KEYWORDS
Arthroscopy; Children; Adolescents

Summary Arthroscopic surgery for children and adolescents is developing fast, thanks to technical progress in adult arthroscopy, improved knowledge of child joint disorders, and instrument miniaturization. The specificity of arthroscopy in children lies, on the one hand, in the small joint size and, on the other, in the presence of neighboring growth plates. There also exist specific pathologies as well as differences in indications in pathologies common to children and adults. These specificities need to be known, and adapted techniques and equipment require to be used, given which arthroscopy is feasible even in infants. Growth plate must be respected, and the residual growth of the operated segment (e.g., in knee ligament reconstruction) needs to be known. Joint decoaptation often does not require traction, and any stress maneuvers (valgus/varus) need to be gentle. The knee is by far the most frequently implicated joint in child arthroscopy, partly due to a rise in sports injuries. There is a variety of traumatic pathologies (osteochondral or meniscal/ligament tears, etc.) and of indications. Arthroscopy in children is safe, given awareness of these indications and respect of certain precautions. The advantages over conventional open surgery are the same as in adults: simpler postoperative course, faster functional recovery and better esthetic result. Arthroscopy will continue to develop in pediatrics in coming years.

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Introduction

Watanabe invented the No. 21 arthroscope in 1958, but only in 1976 did Eilert publish the first series of ‘‘pediatric’’ arthroscopy of the knee joint [1]. The method has continued to develop incessantly since then in childhood applications, thanks to miniaturization and new instruments and accessories adapted to children (electrodes, drill guides, suture and anchorage devices, etc.) and to learning on the part of pediatric orthopedists. The number of arthroscopies continues to increase, extending both to other joints and to ever younger patients and to new pathologies. Arthroscopy was initially developed in traumatology to deal with the rising rate of sports trauma, but indications spread to pediatric orthopedics. That is why the knee is the joint by far the most frequently implicated in arthroscopy, given the
wide range of pathologies encountered and of indications defined.

Over a 5-year period (2004 to 2008), 378 arthroscopies were performed in our department. The knee was the most frequently implicated joint (80%), followed by the ankle (8%), elbow (4%), shoulder (3%), hip (2%) and subtalar joint (1%). In terms of age group, 12% of procedures concerned 0 to 5-year-olds, 15% 6 to 10-year-olds, 50% 11 to 15-year-olds and 23% over 15-year-olds.

The advantages of arthroscopy over "conventional" arthrotomy are the same as in adults: simpler postoperative course, faster functional recovery and better esthetic result. Indeed, arthroscopy is no longer ever performed in meniscal surgery except for grafting.

Children, however, are not small-sized adults: indications and certain technical aspects are specific to pediatrics and need to be fully known to maximize advantage and minimize risk.

Specificities of children and bone growth

The two essential specificities of children’s joints are their small size and the proximity of growth plate.

Equipment

The material used must be adapted in size. A 2.7 mm optic, as well as the traditional 4 mm model, should be available, oriented at 30°. Instruments (forceps, shaver, radiofrequency electrodes, drill guides, fixation material, etc.) likewise have to be scaled down if exploration is not to be restricted and joint cartilage threatened. Exposure maneuvers for joint decoaptation, whether valgus/varus or traction, have to be gentle, to avoid injury to the growth plate or iatrogenic fracture.

Normal growth

Lower-limb growth in children mostly centers around the knee [2]. Residual growth needs to be determined in case of fracture with growth plate involvement or of surgery liable to traumatize the growth plate (cruciate ligament reconstruction, osteosynthesis). Residual growth is about 10 mm per year in the distal femur and 6 mm per year in the proximal tibia, up to the age of 13 and a half years in girls and 15 and a half years in boys [3]. Skeletal maturity is achieved 2 years earlier in girls than in boys. Tibial tuberosity growth plate fusion is achieved late (at 16 years of age in girls and 18 in boys), and represents final lower-limb bone maturity.

