treatment (86-90). Multiple anomalies of the menisci, the patellofemoral joint and the hypoplasia of the bony anatomy makes surgical treatment difficult. Rehabilitation can often be very complex and labour intensive for the child, their carers and the therapy team. Care for the congenital knee should be centralised within units who have the capability not only to treat the ligamentous deficiency, but also any associated limb deficiency or associated ankle and hip joint anomalies. The reconstruction of congenital ligament deficiency will increase with the advent of new lengthening techniques that replace the use of external fixation, and do not allow prevention of knee subluxation with lengthening.

3.7 Incidence of Re-rupture and Contralateral Rupture after ACL Reconstruction

Re-rupture rates vary widely. Two systematic reviews of ACL reconstruction in the skeletally immature reported graft ipsilateral re-rupture rates of 5.8% with the risk of contralateral rupture 11.8% at 5 years (96). This increased at 10 years to 7.9% and 12.5% respectively (97).

In younger patients, and particularly adolescent athletes, failure rates are considerably higher, with one meta-analysis reporting 23% combined ipsilateral and contralateral ruptures (98).

These findings are mirrored in large cases series, some with long follow up, and registry data (99-103). Most re-ruptures will occur in the first two years after reconstruction.

It is appropriate when discussing the option of surgical treatment with patients and their families to quote re-injury rates, both ipsilateral and contralateral, and 1 in 4 is a reasonable figure to use for overall re-injury.

3.8 Revision Paediatric ACL Reconstruction

Data is limited on the outcomes of revision paediatric ACL surgery. In the one study reporting on 90 revisions in children, the graft re-injury rate was 20%, with a quarter of the group requiring additional post-revision surgery (104). The risk of a subsequent third injury is also high (105).

3.9 Non-operative Management of Isolated ACL Rupture in Children

There is little comparative evidence of non-operative vs. operative management in children (91). With high quality, intensive rehabilitation, some will successfully avoid surgery although a significant proportion will require reconstruction for instability (93). The incidence of further meniscal tears due to ongoing instability is a risk but rates appear low (93,94). Attempts to treat a rupture non-operatively must have appropriate therapy resources before consideration, bearing in mind that a significant proportion may benefit from surgery if ongoing stability is an issue. Part of the increases in operative intervention seen in children are due to the benefits of surgery in treating instability and perhaps protecting the menisci and chondral surfaces from damage due to instability. Longitudinal study evidence to support these aspirations remains lacking.

Although carefully planned non-operative management for isolated rupture with close observation until skeletal maturity is reasonable, this may involve avoidance of pivoting sports and strict adherence to a rehabilitation protocol. The risk of growth disturbance caused by surgery is negated. However, if meniscal pathology is already present or there is persisting instability, surgical reconstruction should be considered and it is not acceptable to withhold an offer of definitive surgery until skeletal maturity.

4. Meniscal Pathology

The findings of the BASK/BSCOS survey highlighted that although many surgeons will opt not to treat paediatric ACL injuries, this is not the case when treating meniscal pathology in children. In many ways, this raises greater concerns as the link between meniscectomy and poor functional outcomes and osteoarthritis is well established (106-108). Appropriate treatment and meniscal preservation are of great importance. Data from different Trusts across the UK demonstrate variability in rates of meniscal repair vs meniscectomy where only some may be explained by pathology and age group treated (Figure 1).

