Arthroscopically Assisted Central Physeal Bar Resection

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Abstract: Thirty-seven central physeal bars were removed with an arthroscopically assisted technique. Thirty children (32 cases) have been followed to maturity or physeal closure. There were 19 boys and 11 girls, aged 4–14 years (mean, 9.5 years). Site of arrest was distal femur (15), proximal tibia (9), distal tibia (6), and distal radius (2). Mean follow-up was 6.5 years (range, 2–12 years). Adequate longitudinal growth was realized in 21 patients (70%) just after bar resection. Five patients (17%) required osteotomy, lengthening, or epiphysiodesis in addition to bar resection. In 4 patients (13%), bar resection failed. Failures occurred in those patients whose source of growth arrest was infection (3) or degree of physeal trauma approached 50% (1 case). This is the first series that studies and documents the efficacy of the arthroscope in central physeal bar resection. It provides the best visualization with minimal morbidity. The technique is described, including a discussion of technical tips and pitfalls.

Key Words: central physeal bar, resection, arthroscopic

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Trauma to physeal cartilage may result in either immediate or delayed failure of physeal growth. This depends upon the degree and type of trauma inflicted (eg, mechanical, infection, thermal) and somewhat upon the age of the patient and injury location.[1–7] Complete physeal arrest is best managed by contralateral epiphysiodesis[8] or limb lengthening if residual growth is anticipated to be significant. Partial physeal arrest in a child with significant growth remaining may benefit from the takedown of the bony bar responsible for the arrest.[9–14] Partial arrest, if left untreated, results in angular deformity and/or shortening and may have a devastating effect upon limb alignment and adjacent joint function and longevity.[15–18]

Surgical indications for physeal bar excision are well delineated.[19–23] Methods of mapping the area of arrest have been described by Carlson and Wenger[24] but are evolving with advances in computed tomography (CT) and magnetic resonance imaging technology and the development of software to manipulate digital images.[3,25–29] Incomplete physeal arrest was classified by Bright[20] as peripheral (type 1), central (type 2), or combined (type 3).

We have been using the arthroscope exclusively since 1987 to assist physeal bar removal as described in part 2 reporting in 1995 on 16 successful cases, with an average of a 4-year follow-up.[30]

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Describing the outcome of the patients who were treated with arthroscopically guided central physeal bar removal and who have been followed to maturity, we also describe here the arthroscopic technique of central physeal bar resections (PBRs) itself, with a discussion of technical tips and pitfalls.

Treatment of the peripheral and combined lesions involve resection of the bar from the periphery with direct visualization of both bar and healthy physis. Central bridge removal is far more complicated, as it must take place from above or below the physis to avoid damage to the intact perichondral ring and normal surrounding physis.[31] This may be done by metaphyseal osteotomy—a significant undertaking—or through a metaphyseal or epiphyseal window, as described by Langenskiold [22,32,33] and Peterson.[23] Through this window, one must indirectly visualize the physis with the use of a dental mirror or directly with operating loupes and a bright light. Interestingly, Langenskiold [22] described, in 1981, the use of the arthroscopy lamp as a light source but never reported the use of the arthroscope itself for direct visualization. In 1992, Stricker [34] published a case report with a 2-year follow-up, successfully using the arthroscope to assist in central bar removal in a single case of developmental growth arrest.

METHODS

Thirty-seven patients with central physeal arrest were treated at Yale–New Haven Hospital by a single surgeon. Thirty patients were followed through to maturity or physeal closure; these patients form the basis for this retrospective study. In this group, 32 consecutive PBRs were performed using an arthroscope through a metaphyseal window to directly visualize the physis, as described in the "Technique" section below. Two patients required repeated surgery on the same physis—accounting for 32 procedures. There were 19 boys and 11 girls treated (ratio of girls to boys, 1:1.73), ranging in age from 4 to 14 years (mean, 9.5 years).

All patients had physeal mapping using the method of Carlson and Wenger.[24] Over the past years, we have used a variety of methods to establish 3-dimensionality in our preoperative plan, including tomography, fine-cut CT with 3-dimensional rendering, and magnetic resonance imaging.