Growth disturbance

The drilling of transphyseal tunnels in cruciate ligament reconstruction incurs a risk of iatrogenic growth disturbance [4]. Most reported complications are caused by technical errors, and generally involve the femur. Tunnels should avoid the periphery of the physis and the Ranvier zone. Kercher et al. [5] recently developed an MRI-based 3D reconstruction software to calculate the damaged physeal volume from tunnel diameter and angle: for an 8 mm tunnel, damaged physeal volume is a mean 2.4% of total volume at the distal femur and 2.5% at the proximal tibia, diminishing with patient age. This method could provide a useful aid in surgical planning. A tendon graft inside the tunnel protects against growth disturbance, as demonstrated by Seil et al. [6]. Growth may still, however, be threatened by a "tenodesis effect" of the tension exerted by the graft on the growth plates, as demonstrated in animal studies but only hypothesized in humans [7,8]. Osteosynthesis material or other fixation devices should spare the growth plate as well as possible, or at least limit the number of transphyseal shots, use the smallest possible diameter, and be removed as quickly as possible [9]. The interference screws used in ligament reconstruction should never bridge the growth plate, and should rather be epiphyseal or metaphyseal.

Installation, approach and material according to joint

Shoulder

Installation is in lateral decubitus, without traction; the patient is stabilized by articulated supports and bolsters. Adolescents may be installed in the semi-seated "beach-chair" position, requiring a surgical assistant, or in lateral decubitus under traction for glenohumeral decoaptation. The upper limb is free draped, to be able to be manipulated as needed. The optic portal is via the posterior subacromial soft-point. An anterior, anterolateral or lateral portal is then performed, depending on the indication. The portal is first located intra-articularly by needle; anterior or anterolateral approaches can also be located "inside out" using the Wissinger rod technique. A blunt rod is introduced posteriorly into the joint then through the foramen ovale; it is located under the skin, and a cannula is introduced over the rod. A short 2.7 mm arthroscope is used in patients up to the age of 12 years, and the standard 4 mm model thereafter.

Elbow

The patient is installed in lateral decubitus and stabilized by ventral and dorsal supports. The tourniquet is inflated only if need be. The arm lies on a curved support placed under the tourniquet. Bone landmarks are drawn on the skin. Saline injection in the posterolateral soft point (center of a triangle between radial head, olecranon and capitellum) is made ahead of the posterolateral approach. An anterolateral approach is performed, with the wrist in pronation to safeguard the radial nerve. If necessary, an anteromedial approach is performed after intra-articular location of the needle. Traction, if needed, can be provided by the assistant on request.

Hip

The patient is usually installed on a traction table. A normal table without traction is generally reserved for simple synovial biopsy around the femoral neck or in under-5-year-olds in whom traction can be manual. Bone landmarks are drawn on the skin. Saline is instilled prior to performing the por-
Table 1  Main pediatric arthroscopy series in the literature.

<table>
<thead>
<tr>
<th>Joint and authors</th>
<th>Pathologies</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow Micheli et al. [21]</td>
<td>Osteochondritis</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Stiffness (arthrolysis)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Inflammatory arthritis</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Posterior impingement</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Trauma</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>49</td>
</tr>
<tr>
<td>Hip Kocher et al. [26]</td>
<td>Labral lesion</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Labral lesion following periacetabular osteotomy for dysplasia</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Perthes disease</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Inflammatory arthritis</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Spondyloepiphyseal dysplasia</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Aseptic osteonecrosis</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Slipped capital femoral epiphysis</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Osteochondral fracture</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>54</td>
</tr>
<tr>
<td>Knee Deblock et al. [52]</td>
<td>None (negative exam)</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Meniscal lesion</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Inflammatory arthritis</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Septic arthritis</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Osteochondral fracture</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Osteochondritis dissecans</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Synovial plica</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Discoid meniscus</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>ACL rupture</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Femoropatellar chondropathy</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Tibial intercondylar eminence fracture</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Hemarthrosis</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Arthrofibrosis</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>110</td>
</tr>
</tbody>
</table>

tant, to break negative pressure and achieve decoaptation. Selecting the portal penetration angle is critical and should be assisted by image intensifier. Joint penetration requires a sharp introducer. Anterolateral and lateral portals are used; posterolateral portals incur a risk of posterior circumflex artery lesion. In under-4-year-olds, a 2.7 mm arthroscope is indispensable; a 4 mm model may be used thereafter, if possible with a 70° optic.