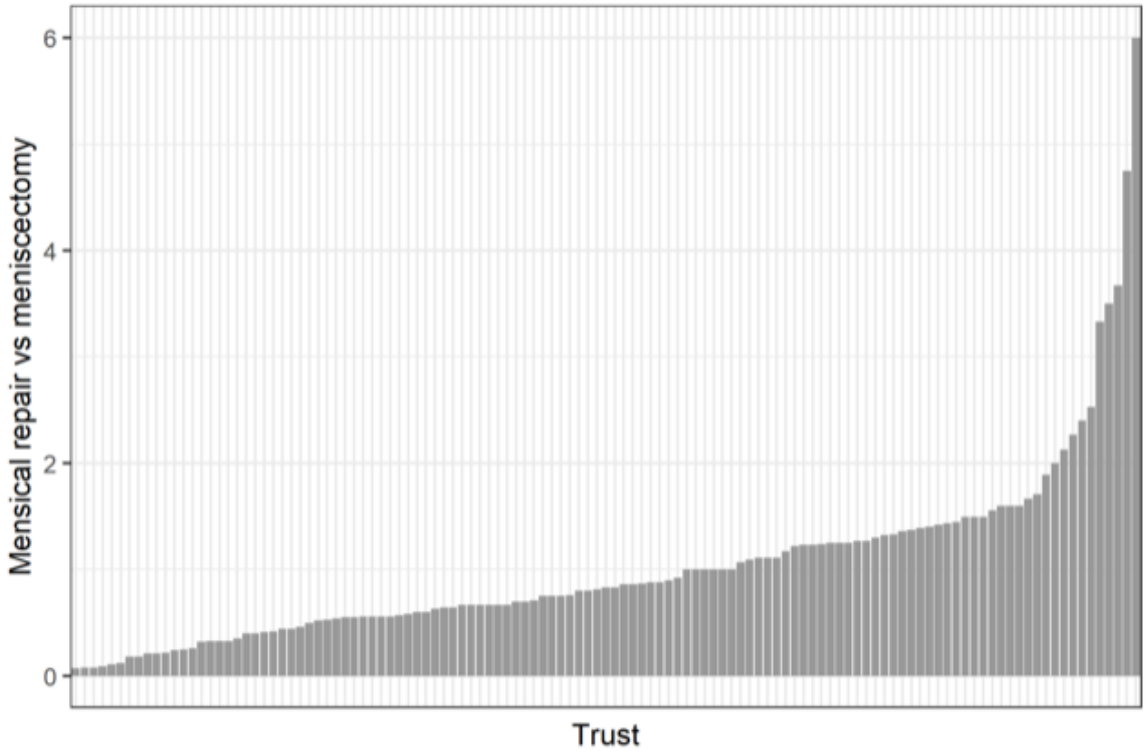

Figure 1: Repair vs Meniscectomy rates for Trusts across the UK (Image kindly supplied by GIRFT/ Edge Health).

The primary goal of all paediatric meniscal surgery is to perform a meniscal repair if at all feasible. Early diagnosis often facilitates easier repair. Although meniscal repair can be straightforward, any surgeon planning to treat a tear must have the ability to treat all types of tears. There is no pre-operative imaging modality that will clearly differentiate easy from difficult cases, and lack of preparation may result in a meniscectomy being performed because it is beyond the skill of the surgeon to perform an adequate repair. The necessary equipment must also be available to manage all tear patterns. Reliance on imaging to make a diagnosis will also lead to injuries being missed.

When performing an arthroscopic procedure, the treating surgeon should have the ability to perform the full spectrum of meniscal repair surgeries including the use of different suturing techniques. They must also be fully aware of the rehabilitation and post-operative

management. Simply being able to perform a diagnostic arthroscopy and having access to meniscal repair devices is not adequate. The same principle applies to all aspects of paediatric knee arthroscopic surgery. Meniscal preservation should be the main focus of treatment.

Anatomical considerations for children raise other issues. Meniscal repair devices were not designed for paediatric use and the chance of iatrogenic injury to adjacent structures may occur if tears are treated as they are in adults, particularly with the lateral meniscus. As an example, the popliteal artery can be less than 5mm from the capsule when repairing the posterior horn of the lateral meniscus medial to the popliteal hiatus via a lateral portal (109,110).

Meniscal tear patterns also differ depending on age. Two thirds of tears seen are in the lateral meniscus. In adolescents, half of meniscal tears are seen with cruciate rupture whereas this figure is less than 30% in younger children. In order of frequency, complex, vertical, discoid and bucket handle tears are seen, suggesting more complex patterns than in adults (111).

4.1 Treatment of Isolated Meniscal Tears

Meniscal repair in children and adolescents is associated with failure rates of around 30-67% (112-114), this figure reducing to 15% for studies including tears associated with ACL rupture (115). There is no consensus on the best method of repair, and no specific evidence for use of biological augmentation of repair, although there is evidence for bone marrow venting (notch microfracture) in adults that may transpose to paediatrics (116). A solid and stable fixation is required in all cases where repair is performed. Re-operation rates for meniscal repair are much higher than for meniscectomy and patients should be counselled appropriately (117).

