Proximal Femur Guided Growth for the Management of Hip Dysplasia in Children with Cerebral Palsy

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Abstract:
Proximal femoral deformity associated with neuromuscular hip dysplasia in children with cerebral palsy (CP) is characterized by increased anteversion, coxa valga, and caput valgum. Guided growth of the proximal femur (PFGG) utilizes a screw to tether the medial portion of the physis to achieve progressive varus alignment of the femoral head and neck with subsequent growth. This procedure has been shown to decrease the head shaft angle and Reimer's migration percentage (RMP) and decrease the need for subsequent skeletal hip reconstructive surgery. The indications, surgical technique, postoperative management, potential pitfalls of this relatively new procedure are reviewed.

Key Concepts:

- Early guided growth of the proximal femur has been shown to be effective when the degree of hip dysplasia is mild, the child is relatively young, and the need for surgical hip reconstruction with femoral and pelvic osteotomies is avoided.
- Early guided growth of the proximal femur to treat progressive neuromuscular hip dysplasia may be combined with soft tissue lengthening of the hip flexor and adductor muscles.
- Late guided growth of the proximal femur may also be performed to minimize the recurrence of proximal femoral deformity at the time of implant removal following hip reconstruction surgery in children with CP.

Introduction

Neuromuscular hip dysplasia in children with cerebral palsy (CP) is characterized by progressive subluxation of the femoral head relative to the acetabulum. This dynamic process is caused by motor imbalance across the hip joint with the hip flexors and adductor muscle groups dominating the hip extensor and abductor muscle groups.[1, 2] Abnormal loading results in growth disruption of the proximal femur and the acetabulum. Deformity of the proximal femur consists of increased femoral anteversion, increased neck shaft angle, and caput valgum.[3] Hip surveillance, utilizing radiographs of the pelvis, can identify hips at risk for subluxation based upon measurement of the migration percentage.[4] There are a wide range of treatment options for neuromuscular hip dysplasia based upon age, degree of displacement, and magnitude of skeletal deformity.[5] In general, earlier interventions result in better outcomes.[1,5] Studies in animal models suggest that tethering of the medial portion of the proximal femoral physis will result in progressive varus deformity of the proximal femur with growth.[6,7]

In children with CP, proximal femoral guided growth (PFGG) with medial screw hemiepiphysiodesis has been shown to decrease the head shaft angle and Reimer's migration percentage (RMP); and decrease the need for subsequent skeletal hip reconstructive surgery.[8-11] The indications, surgical technique, postoperative management, and potential pitfalls of this relatively new procedure are considered below.

Description of the Method

Indications

Early guided growth of the proximal femur may be used for children with Gross Motor Function Classification System (GMFCS) levels I to V. Most of the candidates for this surgery will be GMFCS levels III to V. The optimal age range for this procedure is between 4 and 10 years of age. The RMP should be between 25 and 50%.

Late guided growth of the proximal femur may also be used at the time of hardware removal, usually 6 to 18 months following hip reconstruction surgery, in children with CP. The goal is to minimize the recurrence of proximal femoral deformity (coxa valgus and caput valgum) with subsequent growth. Drill hemiepiphysiodesis is performed through the track of the blade portion of the blade plate under fluoroscopic guidance. The surgical technique is similar to that described below for early guided growth of the proximal femur except that it is done open (not percutaneously) with a drill and curette (not a cannulated screw).

Contraindications

Children less than 4 years of age with CP and early hip dysplasia should generally be managed with hip range of motion exercises, hip abduction orthoses, and botulinum injections into the hip flexor and adductor muscles. Children greater than 10 years of age with CP and hip dysplasia should be managed with surgical hip reconstruction consisting of femoral and (when indicated) pelvic osteotomies.

Children with RMP less than 25% should be treated based upon established hip surveillance guidelines.