Knee

The tourniquet is inflated only if need be.

Two installations are possible, depending on age, indication and surgeon preference. The first is supine on a normal table, with a support to the lateral side of the thigh to maintain the knee in flexion. The other is also supine, but with the legs hanging down and the thigh of the affected limb in a knee-clamp around the tourniquet; this facilitates the use of image intensifier if needed, and is our installation of choice in over-6-year-olds.

Approaches and their performance are as in adults. Care must be taken during varus/valgus maneuvers, especially in meniscal surgery. A 4 mm arthroscope can be used as of 4 years of age, but the 2.7 mm model is needed in younger patients.

Ankle

Installation is supine on a normal table. Bone (medial and lateral malleoli, joint line) and neurovascular landmarks (superficial peroneal and medial saphenous nerves) are drawn on the skin. Nerves and veins are harder to locate under the skin than in adults. The tourniquet is inflated only if need be. We regularly use traction via sterile stocking tied around the ankle with adapted weight (c. 10% of patient weight) hanging off the table to open the joint line; this device is not, however, indispensable, and manual traction by the assistant is enough in some cases, and notably in anterior procedures. Primary anterolateral saline joint injection expands the joint for introduction of the optic introducer; this may be performed under image intensifier. Anterolateral, anteromedial and sometimes posterolateral portals are used. A 2.7 mm arthroscope is used in under-7-year-olds; a 4 mm model can generally be used thereafter, depending on indications.

Other joints

Other joints are also amenable to arthroscopy in children, but with rarer indications. Wrist arthroscopy requires gentle vertical traction using finger traps on the index and
Table 2 Pathologies managed arthroscopically in our department (2004–2008).

<table>
<thead>
<tr>
<th>Pathology</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACL ± meniscal reconstruction</td>
<td>59</td>
</tr>
<tr>
<td>Discoid meniscus</td>
<td>39</td>
</tr>
<tr>
<td>Osteochondritis</td>
<td>36</td>
</tr>
<tr>
<td>Osteochondral fracture</td>
<td>30</td>
</tr>
<tr>
<td>Tibial intercondyle eminence fracture</td>
<td>28</td>
</tr>
<tr>
<td>Femoropatellar instability</td>
<td>24</td>
</tr>
<tr>
<td>Synovial biopsy</td>
<td>23</td>
</tr>
<tr>
<td>Septic arthritis</td>
<td>20</td>
</tr>
<tr>
<td>Talar dome osteochondral lesion</td>
<td>18</td>
</tr>
<tr>
<td>Joint fracture</td>
<td>17</td>
</tr>
<tr>
<td>Isolated meniscal lesion</td>
<td>17</td>
</tr>
<tr>
<td>Removal of metal</td>
<td>14</td>
</tr>
<tr>
<td>Erb’s palsy</td>
<td>8</td>
</tr>
<tr>
<td>Synovial plica</td>
<td>8</td>
</tr>
<tr>
<td>Anterolateral ankle impingement</td>
<td>7</td>
</tr>
<tr>
<td>Exploration</td>
<td>7</td>
</tr>
<tr>
<td>Posterior ankle impingement</td>
<td>5</td>
</tr>
<tr>
<td>Osteochondromatosis</td>
<td>4</td>
</tr>
<tr>
<td>Villonodular synovitis</td>
<td>3</td>
</tr>
<tr>
<td>Stiffness</td>
<td>3</td>
</tr>
<tr>
<td>ACL cyst</td>
<td>2</td>
</tr>
<tr>
<td>Patellar tendon ossicle</td>
<td>2</td>
</tr>
<tr>
<td>Foreign body</td>
<td>1</td>
</tr>
<tr>
<td>Benign epiphyseal tumor</td>
<td>1</td>
</tr>
<tr>
<td>Subtalar synostosis</td>
<td>1</td>
</tr>
<tr>
<td>Congenital hip dislocation</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>378</td>
</tr>
</tbody>
</table>

As we have seen, arthroscopy mainly concerns the knee joint. Indications in other joints, however, are numerous and need to be known. Table 1 presents the main literature series per joint. Table 2 details indications in our department for the period 2004–2008. This section is ordered by pathology, specifying indications for arthroscopy, surgical techniques, main results and, where appropriate, joint specificities.

