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CHAPTER 12.7

Pediatric Orthopedic Surgery

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Percutaneous Pinning of Displaced Supracondylar Humerus Fracture

Surgical Considerations

Description: Supracondylar fractures of the humerus are the most common elbow fractures in children, and the most common pediatric fractures requiring reduction under GA. They have a justifiable reputation for complications because of the risk to the brachial artery, and a high incidence of median or radial nerve palsies. The most serious potential complication is a compartment syndrome of the forearm, resulting in the need for emergency reduction and fasciotomy.

The vast majority of these injuries result from falling on an outstretched arm with the elbow extended—extremely common childhood event. Type 1 supracondylar fractures are minimally displaced and usually stable. They can be managed with a splint alone. Most supracondylar fractures are either Type 2 or Type 3 completely displaced fractures and require general anesthesia for **closed reduction and percutaneous pinning**.

Flexion type supracondylar fractures are more likely to require open reduction than extension type injuries.

Documentation of the neurovascular examination is mandatory immediately before anesthesia and upon awakening. If the neurovascular status is normal, and if the patient has eaten recently, it may be safe to wait 6–8 hours with continued monitoring of the neurovascular status. Reduction is obtained by a combination of traction and manipulation. Complete muscular relaxation is essential during the reduction maneuver. Usually two small, smooth, Kirschner wires are inserted under fluoroscopic control. Many surgeons prefer to use the intensifier screen as a platform; thus requiring the patient to be at the edge of the OR table. Occasionally, the fracture cannot be reduced closed, and an open reduction is necessary. In that case, the arm is reprepped and a small, lateral incision is made to openly visualize and reduce the fracture. The same type of smooth pin fixation is then used. Prolonged skeletal traction, although used (Print pagebreak 1345) in the past, is rarely used and the standard of care is reduction and percutaneous pinning. Following the pinning, either a splint or well padded cast is applied before the patient is awakened.

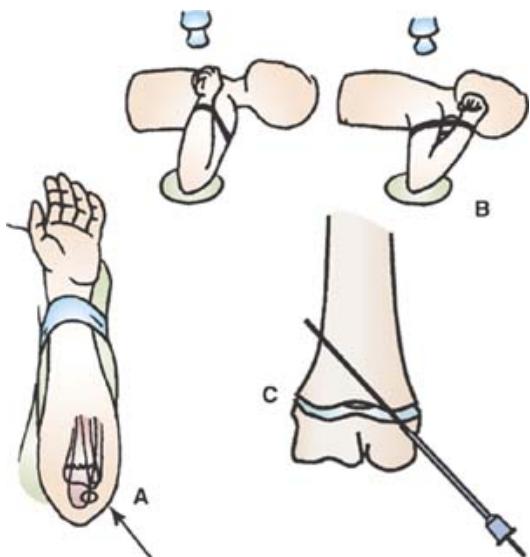


Figure 12.7-1. 1. Percutaneous pinning of supracondylar humerus fracture. (A) The fracture is manually reduced and held with elbow flexed. (B) Fracture reduction is assessed with I.I. (C) The fracture is stabilized with percutaneous K-wires. (Reproduced with permission from Chapman MW: *Chapman's Orthopaedic Surgery*, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Usual preop diagnosis: Supracondylar fracture of the elbow

Summary of Procedures

	Percutaneous Pinning	Open Reduction
Position	Usually supine, occasionally prone or lateral	
Incision	None	1" lateral
Special instrumentation	Power drill, image intensifier or FluoroScan	
Unique considerations	Full-stomach; impending compartment syndrome	
Antibiotics	Usually none	Cefazolin 25 mg/kg
Surgical time	30–60 min	30–90 min
Closing considerations	Cast or splint	
EBL	Minimal	
Postop care	PACU → room; close neurovascular monitoring	
Mortality	Rare	
	Late angular deformity, especially cubitus varus: 10%	
	Nerve palsy (typically radial nerve) from the fracture itself: 7%	
Morbidity	Compartment syndrome (Volkmann's contracture): < 0.5% (some degree of vascular spasm or loss of radial pulse much more common)	
	Stiffness, myositis ossificans	
	Ipsilateral fracture	
Pain score	3–5	3–6

Patient Population Characteristics

Age range	3–10 years with peak age range of 5–8 yr.
Male:Female	1.6:1
Incidence	Frequent
Etiology	Trauma, usually a fall
Associated conditions	Usually normal, healthy child

Wave Anesthetic Considerations

See [Anesthetic Considerations for Upper Extremity Procedures, see p. 1353.](#)

Suggested Readings

1. Bell C, Kain Z: Acute pediatric pain management. In *The Pediatric Anesthesia Handbook*. Mosby, St. Louis: 1997.
2. Dormans JP, Squillante R, Sharf H: Acute neurovascular complications with supracondylar humerus fractures in children. *J Hand Surg*; 1995;20(1):1–4.
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3. Garbuza DS, Leitch K, Wright JG: The treatment of supracondylar fractures in children with an absent radial pulse. *J Pediatr Orthop* 1996;16(5):594–6.
4. Gordon JE, Patton CM, Luhmann SJ, et al: Fracture stability after pinning of displaced supracondylar distal humerus fractures in children. *J Pediatr Orthop* 2001;21(3):313–18.
5. Kasser JR, Beaty JH: Supracondylar fractures of the distal humerus. In *Fractures in Children*. Beaty JH, Kasser JR, eds. Lippincott-Raven, Philadelphia: 2001, 577–624.
6. Mehan ST, May CD, Kocher MS: Operative management of displaced flexion supracondylar humerus fractures in children. *J Pediatr Orthop* 2007;27:551–6.
7. Mehlman CT, Strub WM, Roy DR, et al: The effect of surgical timing on the perioperative complications of treatment of supracondylar humeral fractures in children. *J Bone Joint Surg Am* 2001;83A(3):323–7.
8. Otsuka NY, Kasser JR: Supracondylar fractures of the humerus in children. *J Am Acad Orthop Surg* 1997;5(1):19–26.
9. Pullerits J, Holzman R: Pediatric neuraxial blockade. *J Clin Anesth* 1993;5(4):342–54.
10. Salem MR, Klowden AS: Anesthesia for orthopaedic surgery. In *Pediatric Anesthesia*, 3rd edition. Gregory G, ed. Churchill Livingstone, New York: 1994, 607–56.
11. Shaw BA, Kasser JR, Emans JB, et al: Management of vascular injuries in displaced supracondylar humerus fractures without arteriography. *J Orthop Trauma* 1990;4(1):25–9.