4.2 Meniscal Root and Ramp lesions

Meniscal root injuries are probably more common than previously thought, and make up a significant proportion of overall paediatric meniscal tears (118). Most occur in association with ACL tears, and tend to be lateral root injuries. Surgeons should be familiar with the techniques for repair of meniscal root injuries if treating meniscal pathology. Ramp lesions also tend to occur in association with ACL injury and with a similar incidence to adult cohorts (119). Visualisation via the intercondylar notch and the use of a posteromedial portal are necessary skills for the assessment and repair of Ramp lesions.

4.3 Discoid meniscus

Discoid menisci commonly present with mechanical symptoms and with meniscal tears in over 70% of cases (120). The discoid meniscus has less collagen and vascularity than a

normal meniscus. Management options for the treatment of a symptomatic discoid meniscus include sub-total meniscectomy, partial meniscectomy (saucerisation), stabilisation or a combination of these methods.

The long-term outcomes of surgical treatment are poor. At eight years follow up in a population based study in which most were treated with meniscectomy, half re-tore and half developed radiological evidence of lateral compartment osteoarthritis (121). Interestingly, repair did not seem to affect outcomes. Functional scores also decline with time (122). There is a paucity of large series comparing treatments, making treatment choices difficult. A systematic review attempted to compare outcomes of saucerisation with complete meniscectomy within or beyond four years of surgery (123). With longer follow up saucerisation was significantly better in terms of functional outcomes, although again repair did not seem to make a difference. The lack of a difference with repair may represent heterogeneity of methods of fixation and so the benefits cannot be discounted on current evidence.

The Committee feel that meniscectomy should not be performed as a primary procedure. Peripheral tears should be appropriately prepared and stabilised by meniscal repair. More central tears are often complex in configuration, with poor quality tissues. In these instances, saucerisation with the combination of repair if needed is the preferred method of treatment.

Due to the poor outcomes associated with these types of tear, which make up a significant proportion of paediatric meniscal pathology, surgeons should be cautious about treating these injuries infrequently and consider referral to a high-volume surgeon/unit.

4.4 ACL and Meniscal Tears

A locked knee with a bucket handle tear of the meniscus is an indication for urgent treatment. ACL reconstruction can be deferred or performed at the same time, but delay is probably more appropriate in a younger cohort to prevent arthrofibrosis (63). Healing rates are likely to be lower in the presence of ongoing instability.

Progression of meniscal tears with an ACL-deficient knee is a controversial topic. Many studies identify an increased incidence of meniscal pathology with delayed operative management. Neglected tears are likely to be more complex and difficult to repair (124-126), but an increased risk of developing new tears in an ACL deficient knee managed with non-operative therapy is not yet proven (127).

4.5 Meniscal Allograft Transplants (MAT)

Paediatric patients who have had a meniscectomy are theoretically the ideal candidates for meniscal allograft. Biologically in general, allograft performs well in the paediatric knee (128). Outcomes of MAT at short to mid-term are good but re-operation rates are significant although not necessarily related to failure of graft healing (129,130). It can also be considered in the post-discoid meniscectomy patient (131). The difficulties are sourcing appropriately sized and treated graft and developing the skills to safely perform this procedure. At present, this service in children should be limited to a few centres who will ensure all cases are carefully followed up to prove efficacy and safety.

5. Rehabilitation and Return to Sporting Activity

Statistically, rates of return to pre-injury activity levels are high in children and adolescents but are associated with very high re-injury rates (132,133). Evidence based instruction on the most appropriate rehabilitation program is limited and as a result practice varies very widely (134,135). Returning to sport too early may contribute to graft failure and it is clear that using the same criteria in adults is not appropriate for the younger cohort of patients (136). Children differ in terms of movement patterns, dynamic valgus forces across the knee and the ability to regain strength after surgery. Ability to perform rehabilitation and maintain engagement is limited and risk-taking behaviours are often encountered. The effects of growth and maturation also increase the variables of core strength, neuromuscular control and coordination.

The role of the physiotherapist in post-operative care is important. The quality of the surgery will make no difference if the appropriate rehabilitation is not provided. The BASK/BSCOS survey clearly shows a difference in who it is that carries out the rehabilitation of paediatric ACL and meniscal pathology. This factor is likely to reflect both limitation of resources and where treatment takes place.

Although clinical measurements such as the presence of excessive laxity and post-reconstruction fixed flexion deformity are associated with increased re-rupture rates (137), objective measures and clinical tests are not specific in determining the ideal time to return to sport (138,139) and most studies use time based guidelines (140). This does not mean that functional scoring and clinical tests should not be used in assessment, they are key predictors of successful progression through rehabilitation. The role of psychological readiness must also be factored in, as younger patients are more likely to face issues (141).