Articular fractures

Salter and Harris type III and IV fracture
Reduction of Salter and Harris type III and IV fracture should be anatomical, to limit growth disturbance and arthritic sequelae. Arthroscopy provides an alternative to arthrotomy, enabling full joint lesion assessment and precise minimally invasive control of reduction. Distal tibial fractures (McFarland, Tillaux and triplane) are good indications, with associated percutaneous fixation [10,11]. Other joint fractures can also be successfully managed arthroscopically: e.g., the lateral humeral condyle [12]. No associated complications have been reported in children.

Fracture of the intercondylar eminence of the tibia (tibial spine)
Management of Meyers and McKeever grade-1 fractures [13] is generally agreed to be conservative, with reduction and osteosynthesis for grades 3 and 4. Grade 2 fracture management remains controversial, as surgery has not been demonstrated to be preferable to reduction with cast immobilization. In agreement with several authors, we manage grade 2 fractures with arthroscopic reduction and fixation. It evacuates hemarthrosis, provides joint assessment, notably of meniscal entrapment in the fracture site, and enables precise reduction with fixation. The type of fixation depends upon the size of the fragment and the habit of the surgeon. Direct screwing with one or two cannulated screws is the gold standard. The patient is installed with legs hanging down, with the image intensifier in a lateral position. The limb is draped over the image intensifier. The guide pin is introduced on a lateral parapatellar portal, followed by a 4-mm-diameter self-perforating cannulated screw. Reduction should be anatomical, in order to restore anterior cruciate ligament (ACL) tension. Countersinking is, however, recommended by some authors, as ligament distension is frequent if not systematic [14]. If need be, the screw can bridge the tibial growth plate, but must in that case be removed under arthroscopy at 3 months, to avoid growth disturbance. Whipstitch is an interesting alternative if the fragment is comminuted or too small. Many other effective techniques are regularly reported. Long-term functional results after fracture of the intercondylar eminence of the tibia are good, but with frequent residual laxity (38% of cases for Janarv et al. [15] and 74% for Willis et al. [16]). No complications specific to arthroscopy have been reported.

Osteochondral fracture
Osteochondral fracture occurs frequently in femoropatellar joint trauma, and especially in adolescents and preadolescents [17]. It involves the patella and/or femoral condyles. AP, lateral and Merchant view X-rays should be taken systematically after reduction of patellar dislocation or in case of hemarthrosis with strongly suspected femoropatellar trauma, to look for any osteochondral fracture. In case of doubt, assessment is completed by CT-scan to confirm the osteochondral fracture and specify its size and location. CT will tend to underestimate size the younger the patient. Arthroscopy enables the fragment or fragments to be located and defect size and location to be assessed. If large enough, the fragment should be repositioned and fixed in emergency with a compression screw or pins, possibly in bioabsorbable material. Healing is possible, even if the fragment’s subchondral bone is thin or in places absent [18]. After reduction of traumatic hip dislocation, CT-scan for possible osteochondral fracture is systematic. Arthroscopy enables ablation of any osteochondral fragments.
Non-traumatic osteochondral pathology

Osteochondritis

Osteochondritis dissecans of the femoral condyles. The 2005 Sofcot Symposium specified indications for surgery in children and adolescents [19]. Arthroscopy is generally indicated after the age of 12 years where rest has not relieved symptoms or achieved radiographic reossification or in case of signs of lesion instability on MRI. It provides visual and palpatory assessment and also assesses surface cartilage stability. Treatment consists in transcortilage microperforation of the bony lesion using a 1.2 or 1.5 mm pin and drill, if the cartilage appears stable. The aim is to stimulate subchondral bone revascularization. The relevant region is identified by its dull coloration or softened cartilage; five to 10 perforations are made. If the fragment is unstable, it is fixed by screw, pin or osteochondral mosaicplasty plug [20]. Arthroscopy also enables removal of any loose fragments, with possible associated mosaicplasty in case a defect needs grafting. Screwing and mosaicplasty may be combined, with two osteochondral plugs reinforcing the assembly. Results with the various techniques are better the younger the subject [19].