Closed or Open Reduction of Displaced Lateral Condyle Humerus Fracture

Yellow Surgical Considerations



Description: Lateral condylar fractures of the distal humerus are second only to supracondylar fractures in frequency. Initial radiographs of lateral condyle fractures can look deceptively normal; however, since these fractures cross the physis (growth plate) and enter the articular surface, they require anatomic reduction to restore joint surface congruity and to avoid a premature physeal arrest. In addition, the elbow may be unstable and dislocate if the fracture extends into the trochlea of the humerus. Accurate and stable reduction minimizes the risk of nonunion, a well-known complication resulting from unsuspected rotation of the fracture fragment and by traction forces of the extensor muscles attaching to this condyle. Unlike supracondylar fractures, neurovascular complications are rare with lateral condyle fractures.

Although minimally displaced fractures can be treated with a cast, 60% of lateral condyle fractures are displaced and require manipulation and pinning. Casting without manipulation, and thus requiring no anesthesia, is indicated for stable fractures that are displaced less than 2 mm. **Closed reduction and percutaneous pinning** under fluoroscopic control requires general anesthesia, and is indicated for stable fractures with 2–4 mm displacement. **Open reduction and pinning** is necessary for fractures that are unstable, rotated, or displaced more than 4 mm. Muscular relaxation is advantageous when performing either a closed or open reduction of the fracture. A sterile tourniquet is used for cases requiring open reduction.

Usual preoperative diagnosis: Displaced lateral condyle humerus fracture

Summary of Procedures

	Closed Reduction/Pinning	Open Reduction/Pinning
Position	Supine	
Incision	None	1–2" lateral
Instrumentation	Power drill, fluoroscopy	
Unique considerations	None	
Antibiotics	Usually none	Cefazolin 25 mg/kg
Surgical time	30–60 min	45–90 min
Closing considerations	Cast or splint	
EBL	Negligible	
Postoperative care	PACU → room	
Mortality	Rare	
	Delayed or nonunion	
	Cubitus valgus (more common) or varus	
	Lateral condylar overgrowth	
Morbidity	Physeal arrest	
	Osteonecrosis of lateral trochlea	
	Ulnar nerve palsy	Avascular necrosis of trochlea
Pain score	3–5	3–6

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Patient Population Characteristics

Age range	5–10 yr; average = 6 yr
Incidence	15% of all elbow fractures; more common in summer
Etiology	Trauma
Associated conditions	Usually normal, healthy child

Anesthetic Considerations

See [Anesthetic Considerations for Upper Extremity Procedures, see p 1353.](#)





Suggested Readings

1. Foster DE, Sullivan JA, Gross RH: Lateral humeral condylar fractures in children. *J Pediatr Orthop* 1985; 5(1):16–22.
2. Launay F, Leet AI, Jacopin S, et al: Lateral humeral condyle fractures in children: a comparison of two approaches to treatment. *J Pediatr Orthop* 2004; 24:385–91.
3. Mintzer CM, Waters PM, Brown DJ, et al: Percutaneous pinning in the treatment of displaced lateral condyle fractures. *J Pediatr Orthop* 1994; 14(4):462–5.
4. Thomas DP, Howard AW, Cole WG, et al: Three weeks of Kirschner wire fixation for displaced lateral condylar fractures of the humerus in children. *J Pediatr Orthop* 2001; 21(5):565–9.

Aspiration and Injection of Unicameral Bone Cyst

Surgical Considerations

Description: Unicameral bone cysts (UBC) are benign lesions typically located in the metaphyseal regions of long bones, most commonly in the proximal humerus of a growing child. The cyst is rarely a source of pain until presentation (typically after a fracture). The benign radiographic appearance allows clinicians to follow most lesions without the need for surgical biopsy. Surgical care is indicated when the UBC is of sufficient size and location to cause mechanical weakening (*Print pagebreak 1348*) of the bone and predispose to a pathologic fracture. The goals of surgical care are to confirm the diagnosis of UBC and to reestablish the mechanical integrity of the bone. Diagnosis of a UBC is made by percutaneous aspiration of the lesion, using a standard 16–18-gauge spinal needle under general anesthesia. Fluoroscopic guidance facilitates needle placement. The presence of clear, straw-colored fluid confirms diagnosis of UBC. An alternative diagnosis, such as aneurismal bone cyst, is more likely if frank blood is aspirated. If the lesion contains no fluid, it may be a nonossifying fibroma.

Open biopsy may be necessary if the diagnosis is unclear. However, most cases can be treated adequately with percutaneous aspiration and injection of a radiopaque dye to verify that the entire cavity is contiguous. If the cystic cavity is loculated by bony trabecula, a **curette** or **percutaneous Kirschner** wire is used to convert the lesion into a unicompartmental space so the subsequent injection will easily access the entire lesion. Scraping the inner cyst walls also helps to disrupt the cyst lining and is thought to improve the chance of filling in the cavity. The final surgical step is to introduce a second ‘venting’ needle into the cyst to allow lavage with sterile saline, followed by injection of the cavity with a substance to promote new bone formation. Historically, methylprednisolone has been used, but more recent evidence suggests a higher success rate when autologous bone marrow is injected. **Injectable allograft** bone preparations also can supplement the bone marrow injection. Care must be taken to avoid aspirating from the first needle after the second has been placed, to avoid intraosseous air embolism.

Usual preoperative diagnosis: Unicameral bone cyst

Summary of Procedures

	Percutaneous	Open
Position	Supine	
Incision	None	Length of cyst
Instrumentation	Spinal needles, Kershner wires, I.I.	Curettes
Unique considerations	Risk of air embolus	Additional time for intraop pathology evaluation
Antibiotics	Usually none	Cefazolin 25 mg/kg
Surgical time	30–60 min	60–90 min
Closing considerations	None	Cast or splint
EBL	Minimal	



Postop care	PACU → home	PACU → room/home
Mortality	Rare	
Morbidity	Infection Iatrogenic fracture Growth arrest: rare	
Pain score	0–2	3–6

Patient Population Characteristics

Age range	5–15 yr; not found in adults
Male:Female	1:3
Incidence	20% of benign bone lesions; most common location is the proximal humerus (67%), followed by the proximal femur (15%)
Etiology	Unknown. Venous obstruction → fluid transudate containing high levels of interleukin-1 and interleukin-6, which stimulate osteoclasts
Associated conditions	Usually normal, healthy child. Initial presentation typically follows a pathologic fracture.