We used the following indications for surgery: (1) up to more than 70% of physeal closure on preoperative mapping studies, (2) more than 2 years of skeletal growth remaining based upon predicted bone age and menstrual history, where applicable, and (3) a predicted leg length discrepancy (lower limb) of more than 2 cm. No patient had active infection at the time of surgery. Partial growth arrest at the distal tibia was treated more aggressively, given the significant disability that results from rapid development of varus or valgus deformity. Here, the arrest was treated with immediate epiphysiodesis if the resultant leg length discrepancy was predicted to be manageable with a shoe lift or immediate PBR if these criteria were not met. Several patients in our care were allowed to live with a central arrest (distal femur or proximal tibia only) for a number of years, provided there was no development of angular deformity and leg length difference did not exceed 1 cm. We have had several patients with known small central bridges that have spontaneously "broken" through continued growth and thus avoided surgery. Longitudinal growth and angular change were assessed by CT scanogram and plain radiography.

Each patient examined in this study has completed normal physiological growth or gone on to irreversible physeal closure, allowing an accurate assessment of surgical outcome.

Growth cessation was determined by radiographic closure of the physis, and static length measurements were determined both clinically and by scanogram. Follow-up averaged 6.5 years (range, 2–12 years) and, in all cases, was done until physeal closure.

Based on leg length discrepancy and angulation, we classified the patients outcome in 3 groups: "excellent" was rated an outcome with achieved limb length within 2 cm of the contralateral side and an angulation of less than 9 degrees, "good" was rated a partial longitudinal growth that required contralateral epiphysiodesis and/or lengthening for residual limb inequality (>2 cm) or osteotomy to correct residual angulation of more than 9 degrees at or close to maturity successfully, and "poor" was rated either inadequate or no response to physeal surgery, requiring osteotomy or limb lengthening procedures.

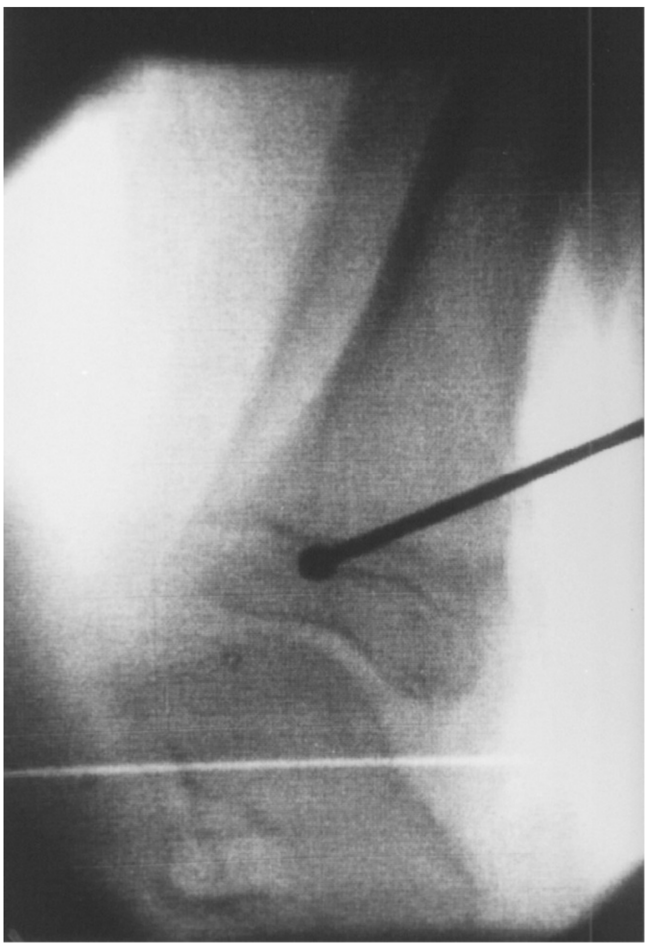

FIGURE 1. Dental burr approaching physeal bar of *distal tibia*.