Osteochondritis dissecans of the lateral condyle of the elbow (Panner’s disease). Medical management with cessation of sport and rest is the rule, although mobilization is encouraged. As with the knee, surgery is indicated in the absence of clinical or radiological improvement or if an osteocartilaginous fragment is released into the joint [21], and should not be delayed if the functional result is to be optimized [22]. Chettouane et al. recently reported good results with a single osteochondral autograft of 8—15 mm diameter, performed by lateral arthrotomy [23].

Osteochondritis dissecans of the talus. This lesion is rarer in children than in adults. Of indeterminate etiology, it involves the medial more often than the lateral angle of the talus. Berndt and Harty [24] define four grades. In grades I and II, management is conservative: cessation of sport, with or without immobilization and non-weight-bearing. In the absence of clinical improvement (persistent pain) or of signs of radiologic reossification by 6 months, surgery is indicated [25]. The indication is confirmed by signs of instability and the absence of signs of revascularization on MRI. Arthroscopic perforation gives good results and should not be delayed, especially in adolescents of 13 years or over [25]. Grades III (partially detached osteochondral fragment) and IV (loose fragment in the joint) are immediate indications for preferably arthroscopic surgery. Procedures include fragment fixation or ablation and curettage of the necrosis region. Medial transmalleolar approaches are contraindicated due to the risk of traumatizing the tibial growth plate. Perthes disease. At the sequela stage, hip arthroscopy enables debridement of any unstable chondral lesions of the femoral head causing conflict with the labrum. Such flap lesions are encountered following Perthes disease, but also in spondyloepiphyseal dysplasia and sickle-cell necrosis [26].

Femoroacetabular impingement

In pediatrics, femoroacetabular impingement is often secondary to hip disorders such as slipped capital femoral epiphysis, Perthes disease or developmental dislocation.

‘Pincer’ or ‘cam’ type, impingement is amenable to arthroscopy, as described by Philippin et al. [27], with good results: they reported a series of 17 patients under the age of 16 years; procedures ranged from ‘bumpcetomy’ to labral repair. Specific instruments were employed, such as arthroscopic knives, and arthroscopic capsulotomy was frequently performed to facilitate surgery. No complications were reported.

The acetabulum is a rare location for exostosis. Exostosis may cause femoral head subluxation, pain and early arthritis. Excision by arthroscopic burr is an interesting alternative to open surgery, which requires dislocating the femoral head [28].

Posterior ankle impingement

Posterior ankle impingement features posterior pain in maximal passive plantar flexion, with the knee at 90°. The origin may be osseous (os trigonum, posterior talar process) or exclusively soft tissue (flexor hallucis longus tendon, scar tissue). Surgery is resorted to only in case of failure of medical treatment comprising rest, immobilization and physiotherapy. Open surgery is associated with a high rate of complications. Posterior arthroscopy as described by Van Dijk seems to provide better results than conventional surgery [29]. The patient is installed prone; lateral image intensification is useful for locating joints. Paratendinous posteroanterolateral then posteroanterior portals are performed on a horizontal line drawn at the tip of the lateral malleolus. Halstead forceps are introduced towards the first interdigital space and pushed to bony contact on both portals. A working space is created using a shaver. The ankle and subtalar joint spaces are located. Various procedures are possible, depending on indications: resection of a hypertrophic capsule, the os trigonum or the posterior process of the talus. The posterior talocalcaneal synostoses may also be resected using the same technique.

In all cases, walking is encouraged after 10 days’ immobilization.