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Anesthetic Considerations

See [Anesthetic Considerations for Upper Extremity Procedures, see p. 1353.](#)

Suggested Readings

1. Alvarez RG, Arnold JM.: Arthroscopic assistance in minimally invasive curettage and bone grafting of a calcaneal unicameral bone cyst. *Foot Ankle Int* 2007;28:1198–99.
2. Bensahel H, Jehanno P, Desgrippe Y, et al: Solitary bone cyst: controversies and treatment. *J Pediatr Orthop* 1998;7(4):257–61.
3. Killian JT, Wilkenson L, White S, et al: Treatment of unicameral bone cyst with demineralized bone matrix. *J Pediatr Orthop* 1998;18(5):621–4.
4. Rougraff BT, Kling TJ: Treatment of active unicameral bone cysts with percutaneous injection of demineralized bone matrix and autogenous bone marrow. *J Bone Joint Surg* 2002;84A(6):921–9.
5. Yandow SM, Lundeen GA, Scott SM, et al: Autogenic bone marrow injections as a treatment for simple bone cyst. *J Pediatr Orthop* 1998;18(5):616–20.

Release for Torticollis

Surgical Considerations

Description: **Congenital muscular torticollis** is a painless tilting of the head due to contracture of the sternocleidomastoid muscle. The head tilts toward the involved side and rotates toward the opposite side (a “cocked-robin” posture such that the chin points to the opposite side). It is associated with breech and difficult deliveries, as well as other musculoskeletal disorders, such as metatarsus



adductus, hip dysplasia, and talipes equinovarus. Multiple theories regarding the etiology of congenital muscular torticollis have been proposed, including fibrosis of the sternocleidomastoid muscle following a peripartum intramuscular bleed, fibrosis resulting from a compartment syndrome of the sternocleidomastoid muscle, intrauterine crowding, and a primary myopathy of the sternocleidomastoid muscle. Eighty percent of cases of torticollis are a result of this congenital contracture of the sternocleidomastoid muscle. Less common etiologies—such as congenital cervical spine malformations (e.g., Klippel-Feil syndrome), neurologic disorders, a cranial or cervical neoplasm, inflammatory conditions (e.g., Grisel's syndrome), or an ocular dysfunction—should also be excluded. Congenital muscular torticollis is seen more frequently on the right side. A persistent torticollis will lead to skull and facial deformities (plagiocephaly). If the child sleeps prone, he will usually lie with the affected side down, resulting in flattening of the face on that side. If the child sleeps supine, flattening of the contralateral skull occurs. This plagiocephaly will become permanent if the torticollis persists and is left untreated.

Initial treatment includes physical therapy for stretching exercises. For children less than 1 year of age, a program of sternocleidomastoid muscle stretching is recommended, with 90% of cases being resolved with this treatment. After 2 years of age, nonoperative treatment is not likely to be effective. Children with persistent torticollis and an unacceptable amount of facial asymmetry preferably are treated surgically before the age of 3 years; however, some improvement in facial asymmetry has been shown even in children surgically treated up to 8 years of age.

Surgical options include a **unipolar release**, a **bipolar release**, **middle-third transection**, or a **complete resection**. Unipolar release involves division of the distal insertion of the sternocleidomastoid muscle and usually is performed for a mild deformity. Bipolar release entails division of both the sternocleidomastoid origin and insertion, and usually is done for more marked involvement. **Z-plasty** of the clavicular head or transfer of the clavicular head to the sternal head may be done to maintain a more normal cosmetic contour of the neck. Potential surgical complications include injury to the spinal accessory nerve, jugular veins, carotid vessels, and the facial nerve. Postop, patients may perform simple stretching exercises, but they often require bracing to maintain a corrected alignment.

Usual preoperative diagnosis: Congenital muscular torticollis

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Summary of Procedures

	Unipolar	Bipolar
Position	Supine	
Incision	Transverse, 1.5 cm superior to sternum and clavicle over muscle insertion	+ 1 cm distal to mastoid process behind ear at muscle origin
Unique considerations	Plagiocephaly	
Antibiotics	Cefazolin 25 mg/kg	
Surgical time	30 min	45 min
EBL	Minimal	
Postoperative care	PACU → room/home	
Mortality	Rare	
Morbidity	Hypertrophic scar	
	Loss of normal muscle contour	Spinal accessory nerve injury
Pain score	3–5	3–5

Patient Population Characteristics

Age range	Onset at birth, surgery after age 1 yr
Male:Female	1:1
Incidence	1/500
Etiology	Fibrosis of sternocleidomastoid; possible intrauterine or perinatal muscle compartment syndrome
Associated conditions	Usually normal, healthy child; hip dysplasia in 20%

Anesthetic Considerations

See [Anesthetic Considerations for Upper Extremity Procedures, see p. 1353.](#)

Suggested Readings

1. Ballock RT, Song KM: The prevalence of nonmuscular causes of torticollis in children. *J Pediatr Orthop* 1996; 16(4):500–4.
2. Davids JR, Wenger DR, Mubarak SI: Congenital muscular torticollis: sequela of intrauterine or perinatal compartment syndrome. *J Pediatr Orthop* 1993;13(2):141–7.
3. Ferkel RD, Westin GW, Dawson EG, et al: Muscular torticollis: a modified surgical approach. *J Bone Joint Surg* 1983; 65A:894–900.
4. Von Heideken J, Green DW, Burke SW, et al: The relationship between developmental dysplasia of the hip and congenital muscular torticollis. *J Pediatr Orthop* 2006;26:805–8.
5. Wirth CJ, Hagen FW, Wuelker N, et al: Biterminal tenotomy for the treatment of congenital muscular torticollis. Long-term results. *J Bone Joint Surg Am* 1992;74(3):427–34.

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Pollicization of A Finger

Surgical Considerations

Description: This procedure is indicated in the infant with congenital absence or hypoplasia of the thumb. A normal finger—usually the index finger—with its tendon, nerve, and vascular supply is shortened and rotated into the position of the thumb ([Fig. 12.7-2](#)). Tendon transfers are performed to substitute for the absent or hypoplastic thenar muscles. These patients may have many other associated congenital anomalies, which should be ruled out prior to surgery.

Variant procedure or approaches: There are several different surgical techniques, which share the basic transposition and rotation of the finger to the thumb position.