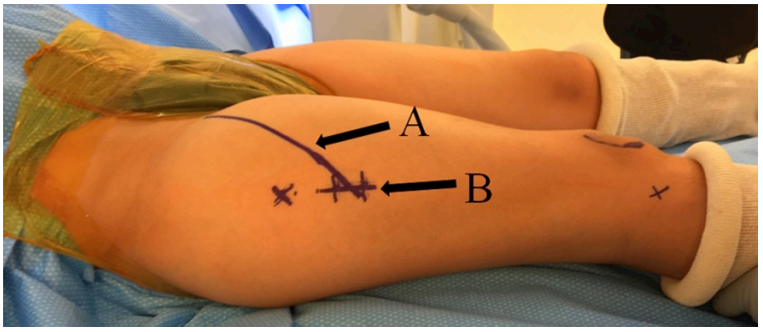

Figure 1. *Determination of starting point for guidewire of cannulated screw. The patient is supine with the hip maximally internally rotated. Line A is drawn under fluoroscopic guidance to cross the proximal femoral physis in the medial one-third. Line B is drawn between the greater trochanter and the head of the fibula (both marked by "X"). The intersection of lines A and B denotes the starting point for the guidewire.*

Children with RMP greater than 50% should be managed with surgical hip reconstruction consisting of femoral and (when indicated) pelvic osteotomies. Palliative (salvage) surgery is performed for long standing, high-grade subluxation or dislocation when there is significant deformity of the femoral head.

Preoperative Preparation

Comprehensive assessment of medical comorbidities and presurgical anesthesia optimization, particularly in children with significant motor impairment, seizure disorders, history of pneumonia, and feeding disorders that require gastrostomy tube, are essential for performing safe surgery.[12]

Positioning

Guided growth of the proximal femur should be performed on a completely radiolucent surgical table. The procedure is performed under fluoroscopic guidance. The child is placed supine on a small midline towel bump and is prepped from the lower abdomen to the toes so that each hip and lower extremity is completely in the surgical field.

Operative Technique

The hip is maximally internally rotated until the femoral neck appears to be parallel to the surgical tabletop (as appreciated under fluoroscopy) to correct for the typical

Figure 2. *"Easy lateral" view of the proximal femur, femoral neck, and femoral head. The patient is supine with a bump placed beneath the targeted hip. The C-arm is rotated 20 to 30 degrees towards the lateral position for the targeted hip (solid red arrow). The hip is maintained in extension and the pelvis/hip are gently rotated externally until the patella is perpendicular to the fluoroscopy beam (dotted red arrow). This technique minimizes the chance of bending the guide wire when obtaining the lateral view.*

increased femoral anteversion. The tip of the greater trochanter and the fibular head are marked, defining a lateral line on the femur. A pin is placed on the anterior aspect of the hip and adjusted under anteroposterior (AP) fluoroscopic guidance to lay over the femoral neck and cross the medial one-third of the proximal femoral physis, defining an anterior line over the proximal femur. Its position is marked on the skin with an indelible pen. The intersection of the anterior and lateral lines denotes the starting point for the guidewire (Figure 1).

An appropriately sized (for 4.0 to 7.0 mm cannulated screw) smooth tipped guidewire is placed through the skin and advanced until the tip is touching the femur. The wire is placed parallel to the tabletop and is oriented along the anterior line marked on the skin. The pin is advanced under fluoroscopic guidance into the lateral one-quarter of the femoral neck, with its trajectory towards the medial one-third of the proximal femoral physis.

A knife is used to make a 0.5 to 1 cm incision through the skin and iliotibial band about the guide pin entry site along the previously identified lateral line. A hemostat is used to spread through the underlying vastus lateralis muscle down to the femur. A depth gauge or cannulated screwdriver is placed over the guidewire down to the femur to protect the guidewire from bending while obtaining the lateral fluoroscopy view. A standard frog lateral view is avoided as this will bend the guidewire. An "easy lateral" view (LAT) is obtained by rotating the C-arm 30 to 40 degrees towards the lateral view and then rotating the pelvis/hip in the opposite direction (i.e., operative side down), in order to obtain a lateral view of the proximal femur, femoral neck, and femoral head (Figure 2).

On the AP view the guidewire should be oriented to cross the medial 1/3 of the proximal femoral physis (Figure 3).