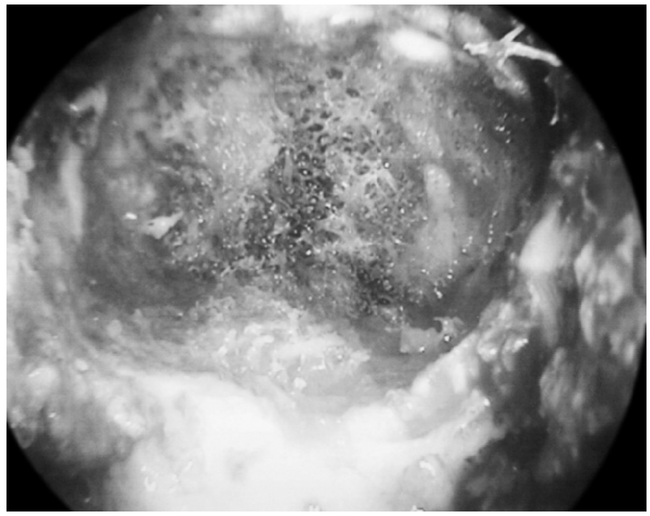

FIGURE 2. Complete ring of physeal cartilage after resection of the bar.

TECHNIQUE

The technique of bar resection follows that pioneered by Langenskiold [22,32,33,35] and Peterson,[23] differing in the use of the arthroscope for direct physeal visualization. Under general anesthesia, the limb is exsanguinated, and tourniquet is used to allow a bloodless field. Fluoroscopy is used to identify the bar, and a small incision in the metaphyseal area is made. Soft tissues are retracted, and a Hall drill (Zimmer Inc., PO Box 708, Warsaw, IN 46581-0708, USA) with a 3- to 5-mm dental burr is used to create a metaphyseal window, averaging 7 to 9 mm in diameter. The burr is advanced using biplane fluoroscopy until the bar is encountered (Fig. 1).

The burr is passed into the epiphysis, creating a 5- to 7-mm window through the physis at the site of the arrest. The cavity is then irrigated and dried with a narrow suction tip (Frasier) (Busse Hospital Disposables, PO Box 11067, Hauppauge, NY 11788-0920), and a 5-mm, 30-degree arthroscope is introduced dry into the canal produced. We have used a 70-degree arthroscope in certain circumstances. However, if one is not facile with this technique, this is not recommended. If no cartilage (a bright white line) is identified, the burr is placed into the cavity, and fluoroscopy is used to guide further widening of the canal at the level of the physis. This usually involves a constant exchange between burring under fluoroscopy, followed by irrigation, suction, and arthroscopy of the canal. Once physeal cartilage is identified, the arthroscope assists in the removal of bone until a complete ring of cartilage is identified (Fig. 2).

Caution must be taken to avoid both excessive removal of physeal cartilage and inadequate removal of bridging bone.

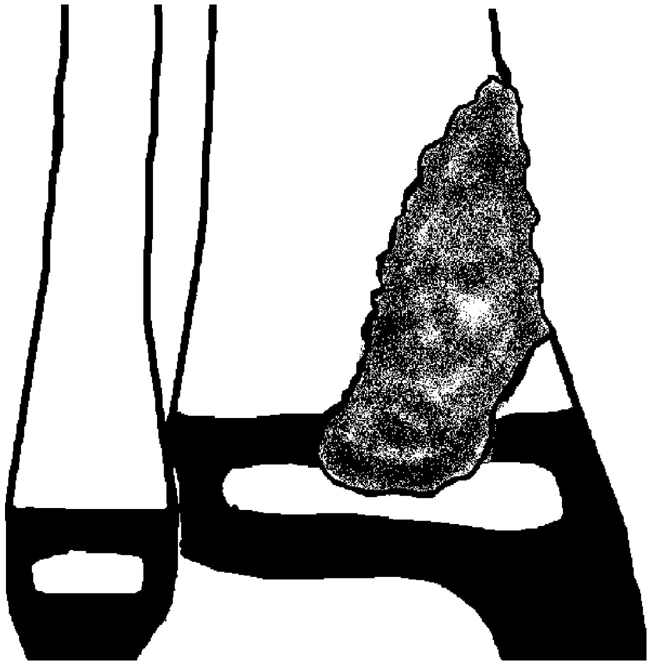

FIGURE 3. Fat interpositum after bar resection in a distal tibial physis.

One cannot burr and use the arthroscope simultaneously, as "scatter" from the burr clouds the camera lens. We have tried visualizing the physis "wet" with continued irrigation with fluid, but even scant amounts of blood in the fluid obscure visualization caused by the Tyndall effect.