Usual preop diagnosis: Aplastic thumb; hypoplastic thumb; radial club hand; radial longitudinal deficiency

Summary of Procedures

Position	Supine, with arm extended on hand-surgery table
Incision	Multiple incisions on the hand
Special instrumentation	Pneumatic tourniquet; magnification loupes
Antibiotics	Cefazolin 25 mg/kg (children)
Surgical time	3–4 h
Tourniquet	100 mmHg above systolic; max time = 120 min
Closing considerations	Complex skin flaps are necessary. A plaster splint is placed while the patient is still anesthetized.
EBL	Minimal; performed under tourniquet control.
Postop care	PACU → overnight admission for observation or perfusion to the transposed finger
Mortality	Minimal

Morbidity

Pain score

Ischemia (loss of digit): Rare
Skin flap necrosis: Moderately common
1–2

Patient Population Characteristics

Age range

1–2 yr is ideal time for surgery. Procedure should be done before patient begins school.

Male:Female

1:1

Incidence

Overall, about 1/20,000 live births require a variant of this procedure.

Etiology

Unknown; also associated with thalidomide ingestion.

Associated congenital anomalies of the upper extremity, esophagus, spine, and lower extremities

Absence of radius (radial club hand), common

Various forms of syndactylies, common

Abnormalities of the hematopoietic system (Fanconi's syndrome), cardiovascular system (ASDs in Holt-Oram syndrome), spine, and GI system, along with hypothyroidism, are frequently associated.

Associated conditions

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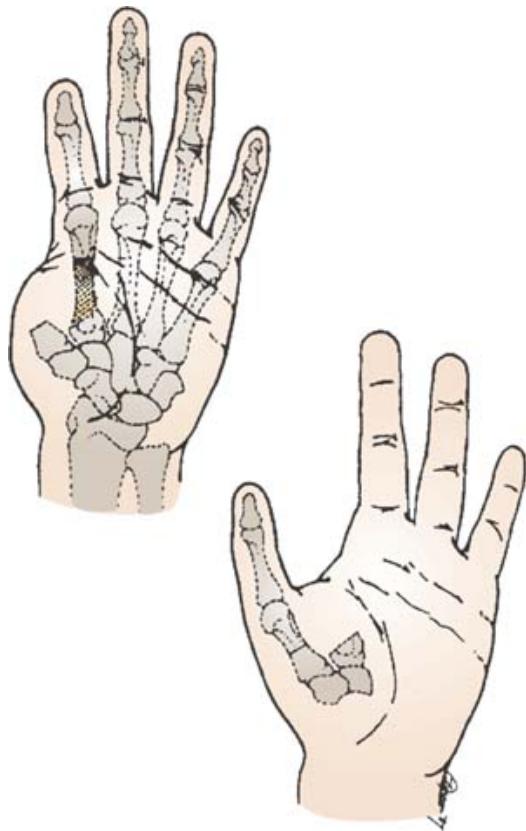


Figure 12.7-2. 2. Pollicization of a finger. (Reproduced with permission from Chapman MW: *Chapman's Orthopaedic Surgery*, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Anesthetic Considerations

See [Anesthetic Considerations for Upper Extremity Procedures, see p. 1353.](#)



Suggested Reading

1. Light TR: Amputations of the hand. In *Chapman's Orthopaedic Surgery*, Vol 2, 3rd edition. Chapman MW, ed. Lippincott Williams & Wilkins, Philadelphia: 2001, 1454–5.

Syndactyly Repair

Surgical Considerations

Description: Syndactyly refers to congenital failure of separation of two or more fingers. It is complete if it extends to the ends of the fingers; incomplete syndactyly extends short of the finger ends. A **simple syndactyly repair** joins fingers by only skin and fibrous tissues. A **complex syndactyly repair** signifies fusion of adjacent phalanges or interposition of accessory phalanges, with frequent abnormalities of the neurovascular structures. Surgical separation is performed in the first few years of life for functional, as well as aesthetic reasons. The technique involves creation of a dorsal, proximally based skin flap to recreate the web. A zigzag dorsal and palmar incision is then created, separating from the distal end in a proximal direction. The digital nerve and arteries are dissected proximally as far as possible. Primary closure is almost never possible, and supplemental full-thickness skin graft harvested from the groin is used to complete the closure. Usually only one site is done at a time per hand; and, never should both sides of a digit be released, because of risk to the vascular supply. It is not always possible to save all the bony elements. Patients with conditions such as Apert syndrome must undergo careful evaluation of the airway.

Usual preop diagnosis: Syndactyly of fingers; bifid finger, thumb/finger

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Summary of Procedures

Position	Supine
Incision	Zigzag between digits; skin graft donor site from groin
Special instrumentation	Magnification loupes always necessary. Tourniquet is mandatory.
Unique considerations	Groin skin also must be taken for graft closure.
Antibiotics	Usually none
Surgical time	2–4 h
Closing considerations	Above-the-elbow cast or splint to keep incision away from mouth and other hand of the infant or child
EBL	20 mL
Postop care	PACU → home, if simple syndactyly
Mortality	None associated with procedure.
Morbidity	Partial slough of flaps or skin graft requiring revision Scarring and some stiffness of fingers Angulatory deformities late, occasionally depending on degree of involvement of the skeleton and joint
Pain score	1–3

Patient Population Characteristics

Age range	6 mo–5 yr
Male:Female	2:1
Incidence	1/2,000 births (the most common significant congenital hand anomaly)

Etiology

Associated conditions

Family Hx (10–40%); failure of differentiation in the 6th–8th wk of intrauterine life
Polydactyly, accessory phalanges; Apert syndrome; Poland syndrome

Anesthetic Considerations

See [Anesthetic Considerations for Upper Extremity Procedures, see p 1353.](#)

Suggested Readings

1. Bauer TB, Tondra JM, Trusler HM: Technical modification in repair of syndactylism. *Plast Reconstr Surg* 1956;17:385–92.
2. Chang J, Danton TK, Ladd AL, et al: Reconstruction of the hand in Apert's syndrome: a simplified approach. *Plast Reconstr Surg* 2002;109(2):465–70.
3. Ezaki M, Kay SP, et al: In *Green's Operative Hand Surgery*. Green DP, Hotchkiss RN, Pederson WC, eds. Churchill Livingstone, Philadelphia: 1993, 325.