In the absence of clear guidelines and variable practice, surgeons should be very cautious in allowing return to performance before a year post surgery, bearing in mind that purely time based criteria are not adequate. They should engage with their colleagues in physiotherapy to ensure appropriate therapy is taking place both before and after surgery and support the adequate resourcing of this critical aspect of care. Returning to pre-injury levels of sport is a multi-disciplinary decision. Surgeons should ensure that appropriate age-specific rehabilitation is available, and that the treating physiotherapist has appropriate training and experience with ACL and meniscal rehabilitation in children. If these facilities are not available surgery should not take place but rather onward referral to a centre where they exist.

Ultimately clearance to return to pre-injury levels of sports should be based on clinical examination, functional outcomes and measures, psychological readiness and the type of sport the patient plans to participate in.

6. Injury Prevention

Children demonstrate poor core stability and neuromuscular control, stiff landing and dynamic valgus, often combined with further decompensation of movement patterns related to growth. There is substantial high level evidence that the implementation of injury prevention programs in children reduces the risk of knee injury, particularly injuries to the anterior cruciate ligament (141-161). Availability and compliance with such programs remain a challenge. They often include methods to improve core strength, balance, dynamic stabilisation, hamstring lengths and landing strategies.

We as Orthopaedic Surgeons have a responsibility to minimise harm to our patients, and this includes advocating injury prevention in the healthcare, educational and sporting settings. Those that treat paediatric knee injuries should try to engage on a local level to encourage injury prevention programs. This could include local schools and sports clubs for example.

The high incidence and morbidity of ACL injury and its sequelae are well recognised and documented. As such the profession should continue to engage with and urge authorities and healthcare commissioners to fund, support and popularise injury prevention for all children. Sports governing bodies on a local, regional and national level also have a valuable role to play here, and collaboration with both the government and our specialist societies would facilitate a joined-up approach to tackle this. Guidance on safe levels and safe amounts of sport for children of different ages should be clear and available to parents, coaches, teachers and clinicians. Injury prevention programs would result in a reduction of both short term and long term morbidity. In addition, they would help to tackle the obesity crisis, as well as improving the well-being of all children, and would significantly reduce cost burden of treatment. It is better to prevent an ACL injury in the first place than to argue over the best technique for a surgical reconstruction. Post-operative rehabilitation after knee surgery is critical for good outcomes. It is also inherently linked to injury prevention, in reducing both the risk of re-rupture and also contralateral injury.

7. Outcome Data

Recording of patient reported outcome measures at present is not compulsory, but this is strongly advised for all surgeons performing paediatric ACL reconstruction. It is the opinion of the Committee that this should be a standard compulsory requirement.

The use of scores currently recommended for adult ACL reconstruction are not appropriate for children. Age specific and validated scoring methods are recommended, and of these the PEDI-IKDC is most appropriate based on current evidence for patients under 16 (162-164). The KOOS-child can be used, and is appropriate for over 10s but is validated in only 1 study (165). HSS Pedi-FABS (166-167) can be used for over 10s but is not yet validated.

The Committee reviewed registry data and methods of recording paediatric outcomes from around the world. Examples of paediatric-specific initiatives include the ESSKA Paediatric ACL Monitoring Initiative (PAMI). Engagement with this initiative is appropriate, and an alternative until the National Ligament Registry has paediatric specific ACL data recording.

With high ACL failure rates, data recording and the use of registries for children is essential with appropriate national support to allow robust data collection.

8. Requirements for Safe Surgery in the Paediatric Population

There are guidelines from the Royal College of Surgeons (168) and the Royal College of Anaesthetists (169) on the safe care of children both for emergency and elective surgical conditions. Surgeons treating children should be familiar with these guidelines as well as arrangements of their operational delivery networks and strategic clinical networks if these exist. Knowledge and training on Safeguarding children is also necessary.

In some instances, a lack of availability of paediatric operating facilities or staffing of beds may be an issue. Treatment should not be delayed for lack of these facilities, and early referral to a unit with appropriate resources should take place.