Primitive and secondary capsule, tendon and ligament pathologies

Erb’s palsy

Erb’s palsy often induces shoulder internal rotation contracture due to external rotator muscles palsy. Several surgical procedures have been described to restore active external rotation and prevent shoulder osteocartilaginous deformity. The principle consists in anterior capsule and ligament release associated to muscle transfer (latissimus dorsi and/or teres major) to the rotator cuff. In 2003, Pearl recommended arthroscopic capsule, ligament and muscle release [30]; he performed anterior tenocapsulotomy, including sectioning the anterior capsule and medial and inferior glenohumeral ligaments and subscapularis muscle tendon. The gain in external rotation was considerable (67—81°), but at the cost of active internal rotation due to sectioning the subscapularis. Latissimus dorsi muscle transfer seems to prevent recurrence. We perform arthroscopic anterior release, respecting the subscapularis and pectoralis major muscles [31]. After installation as is section 3, the shoulder is placed in maximal external rotation,
and the medial and inferior glenohumeral ligaments are located. The capsule is sectioned at the labrum, using a bipolar vaporization electrode introduced anterolaterally, thus sectioning the anterior capsule and the lower part of the superior glenohumeral ligament. Sectioning continues along the biceps tendon, to the upper part of the su-
pe-
rior glenohumeral and coracohumeral ligaments. The middle glenohumeral ligament is sectioned if the gain in external rotation seems insufficient. In a second step, the lat-
simus dorsi is transferred onto the supraspinatus tendon. The patient is immobilized in a thoracobrachial cast in 90° abduction and maximal external rotation for 6 weeks. Poste-
rior glenohumeral dislocation is an obstacle to arthroscopic treatment. Eight patients aged 1 – 12 years were operated on in our department. Mean gain in external rotation was 50° at a minimum 1 year’s FU, with internal rotation unchanged, scoring 2 on the Mallet score. We found no complications. This technique is minimally invasive, and effective when performed before onset of osteoarticular deformity. The fact that the subscapularis is respected conserves internal rotation and avoids inducing anterior glenohumeral instabil-

ty.

Anterior cruciate ligament (ACL)

Traumatic knee hemarthrosis in children is associated with ACL rupture in 52% of cases in boys and 16% in girls [32]. Such lesions, then, are not rare, and incidence is indeed increasing with ever earlier and more intensive practice of contact sports. ACL reconstruction is indicated in case of symptoms of instability and/or associated meniscal lesion. Issues of anatomy, isometry and graft fixation quality are as in adults, with the additional need to respect growth plates. Many specifically pediatric techniques have been described [33]. Surgery is preferably arthroscopic, although arthro-
tomy remains possible. In both femur andibia, bone tunnels are intra-epiphysial, transphyseal or metaphyseal "over the top" to the femur. Transphyseal tunnel should be as small as possible in diameter (≤ 9 mm) and as vertical as possible. No implants (interference screw, staple, etc.) should bridge the growth plate. In intra-epiphysial techniques, introduc-
ing the arthroscope into the tunnel enables the growth cartilage to be checked for breakage. In children, patellar tendon grafts are characterized by anterior tibial tuberos-
ity growth plate, to be respected by means of Clocheville’s technique [34]. Other grafts show no specificity. We perform femoral and tibial intra-epiphysial tunnels, but prefer a tibial transphyseal tunnel in adolescents, as it provides better tibial fixation. Results are good, despite greater residual laxity than in adult series [35]. The Sofcot 2006 Symposium of 102 cases included four early complications: one postoperative aspiration for hemarthrosis, one second-
look arthroscopy for Cyclops syndrome, one arthrolysis for flexion contracture and one case of septic arthritis, with only the last two causing poor long-term results. A sin-
gle case of significantly disturbed growth was reported: a boy, 14.5 years old at surgery, developed secondary valgus femoral malalignment due to lateral and posterior growth arrest caused by a technical error during the drilling of the femoral tunnel in a modified Clocheville technique; poor toler-
ance of the valgus led to surgical correction by osteotomy at skeletal maturity.

Posterior cruciate ligament (PCL)

PCL lesions are rare in pediatrics. They are generally due to avulsion of the tibial insertion, which is sometimes detected only on MRI [36]. Intra-substance rupture is even rarer, but can induce posterior or posterolateral instability requiring arthroscopic reconstruction [37].