Anesthetic Considerations for Upper Extremity Procedures

(Procedures covered: percutaneous pinning; displaced supracondylar humerus fracture; closed/open reduction; displaced lateral condylar humerus fracture; aspiration/injection unicameral/bone cyst; torticollis release; pollicization of finger; syndactyly release)

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Preoperative

The majority of children presenting for repair of upper extremity fractures are otherwise healthy. Most of these patients present for repair of a traumatic injury; thus, the preop workup is routine. Some arm procedures, such as repair of a compound fracture, require immediate attention and necessitate emergency surgery and full-stomach considerations (see [p. B-4](#)).

Laboratory

Premedication

Tests as indicated from H&P.

Standard premedication (see [p. D-1](#)).

Intraoperative

Anesthetic technique: GETA or LMA, since small children rarely tolerate regional anesthesia alone. In the older patient, regional anesthesia may be appropriate, and can reduce the risk of aspiration pneumonitis associated with GA in the patient with a full stomach. A combined technique offers the advantages of reduced anesthetic requirements and postop pain relief; however, regional anesthesia is relatively contraindicated in patients with neurovascular damage.

General anesthesia:

Induction

Maintenance

Emergence

Standard induction (see [p. D-1](#)) except in acute-trauma patients, where rapid-sequence induction is appropriate (see [p. B-5](#)).

Standard maintenance (see [p. D-3](#)).

Management of emergence and extubation should be routine, except in difficult airway cases, which require awake extubation. Skin closure is frequently followed by application of a splint; patient should remain anesthetized during splinting procedure.



Regional anesthesia:

Ultrasound guidance: Ultrasound-guided nerve block techniques are increasingly used in the pediatric anesthesia. The use of ultrasonography increases the ability to position the needle as close to the nerve as possible avoiding inadvertent trauma to the adjacent structures. Direct visualization also helps in optimizing the volume and distribution of the local anesthetic thus improving the safety and efficacy of the block.

Anesthetics and doses

See [Table 12.7-1](#).

Phrenic nerve block → hemidiaphragm paralysis is an inevitable consequence of the interscalene block. Major complications (e.g., total spinal or pneumothorax) resulting from interscalene block are very rare; therefore, this technique is suitable for outpatients. Interscalene block is contraindicated in patients with contralateral recurrent laryngeal nerve or phrenic nerve palsy.

The infraclavicular approach to brachial plexus block has the advantage of blocking the axillary and musculocutaneous nerves. The coracoid approach is shown to be safer than the classical approach. Use of ultrasonography increases the efficacy and safety of this block.

The medial aspect of the upper arm is innervated by the intercostobrachial nerve (T2) and requires a separate subcutaneous field block in the axilla, especially when a tourniquet is used. The lateral cutaneous nerve of the forearm, a sensory branch of the musculocutaneous nerve supplying sensation to the lateral forearm, is frequently missed by the axillary approach to the brachial plexus. Thus, a block of this nerve at the elbow is sometimes necessary. The dose volume of local anesthetic required varies with the height and weight of the child. As a rule, the child's body surface area can be used as an approximate proportion of the usual adult volume (e.g., a 1.7 M^2 adult will require 40 mL of local anesthetic; a 1 M^2 patient requires 20–25 mL). Care must be taken to avoid local anesthetic overdose (see [Table 12.7-1](#)).

Supplemental sedation may be accomplished with use of propofol by continuous infusion (50–150 mcg/kg/min).

Minimal blood loss

IV: 20 ga × 1

NS/LR @ 1.5–3 mL/kg/h

IV catheter should be placed in the contralateral upper extremity.

Standard monitors (see [p. D-1](#)).

and pad pressure points.
eyes.

Total spinal

Epidural anesthesia

IV injection (Sz/dysrhythmias)

Stellate ganglion block (Horner's syndrome)

Laryngeal nerve block

Phrenic nerve block

Pneumothorax

Hematoma

Pneumothorax

Inadvertent intravascular injection

Inadequate block

Intravascular injection

Peripheral nerve damage

Axillary hematoma

Axillary artery thrombosis

Pneumothorax

Resuscitative equipment, including airway management tools, should be immediately available.

Axillary block

Supplemental sedation

Blood and fluid requirements

Monitoring

Positioning

Interscalene block complications

Infraclavicular block complications

Axillary block complications

The coracoid approach has reduced risk of complications.

Very minimal doses of local anesthetic can cause CNS toxicity if reverse flow occurs during an intraarterial injection. Axillary thrombosis and pneumothorax are extremely rare.

**Table 12. 7-1.** Maximum Recommended Doses of Anesthetics for Regional Anesthesia

Drug	mg/kg (*with epinephrine)	Duration (min)
Lidocaine	5 (*7)	45–180
Bupivacaine	2.5 (*3)	180–600
Ropivacaine	3	180–600
Tetracaine	1.5	180–600
2-Chloroprocaine	8 (*10)	30–60
Procaine	8 (*10)	60–90

Postoperative

Pain management	PCA (see p. E-4). Regional block	Combined regional-GA provides excellent postop pain management.
Tests	None routinely indicated.	

Suggested Readings

1. Marhofer P, Greher M, Kapral S: Ultrasound guidance in regional anaesthesia. *Br J Anaesth.* 2005;94(1):7–17.

2. Marhofer P, Sitzwohl C, Greher M, et al: Ultrasound guidance for infraclavicular brachial plexus anesthesia in children. *Anaesthesia* 2004;59:642–6.

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Posterior Spinal Instrumentation and Fusion

Surgical Considerations

Description: **Posterior spinal instrumentation** refers to implanted metal rods affixed to the spine to correct and internally splint the deformed spine. Originally designed for scoliosis, posterior spinal instrumentation is commonly performed simultaneously with **spinal fusion** for a variety of diagnoses, including fracture, tumor, degenerative changes, and developmental spinal deformity. Although posterior spinal instrumentation with the ratcheted **Harrington rod** gained widespread usage in the 1970s, it is no longer used by spinal surgeons. The current standard is a hook-rod system, such as the **Cotrel-Dubousset** (C-D), the **Texas Scottish Rite Hospital** (TSRH), the **Miami Modular Orthopaedic Spinal System** (MOSS) and the **Universal Spine System** (USS). Regardless of the surgeon's choice of instrumentation, the spine is approached by an extensive midline posterior incision, in which a subperiosteal exposure (typically T2-5 down to L1-4) is used to elevate all the paraspinous muscles as far laterally as the tips of the transverse processes. Typically, 4–8 hooks are affixed to the posterior spinal elements (lamina, pedicles, or transverse processes) on both the concave and convex sides of the spine ([Figure 12.7-3](#)). These points of spinal fixation are then joined to two contoured rods. By compressing along the convex surfaces and distracting along the concave surfaces, some degree of rotational correction is possible. Some spine surgeons advise the patient to wear a brace for the initial months following surgery; however, body casts are no longer necessary.