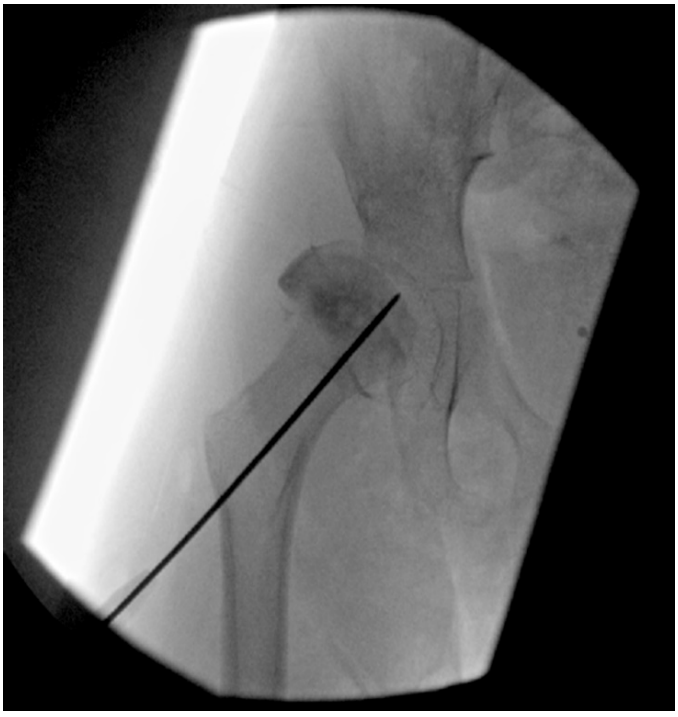

Figure 3. *Optimal alignment of the cannulated screw on the AP view. The screw crosses the medial 1/3 of the proximal femoral physis. In this case, an arthrogram was done to better identify the contours of the femoral head.*

On the LAT view, the guidewire should be oriented to cross the middle 1/3 of the proximal femoral physis (Figure 4).

Once the orientation has been confirmed on AP and LAT views, the guidewire is advanced across the physis until the tip is located within the femoral head. A depth gauge is used to determine the length of the cannulated screw. A cannulated drill bit is placed over the guidewire and advanced to just cross the physis. The selected screw is advanced over the guidewire under fluoroscopic guidance until it has crossed the physis and a minimum of three threads are in the femoral head. Final AP and LAT fluoroscopic views are obtained to confirm screw location. The guidewire is removed and the surgical incision closed. Local anesthetic is injected about the incision, and a sterile dry dressing is applied. Final alignment of the screw on AP and LAT fluoroscopic views are obtained and saved to the patient's medical record to document screw location and for use as comparison during follow up (Figures 5 and 6).

Tips and Pearls

The location of starting point for guidewire placement is lateral (due to increased femoral anteversion) and distal (due to coxa valga and increased neck shaft angle). This is the opposite pathoanatomical situation to that seen when pinning a slipped capital femoral epiphysis (SCFE) where the starting point for the guidewire is anterior due to diminished femoral anteversion associated with SCFE and posterior displacement of the femoral head relative to the femoral neck. There may be limited femoral head "real estate" for pin and screw placement due to caput valgum. In such cases, the surgeon may have to compromise positioning of screw towards the middle 1/3 of the proximal femoral physis on AP view. An intraoperative arthrogram can be helpful in determining whether the tip of the screw is in the cartilaginous portion of the femoral head (Figures 7 and 8).