Patellofemoral joint

There is no role for arthroscopy in the treatment of per-
manent or habitual dislocation in children, which requires realignment by open surgery. It is, however, useful in case of failure of conservative management of objective or subjective patellofemoral instability. Many procedures are available and are often associated à la carte, customized in the light of exhaustive assessment. Luhmann et al. demonstrated the advantages of systematic arthroscopy in patellofemoral realignment in adolescents: it provides com-
plete joint exploration for associated lesions (osteochondral fractures, chondropathy, etc.) that may go undetected on limited arthrotomy [38]. It further assesses the patellar course and the immediate impact of surgery.

Certain realignment techniques involving soft tissue can be performed under arthroscopy, avoiding unsightly and painful anterior scarring and facilitating rehabilitation. Iso-
lated performance of such procedures applies only when there is no bone abnormality.

Lateral retinacular release. It is facilitated by a bipolar hook for coagulation, especially in the superolateral artery of the knee, hemorrhage being the prime complication. Gerbino et al. [39] assessed long-term results for lateral retinacular release in a heterogeneous adolescent popula-
tion (objective and subjective instability and anterior knee pain): 18% of patients required revision surgery for persist-
tent symptoms, independently of gender or indication; the others were satisfied, with good functional scores main-
tained over time. Other than in anterior knee pain, this procedure should be associated to medial retinacular repair. Medial retinacular repair. “All-inside” arthroscopic medial retinacular reconstruction techniques have been described, such as plicature by separate sutures tied within the joint (Halbrecht) [40] or thermal capsulorraphy [41]. The inventors reported good results, but these techniques should be reserved for subjective instability. For objective instability, we prefer minimally invasive techniques such as Chassaing’s, using a free gracilis tendon autograft [42], or else open surgery.

Surgery is not indicated in acute patellar dislocation in children and adolescents if there are no combined lesions [43]. AP, lateral and Merchant view X-rays should be system-
atic in acute dislocation, to rule out osteochondral fracture, frequently associated in pediatrics. When in doubt, assess-
ment should be completed by MRI or CT scan.

Patellar ligament ossicle

This is a fairly rare but classic sequela of Osgood-Schlatter (tibial tuberosity apophysitis) or Sinding-Larsen-Johansson disease (apophysitis at the apex of the patella). Evolution over skeletal maturity tends to be spontaneously favorable, but disabling anterior pain, associated with a non-fused ossicle, persists in some patients. In case of resistance to con-
servative treatment, arthroscopic excision is a treat-

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ment of choice rather than conventional transtendinous excision, to avoid an anterior scar that is often painful, especially in the kneeling position [44]. For distal ossicles (tibial tuberosity), the approach is slightly higher than usual, for good visualization of the anterior edge of the tibia. The Hoffa ligament is resected and the intermeniscal ligament located; the patellar tendon is then detached step by step in contact with the bone, preferably using a radiofrequency electrode. The ossicle is then located under image intensifier, using a percutaneous needle, which is then located within the joint. The ossicle is carefully dissected, respecting the tendon, and removed by forceps or nibbled if too large. The tibial tuberosity can then be smoothed using a burr, as in acromioplasty. Weight-bearing is immediate, with a knee splint for 3 weeks. Some rehabilitation sessions precede resumption of sports after 3 months.

Fibrocartilage lesions

Discoid meniscus

Discoid meniscus should be suspected in children in case of limited extension and audible knee snap. Diagnosis is by MRI, based on precise criteria [45]. Only symptomatic discoid meniscus should be treated. Arthroscopy is based on meniscectomy or "saucerization", which consists in trimming out the center of the dysplastic meniscus. If need be, it can be associated to repair of an unstable anterior or posterior segment or to partial meniscectomy of a fragment unamenable to repair [46]. Classical anterolateral and anteromedial portals are used. The meniscus is incised using a scalpel, and the center is then trimmed out by basket forceps and the free edge smoothed using a shaver. A Beaver knife is useful for incising the anterior segment, which is hard to reach. Stability and absence of resultant meniscal lesion should be checked. Hypermobility menisci can be stabilized by posterior suture, involving the popliteal tendon if need be. Thermal capsulorraphy has also been reported to be successful [47]. Arthroscopy gives good results: Ahn et al. reported no revision at a mean 4 years' FU of 28 cases, and little if any functional impairment [46]. Treatment should not, however, be delayed after symptom onset, to avoid extensive meniscectomy [48].