Sublaminar wire loops ([Fig. 12.7-4](#)) are commonly used instead of the hook-rod method of spinal instrumentation when treating neuromuscular spinal deformity (e.g., cerebral palsy, muscular dystrophy, myelomeningocele, or spinal muscular atrophy). This alternative construct provides more points of fixation to the spine and eliminates the need for postop bracing. When a large degree of pelvic obliquity is a component of the patient's deformity, the instrumentation often is extended into the iliac wings ([Fig. 12-7.5](#)).

Somatosensory evoked potentials (SSEP) and **motor evoked potentials** (MEP) are used routinely in centers where spinal deformity correction surgery is common. Close coordination among the surgeon, spinal cord monitoring personnel, and anesthesiologist is necessary to properly recognize adverse intraop spinal events and to minimize the occurrence of false-positive findings. Many spine surgeons also request that an intraop wake-up test be performed to further verify spinal cord function.

Usual preop diagnosis: Scoliosis (usually idiopathic or neuromuscular); kyphosis (increased round back); reconstruction for tumor, trauma, or other.

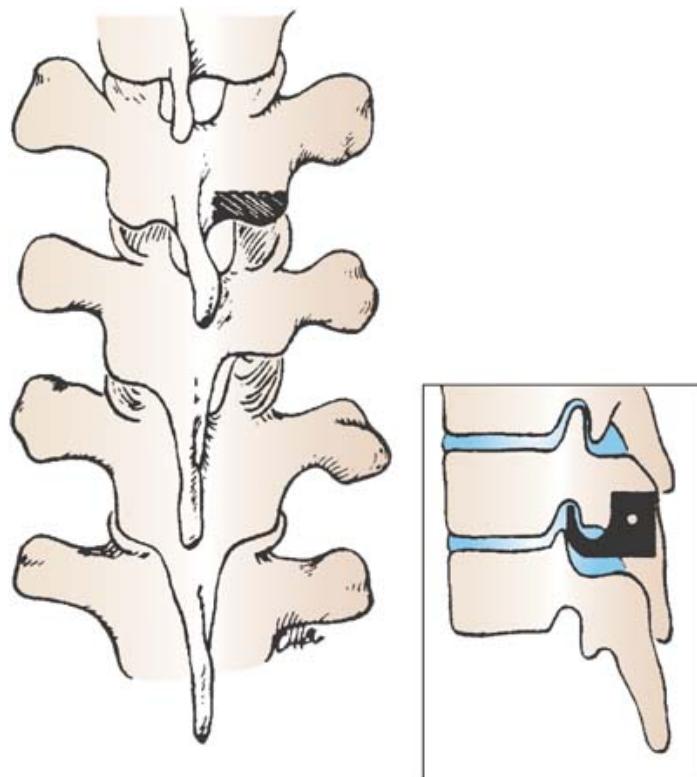


Figure 12.7-3. 3. Placement of a standard pedicle hook, in a hood-rod device. (Reproduced with permission from Chapman MW, ed: *Operative Orthopaedics*, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

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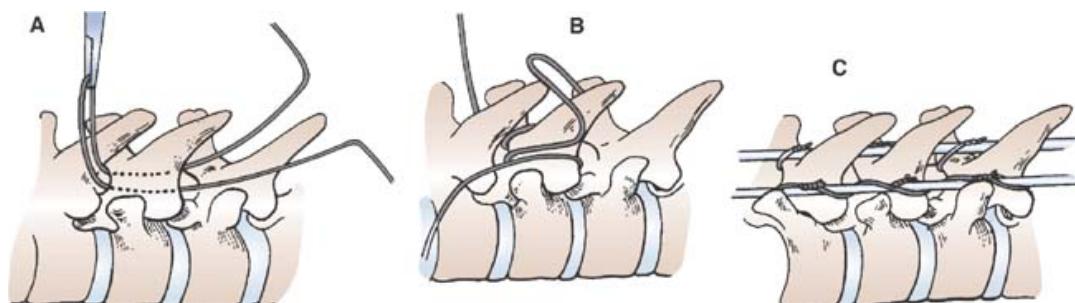


Figure 12.7-4. 4. An example of passing and attaching sublaminar wires. (Reproduced with permission from Chapman MW, ed: *Operative Orthopaedics*, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

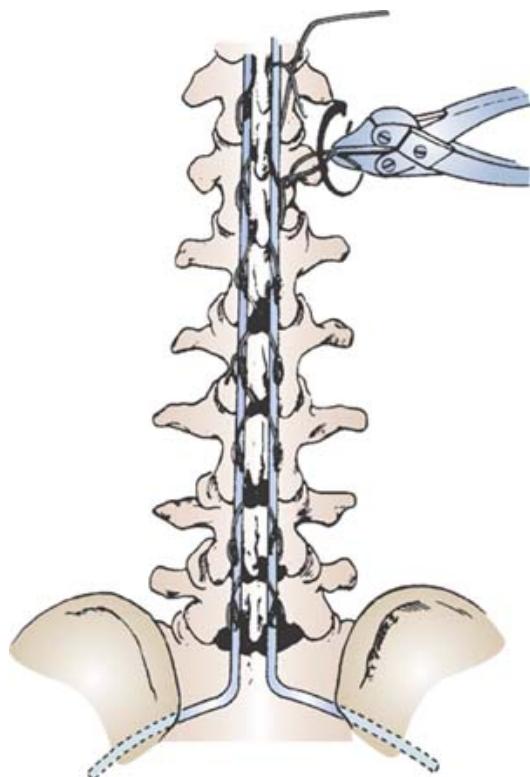


Figure 12.7-5. 5. Positioning rods in pelvis; sublaminar wires being tightened. (Reproduced with permission from Chapman MW, ed: *Operative Orthopaedics*, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