In cases of trauma, the physis can be severely distorted, and bone can intercalate into the physis at various locations surrounding the primary bar. One can mistake these minor undulations for the primary bar and stop the resection prematurely. This is to say that it is possible to see a complete ring of physeal cartilage but still have residual bridge outside the arthroscopic field.

Hence, one must use judgment about the resection margins based upon preoperative mapping and intraoperative findings of both the arthroscope and fluoroscopic images.

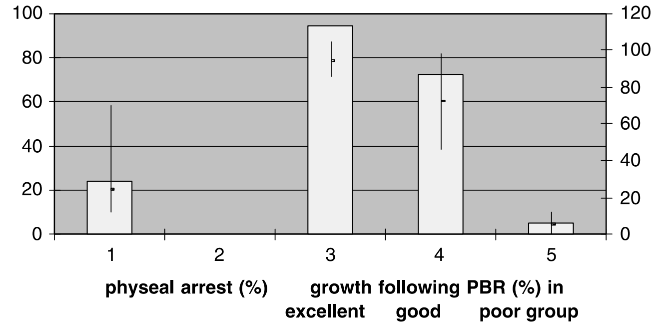

FIGURE 5. Preoperative physeal arrest and growth after the PBR in the different groups.

After resection, fat is obtained locally and sutured into the periosteum and soft tissue in the metaphysical area. Tourniquet is not deflated before wound closure in an attempt to hold the graft in position (Fig. 3).

RESULTS

Thirty-seven patients have undergone PBR. These results include data collected on the 30 patients who have been followed-up through to maturity or physeal closure. Location of growth arrest was distributed as follows: distal femur (15), proximal tibia (9), distal tibia (6), and distal radius (2) (Fig. 4). The etiology of arrest was found to be trauma (24 patients), infection (3 patients), tumor (2 patients), and 1 case of combined open trauma with superimposed infection (Fig. 4). There were no cases of "developmental" growth arrest, and the procedure has not been used on patients with Blount disease. Based upon preoperative mapping, area of physeal arrest averaged 24% (range, 12%–70%). We classified the results based on leg length discrepancy and angulation as excellent, good, and poor.

Twenty-one (70%) of 30 patients achieved limb length that was within 2 cm of the contralateral side and an angulation of less than 9 degrees, which defined as "excellent" (Fig. 4). In this group, the limb segment after PBR had growth ranging from 86% to 105% (mean, 94%) (Fig. 5). Four of these patients had osteotomy to correct angulation at the time of PBR, and all maintained this corrected angulation. The

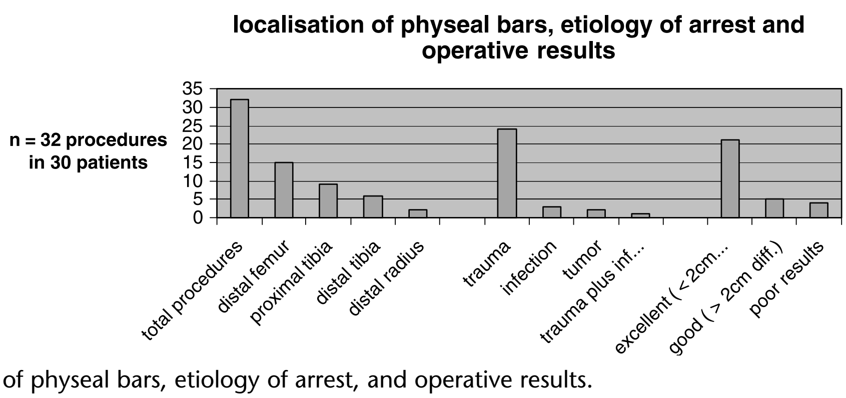

FIGURE 4. Localization of physeal bars, etiology of arrest, and operative results.

remaining patients in this group had either no angular component to their arrest or angulation less than 9 degrees that improved after PBR.