8.1 Transition of patients

For those working in Paediatric centres local transition guidelines will be available and should be followed. Bearing in mind that many patients will be in early adolescence and with the requirement of further surgery always a possibility considering the failure rates seen in the treatment of soft tissue knee pathology, a clear pathway of transition to adult services should be available for those performing surgery (170). This will involve developing networks with colleagues treating adult pathology, and in the same way, a reciprocal arrangement will be required for paediatric patients seen by those treating adults.

8.2 Volume of Surgery

Discussion as to how many of a given procedure a surgeon should perform is a topic that stimulates emotion for a number of reasons. This is an increasingly important topic that with the advent of National Joint Registries, the National Ligament Registry and Getting It Right First Time (GIRFT) will become a feature of all surgical orthopaedic practice. GIRFT is currently applicable to the NHS in England alone although similar principles are being adopted in the devolved nations.

There is good data from other surgical specialties such as surgical oncology and cardiovascular surgery that identify a link between good outcomes and volume of surgery.

Centralisation of services improves outcomes for a number of organisational reasons as well as surgical volume (171).

There will always be surgeons who can perform a low case volume of a procedure and obtain good outcomes but for the majority, this link with volume is important and relates not only to the skill of the surgeon, but also to the resources they have available in their unit.

One article assessing the epidemiology of ACL surgery in adults identified higher re-operation and readmission rates in low volume hospitals and low volume surgeons (172). However, data for paediatric ACL surgery in relation to surgeon and unit volume is not available.

It is also essential to consider the volume of arthroscopic surgeries, in particular those dealing with meniscal pathology, where the BASK/BSCOS survey identified a larger cohort of surgeons who would treat meniscal in comparison to ACL pathology. Volume of overall arthroscopic cases is of importance, as is the frequency of treatment of children.

It is not possible to give an evidence-based figure for volume of total arthroscopic cases or ACL reconstructions required to attain good outcomes, but we can to some extent be guided by figures used for knee surgery in general.

It is the opinion of the committee that where possible, paediatric knee surgical care should be delivered by surgeons combining experience in adult soft tissue knee surgery and paediatric orthopaedic surgery. All surgeons should have good volumes and experience to support good outcomes of care, ideally as a multi-disciplinary team (MDT). The outcomes of the BASK/BSCOS survey clearly highlight that surgeons from both the paediatric and adult sector prefer the option of multi-disciplinary care, followed by referral to a high-volume surgeon. How this would work would depend on the local availability of specialist services and geography. Differences will be seen across regions as a result. In a stand-alone Children's Hospital, facilitating the appointment of an experienced visiting surgeon to provide the service can be considered.

If the formation of an MDT service is not possible due to service limitations and there is no appropriate regional service to which patients can be referred, then a single surgeon service may be considered. It is the opinion of the Committee that if fewer than 5 ACL reconstructions per annum in the skeletally immature are being performed in children by an adult orthopaedic knee surgeon, they should consider referring cases to a colleague with a high-volume practice. For the Paediatric orthopaedic surgeon, more than 10 reconstructions per year should be performed with a minimum of over 40 arthroscopic knee procedures per year. Whilst these volumes could be achieved in isolation in dense urban settings, it is likely that dual consultant (Paediatric Surgeon and Adult Knee Surgeon) operating will become more common in many regions. Similarly, whilst meniscal repair volumes are not high for many practitioners, there must be familiarity with techniques for those embarking on meniscal repair in the paediatric population and therefore the committee recommend that surgeons should consider the sustainability and overall volume of their arthroscopic practice.

Moving forward, those doing lower case volumes will have a particular responsibility to demonstrate their results remain comparable with those in higher volume centres. The focus

must always reflect our desire to deliver consistent, optimal results to the paediatric population with knee pathology.

8.3 Training of Future Surgeons

A sub-specialty for the paediatric knee is clearly developing in Europe and North America, and it is likely that we are seeing the beginning of this here in the UK. There are a few good examples of a high standard of care centred around the child across the country.

In planning for the future, fellowship training for the paediatric knee needs to be developed for those planning to treat this pathology. This would enable a paediatric orthopaedic surgeon to focus on arthroscopic knee surgery with case volume to allow adequate skills to develop. It would also allow an adult knee surgeon to focus skills in this area if they wished to treat the paediatric cohort. At present these fellowships do not exist, and until this develops, paediatric orthopaedic surgeons wishing to treat soft tissue knee pathology should aim for dual fellowship training.

8.4 Acknowledgements

The committee would like to thank Mr James Hunter, GIRFT lead for Paediatric Orthopaedics for his input.

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