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Summary of Procedures

Position	Prone (on spinal frame or bolsters); avoid abdominal, elbow, and ocular compression.
Incision	Posterior midline; optional separate iliac crest bone graft
Special instrumentation	Rods, hooks, pedicle screws, wires
Unique considerations	“Wake up” test and/or SSEPs; frequently, induced ↓ BP is requested; prolonged prone positioning places brachial plexus and ulnar nerve at risk.
Antibiotics	Cefazolin 1–2 g iv
Surgical time	2–6 h
Closing considerations	Greatest blood loss typically toward the end of procedure. Avoid hypotension after instrumentation is implanted.
EBL	1,200–3,000 mL
Postop care	ICU: 1–2 d
Mortality	0–0.5%
Morbidity	Acute ileus: Very common Genitourinary infection: 5–7% Hematoma, massive bleeding: 1–5% Pneumothorax, pneumonia, atelectasis: 1–5% Hook dislodgement requiring reoperation: 0–2% Wound infection: 0–2% Superior mesenteric artery syndrome: 0–1% Thromboembolism: < 1% Spinal cord injury and/or root injury: 0.6% Delayed: Pseudarthrosis: 0–5% Late rod fracture: 0–5% Progression of spinal deformity: 0–2%

Pain score

7–9

Patient Population Characteristics

Age range	Usually 8–40 yr
Male:Female	1:5
Incidence	1–2/10,000
Etiology	Idiopathic (50–75%); neuromuscular (20–30%); associated with syndromes such as osteochondral dystrophies, osteogenesis imperfecta, etc. (5%); congenital scoliosis (2–5%) Neuromuscular: Friedreich's ataxia (myocarditis and other cardiovascular anomalies; sudden death) Myelomeningocele (latex allergy, chronic UTI, hydrocephalus) Muscular dystrophy (muscle weakness, cardiomyopathy, dysrhythmias, succinylcholine → prolonged muscle contraction, ↑ sensitivity to respiratory depressant effect of barbiturates, opiates, and benzodiazepines) Cerebral palsy (GERD, ↓ airway protective reflexes, ↑ postop pulmonary complications, malnourishment, Sz, medication may interfere with Plt function) Higher incidence of MH Connective tissue disease: Ehlers-Danlos and Marfan syndromes (avoid ↑ BP → aortic dissection; ↑ risk of pneumothorax). Osteogenesis imperfecta (position and intubate with great care). Congenital osteochondral dystrophies
Associated conditions	

(Print pagebreak 1359)

Anesthetic Considerations

See [Anesthetic Considerations for Spinal Reconstruction and Fusion, \(see p. 971\).](#)

Suggested Readings

1. Auerbach JD, Lonner BS, Antonacci MD, et al: Perioperative outcomes and complications related to teaching residents and fellows in scoliosis surgery. *Spine* 2008;33(10):1113–8.
2. Bridwell KHL: Spinal instrumentation in the management of adolescent scoliosis. *Clin Orthop* 1997;335:64–72.
3. Borgeat A, Blumenthal S: Postoperative pain management following scoliosis surgery. *Curr Opin Anaesthesiol* 2008;21(3):313–6.
4. Dubousset J, Cotrel Y: Application technique of Cotrel-Dubousset instrumentation for scoliosis deformities. *Clin Orthop* 1991;264:103–10.
5. Heller KD, Wirtz DC, Siebert CH, et al: Spinal stabilization in Duchenne muscular dystrophy: principles of treatment and record of 31 operative treated cases. *J Pediatr Orthop* 2001;10(1):18–24.
6. Thomson JD, Banta JV: Scoliosis in cerebral palsy: an overview and recent results. *J Pediatr Orthop* 2001;10(1):6–9.



7. Torre-Healy A, Samdani AF: Newer technologies for the treatment of scoliosis in the growing spine. *Neurosurg Clin N Am* 2007;18(4):697–705.

Anterior Spinal Fusion for Scoliosis

Surgical Considerations

Description: Anterior spinal fusion is performed through a transthoracic and/or retroperitoneal approach to the vertebral bodies, in which the intervertebral discs are removed and a bone graft is placed between the vertebral bodies. The disc removal (“release”) loosens the spine and allows greater deformity correction than posterior-only procedures. Often, no instrumentation is used anteriorly when the anterior fusion is performed as a first stage to a “front-and-back” fusion. (In such cases, posterior spinal instrumentation is subsequently implanted to correct the spinal deformity.) Anterior spinal instrumentation is performed when a posterior spinal fusion is not needed (e.g., idiopathic thoracolumbar or lumbar scoliosis).

When instrumentation of the anterior spine is performed, the surgical approach is through a flank incision, then through a rib bed on the convex side of the curve (usually the 10th rib). The retroperitoneal plane is entered and developed by blunt dissection behind the transversus abdominis muscle. The pleural cavity is entered, and the diaphragm usually must be divided circumferentially near its costal origin and around posteriorly to the spine. The prevertebral areolar plane is then entered and the segmental vessels to each vertebral body are clipped or cauterized in the midline. The psoas muscle is elevated off the lateral aspects of the vertebral bodies. Each disc in the fusion area (usually 3–5 discs) is excised back to the posterior longitudinal ligament. Next, vertebral screws (e.g., **Texas Scottish Rite Hospital [TSRH]**, **Miami Modular Orthopaedic Spine System [MOSS]**, **Universal Spine System [USS]**) instrumentation) are inserted transversely across the appropriate bodies and joined at their heads by a rod ([Figs 12.7-6](#) and [12.7-7](#)). Bone graft (typically from the rib harvested during the surgical approach) is placed within each discectomy level. A chest tube is placed before closure of the thoracic cavity.

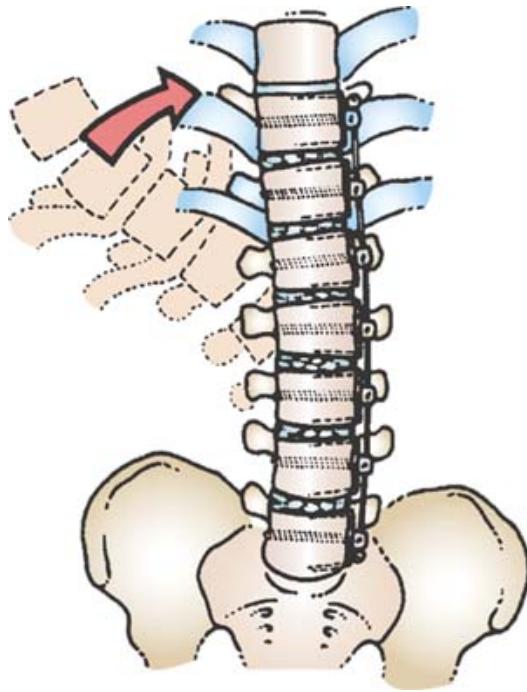


Figure 12.7-6. Dwyer instrumentation used to make spinal correction. (Reproduced with permission from Crenshaw AH, ed: *Campbell's Operative Orthopaedics*, 8th edition. Mosby-Year Book, St. Louis: 1992.)