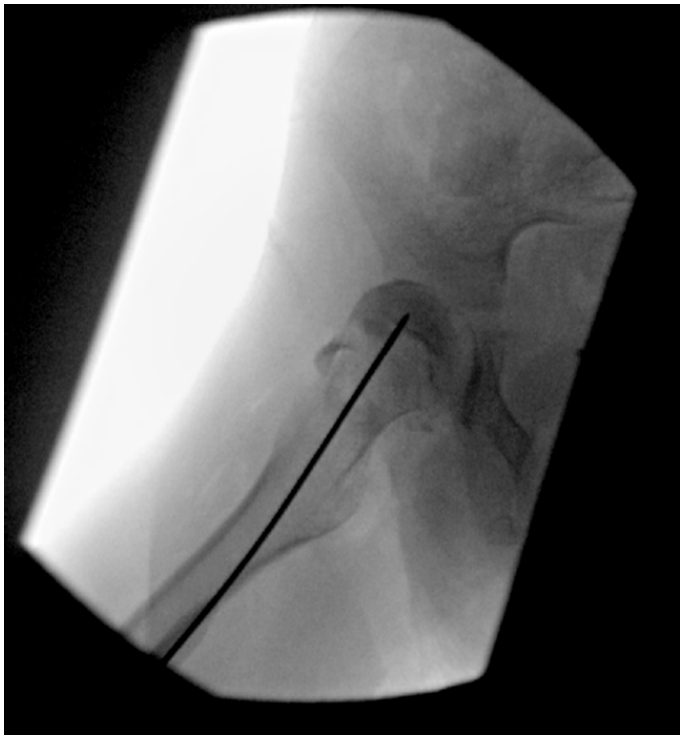

Figure 4. *Optimal alignment of the cannulated screw on the LAT view. The screw crosses the middle 1/3 of the proximal femoral physis. In this case, an arthrogram was done to better identify the contours of the femoral head.*

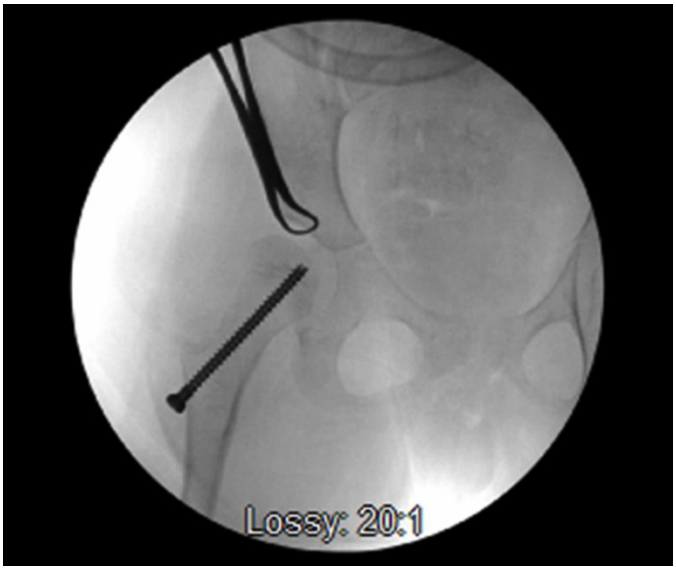

Figure 5. *Final AP fluoroscopy image shows desired screw placement across the medial third of the proximal femoral physis with three threads crossing the physis.*

If using threaded tipped guidewire, advance on reverse to maintain control of the guidewire and avoid joint penetration. The frog lateral position should be avoided, and the "easy lateral" technique should be used to minimize the chance of bending the guidewire. Avoid displacing the guidewire by using an obturator wire when removing the cannulated drill bit. There is no consensus in the literature regarding optimal screw diameter, with reported screw sizes ranging from 4.0 to 7.3 mm.[8-11] In most cases, a 4.5 mm screw is ideal, given the size of the femoral neck and head in children with CP who are appropriate candidates for PFGG. A fully threaded cannulated screw is preferred to facilitate screw exchange/removal if indicated. Do not countersink screw head into lateral femoral cortex. The screw head should be left proud of the lateral femoral cortex to facilitate screw exchange.