Traumatic meniscus

Meniscal lesion in a stable knee is more common in children (42% in the Sofcot 2005 Symposium series [49]) than adults (c. 15%, depending on the series). The lateral meniscus is involved in 60% of cases. Conservative management is the rule when the knee is stable or the ACL reconstructed, and consists in rasping with or without meniscal repair for lesions in excess of 10 mm and/or unstable on probing. Meniscal repair has no specificities in children. "All-inside" suture is used for the middle and posterior segments, and the "out-in" technique for the anterior segment. The Fast Fix® and Ultra Fast Fix® implants are equipped with a breakable plastic sheath to control needle and implant depth, which should be adapted to the child's size. Valgus/varus maneuvers for joint-line opening should be cautious, to avoid damage to the growth plates around the knee. Results are comparable to those obtained in adults, with a 75% success rate [50]. Meniscectomy, when required, should be as partial as possible.

Acetabular labrum

Labrum tears mainly occur in adolescents and may be idiopathic or secondary to hip dysplasia, Perthes disease or slipped capital femoral epiphysis [51]. They may cause pain and intra-articular snapping. Arthroscopy is the reference technique for precise lesion assessment and treatment by reinsertion or partial resection [26,27,52].

Synovial pathology

Synovial pathology is the sole indication for diagnostic arthroscopy of the knee in children since the advent of MRI [53]. It enables complete joint exploration and inspection of the synovial joint (shape, color, trophicity, etc.) as well as directed biopsy and a wash-out effect. It is also indicated for treatment of certain synovial pathologies.

Synovectomy

Arthroscopic synovectomy may be indicated in several synovial pathologies, and may be partial or total, associating two classic, two posterior and two superior portals. Preferably, a shaver is used, with a radiofrequency electrode for coagulation. The need for the additional portals can be determined on preoperative MRI. The most frequent indications in children are idiopathic juvenile arthritis resistant to medical treatment, villonodular synovitis or productive synovial chondromatosis. In hemophilic arthropathy, it facilitates rehabilitation, fundamental to the functional result [54].

A plica is a synovial fold forming a band, and is usually asymptomatic. Plica mediopatellaris, however, may cause pain or pseudomeniscal syndrome; management is then by simple arthroscopic excision.

Septic arthritis

In septic arthritis of the knee, arthroscopic wash-out is less invasive than arthrotomy and enables complete exploration and lavage as well as directed synovial biopsy where diagnosis is doubtful [55]. It may be extended to any joint accessible to arthroscopy.

Extra-articular endoscopy

Endoscopy backs up curettage of benign epiphyseal tumor, ensuring completeness and absence of joint penetration [56]. It is also useful for locating any central bone bar during Langenskiold procedure [57]. Several authors have also reported fascia lata lengthening under endoscopy in painful external snapping hip resistant to conservative management [58].

Arthrolysis

Indications for arthrolysis are exceptional in pediatrics. Surgery has no specificity, apart from respecting the growth plate and Ranvier zone.
Conclusion

Pediatric arthroscopy is in full development. The advantages are the same as in adults: simple postoperative course (shorter hospital stay and faster healing), faster functional recovery and less scarring. The literature is as yet poor as compared to that for adults. Large series with a good level of evidence will be needed for formal validation of treatment indications. Arthroscopy is a safe method in children if the specificities are respected. Certain indications have now been validated, such as meniscal and knee ligament lesions or osteochondritis dissecans of the femoral condyle, but others remain experimental, have not been demonstrated to provide benefit over conventional surgery and therefore still require assessment.

Conflict of interest statement

None.

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References

Arthroscopic surgery in children