Five patients (17%) had partial longitudinal growth that required contralateral epiphysiodesis and/or lengthening for residual limb inequality (>2 cm) or osteotomy to correct residual angulation of more than 9 degrees at or close to maturity. We called this group "good" (Fig. 4). In this group, the limb segment after PBR had growth ranging from 46% to 98% (mean, 72%) (Fig. 5). One patient had essentially normal longitudinal but angular growth of 15 degrees and required 2 osteotomies to correct genu varum. Ultimate leg length in this patient was within 1 cm of the contralateral side with 2 degrees of angulation, and the limb segment that had undergone PBR was 98% the length of its contralateral counterpart.

Four patients (13%) had either inadequate or no response to physeal surgery and were deemed failures ("poor"), requiring osteotomy or limb lengthening procedures (Fig. 4). In this group, the limb segment after PBR had growth ranging from 0% to 12% (mean, 5%) and a mean angulation of 14 degrees (Fig. 5). Three of the patients in this latter group had physeal arrest on the basis of infection, and the final patient had approximately 50% physeal arrest before the procedure.

There were no postoperative fractures, infections, or intraoperative complications such as neurovascular injury.

DISCUSSION

There are several different reasons for disturbances of the physeal growth (eg, infection, mechanical, or thermal trauma). Up to now, complete physeal arrest is best managed by contralateral epiphysiodesis.[8] As partial physeal arrest left alone could lead to angular deformity and/or limb shortening, disturbing the limb alignment and function, several operative approaches have been made to solve these late effects.[19–23] Nevertheless, the minimal invasive techniques available these days, especially arthroscopic techniques, have been rarely tried to be used in physeal bar removals. Langenskiold,[22] in 1981, described the use of the arthroscopy lamp as a light source but never reported the use of the arthroscope itself for direct visualization. In 1992, Stricker[34] published a case report with a 2-year follow-up, successfully using the arthroscope to assist in central bar removal in a single case of developmental growth arrest. Therefore, we consider our study as the first successful attempt to use the arthroscopic methods for direct visualization available today in a large group of patients with physeal arrest.

Treatment of physeal arrest is a technically demanding procedure—and not always successful—but critically necessary to reestablish growth in the extremity of a child who has sustained traumatic growth plate closure. Often, limb lengthening, with its high complication rate, was required. Some cases were considered hopeless, in which more than 50% of the physis is damaged. In our patients, we could prove that even physeal arrests of up to 70% (1 patient, excellent outcome) could be treated successfully using arthroscopic techniques (mean physeal arrest, 24%). If possible, PBR should be attempted when the criteria previously noted can be met. By the use of modern arthroscopic methods significantly, better results can be achieved than those described by different authors beforehand.

The literature describes different success rates from open physeal resection. Williamson and Staheli[14] report on 29 primary PBRs in 28 patients. In the patients they observed for 2 years, 11 (65%) showed excellent, 2 (12%) fair, and 4 (23%) poor results. By using his invasive method, he could achieve an overall mean growth of 83%.

In 1981, Langenskiold[22] describes 43 operations on 35 patients for partial closure of a growth plate. His results were good in 36 cases (84%) and called questionable in 7 patients (16%). The bone bridge connecting epiphysis to metaphysis was removed and replaced with a free fat transplant, which was tested by Langenskiold sufficiently in a rabbit model in 1975.[32] We still consider free fat as the best interposition material nowadays, as it does not require a second procedure for removal and is very sufficient in preventing rebridging. By using Langenskiold 's method, he noted that deformation of the joint surface could be prevented as compared with osteotomy or leg lengthening. Now, adding the advantages of our arthroscopic procedure, this idea is carried even further.

Birch et al[1] especially described anatomical problems when approaching the physis consisting of muscles, tendons, and joint capsule, which often obstruct the view to the physeal arrest. These problems now also vanish when working under direct arthroscopic visualization.

By now, using the arthroscopic approach, excellent results were found in 70%, good results in 17%, and poor results in 13% of the patients. Although this is still certainly not 100%, it means that approximately 87% of children can escape the complications and rigors of limb lengthening, the permanent shortening of epiphysiodesis, or repeated osteotomy for angular growth. Our results are similar to those reported for success of resumed physeal growth using open surgical techniques, but using the arthroscope—with its inherent light source and ability to magnify images—greatly assists in this technically demanding procedure and even leads to higher success. It provides the best visualization with minimal morbidity. We hereby present the first series that studies and documents the great efficacy of the arthroscope in central PBR.

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