Postoperative Care

Early guided growth of the proximal femur is usually combined with adductor and hip flexor soft tissue releases, and postoperative immobilization is driven by the latter. The child is maintained full time in a hip abduction pillow for 2 to 4 weeks. Following full-time immobilization, the child is transitioned to using the abduction pillow night and naps (up to 12 hours per day), and may resume preoperative community-based physical therapy for range of motion and standing. Follow-up radiographic evaluation of hip alignment and screw location after early PFGG is performed every 6 months. AP pelvis view, with the hips maximally internally rotated, and LAT hip views are required. Optimal positioning may be a challenge due to spasticity and patient cooperation. The primary radiographic measurement is the RMP; secondary measurements may include the neck shaft and head shaft angles.[3,4,9]

Late guided growth of the proximal femur occurs at the time of hardware removal, and postoperative immobilization is driven by the latter. A hip abduction orthosis is used for comfort for 2 weeks following surgery. Community-based physical therapy is withheld for 4 months following surgery to minimize the risk of pathological fracture through the empty blade track and screw holes. Follow-up radiographic evaluation of hip alignment after late PFGG is performed every 12 months. AP pelvis

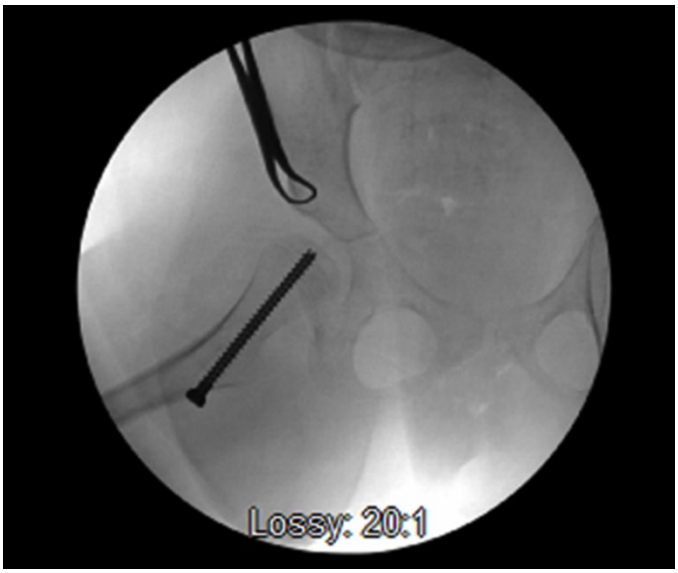

Figure 6. *Final LAT fluoroscopy image shows desired screw placement across the middle third of the proximal femoral physis with three threads crossing the physis.*

Figure 7. *The tip of the guidewire is at the edge of the capital femoral ossific nucleus, which is asymmetrically located within the femoral head (due to caput valgum deformity). The location of the tip of the guidewire relative to the joint surface is not certain.*

Figure 8. *Arthrogram after screw placement confirms that the tip of the screw, while eccentrically located relative to the capital femoral ossific nucleus, is well within the margins of the cartilaginous femoral head.*

view, with the hips maximally internally rotated is required. Optimal positioning may be a challenge due to spasticity and patient cooperation. The primary radiographic measurement is the RMP; secondary measurements may include the neck shaft angle, head shaft angle, and acetabular index.[3,4,9,13]

Complications/Salvage

Growing off of the screw following early guided growth of the proximal femur has been reported to occur in between 15 and 50% of cases.[8,10,11] The RMP should be followed carefully in these cases. If it is between 40 and 50 % or progressive increase in the RMP is documented, then the screw should be revised. In most cases, the screw should be revised, so initiating this treatment strategy requires a commitment to replacing the screw when indicated.

Progressive hip subluxation following early guided growth of the proximal femur has been reported to occur in 5 to 20% of cases.[8,10,11] If the RMP progresses to greater than 50% despite early proximal femoral guided growth, the treatment is deemed a failure. In these cases, the screw should be removed and a skeletal hip reconstruction, consisting of proximal femoral varus and rotational osteotomy with/without acetabular osteotomy, should be performed.

Summary

Proximal femoral guided growth (PFGG) with medial screw hemiepiphysiodesis is a relatively new treatment option for the management of neuromuscular hip dysplasia in children with CP. The procedure was first developed in an animal model, and recent studies have shown that PFGG is effective in modulating the growth of the proximal femur to correct coxa valga and caput valgum deformities. This in turn prevents progressive subluxation of the hip as measure by the RMP. The cannulated screw should cross the proximal femoral physis in the medial third on the AP view and middle third on the LAT view. Growing off of the screw may occur, requiring regular follow-up and commitment to revision of the screw when necessary.

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