Usual preop diagnosis: Idiopathic or neuromuscular scoliosis

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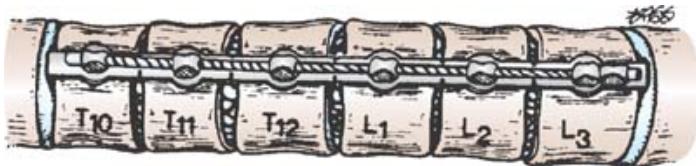


Figure 12.7-7. 7. Instrumentation from T10-L3 (Zielke). (Reproduced with permission from Chapman MW, ed: *Operative Orthopaedics*, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Summary of Procedures

	Fusion with Instrumentation	Release (No Instrumentation)
Position	Full lateral decubitus (Fig. 12.7-8)	
Incision	Flank: over rib at top vertebra in the curve (usually T9-T11)	
Special instrumentation	Screws, staples, rods	None
Unique considerations	Flex OR table at thoracolumbar junction until disc removal and deformity correction. Procedure often followed by posterior spinal fusion. Proximity of great vessels → potential for major bleeding. Patients with neuromuscular scoliosis often have poor generalized nutrition. SSEP/MEP often used to monitor spinal cord function.	Uninstrumented release is always followed by posterior spinal fusion with instrumentation.
Antibiotics	Cefazolin 25 mg/kg iv	
Surgical time	3–4 h	2–3 h
Closing considerations	Chest tube always used; hypotension, if used electively, must be reversed before closure.	
EBL	500–2,000 mL	250–2,000 mL
Postop care	ICU 1–2 d	
Mortality	0–2%, depending on underlying conditions Overall: 30%, depending on underlying condition Ileus and atelectasis: 50% UTI: 10–25% (common in spina bifida) Minor transient root weakness, or paraesthesia: 10–20% Partial sympathectomy: Common Late kyphosis above instrumentation: 5–10%	
Morbidity	Nonunion and hardware failure: 5% Massive blood loss: 2–5% Respiratory failure: 1–2% Pneumonia: 1% Paraplegia (acute anterior spinal artery syndrome): <1% Thromboembolism: Rare (<5% in children)	—
Pain score	5–8	4–7

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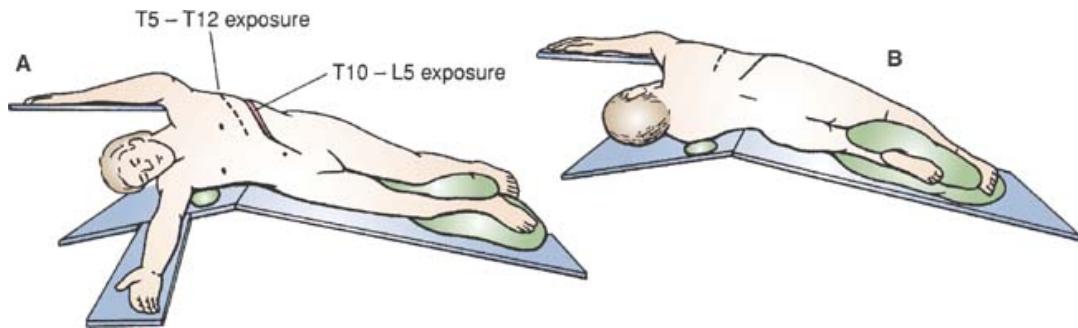


Figure 12.7-8. 8. Lateral decubitus position (diagrammatic) for anterior spinal procedures: (A) anterior view; (B) posterior view. Roll is placed under axilla to minimize axillary artery compression. Skin incision for exposure of T5–T12 is shown with the dotted line. (Reproduced with permission from Chapman MW, ed: *Operative Orthopaedics*, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Patient Population Characteristics

Age range	5–35 yr
Male:Female	Idiopathic: 1:10 Neuromuscular: 1:1
Incidence	< 1/10,000
Etiology	Idiopathic scoliosis; neuromuscular disease (especially cerebral palsy, spina bifida, polio, myopathies, muscular dystrophies); other genetic bone dysplasias; Marfan syndrome
Associated conditions	See Associated Conditions for Posterior Spinal Instrumentation and Fusion, p. 1356 .

Anesthetic Considerations

See [Anesthetic Considerations for Spinal Reconstruction and Fusion, \(see p. 971\)](#).

Suggested Readings

1. Betz RR, Harms J, Clement DH III, et al: Comparison of anterior and posterior instrumentation for correction of adolescent thoracic idiopathic scoliosis. *Spine* 1999;24(3):225–39.
2. Betz RR, Shufflebarger H: Anterior versus posterior instrumentation for the correction of thoracic idiopathic scoliosis. *Spine* 2001;26(9):1095–1100.
3. Hammnerberg KW, Rodts MF, DeWald RL: Zielke instrumentation. *Orthopedics* 1988;11(10):1365–71.
4. Kaneda K, Shono Y, Satoh S, et al: New anterior instrumentation for the management of thoracolumbar and lumbar scoliosis. Application of the Kaneda two-rod system. *Spine* 1996;21(10):1250–61.

Pelvic Osteotomy

Surgical Considerations

Description: Pelvic osteotomy is used to improve hip instability in cases of developmental hip dysplasia. The purpose of the





procedure is to improve the coverage of the femoral head and stimulate appropriate growth of the shallow (*Print pagebreak 1362*) acetabulum. It is frequently performed in conjunction with open reduction, and occasionally with femoral osteotomy. The surgical approach is made along the iliac crest, exposing the external (gluteal) surface of the iliac bone, and sometimes the internal (iliac) surface as well. The pelvis is osteotomized closely above the acetabulum, and sometimes through the pubis and ischium, depending on the direction of rotation and reorientation desired. Pelvic osteotomies either reorient an intact acetabular hyaline cartilage surface or are designed as salvage procedures to enlarge the acetabulum by fibrocartilage metaplasia (see [Acetabular Augmentation and Chiari, p. 1364](#)). **Salter's innominate osteotomy** is the classic reorientation osteotomy, in which a complete cut of the supraacetabular iliac bone allows rotation through the symphysis pubis. **Pemberton's operation** is a slightly more difficult incomplete iliac osteotomy, rotating on the triradius cartilage ([Fig. 12.7-9](#)), which is at the center of the acetabulum in young children. The Steel, "Dial" or **Eppright osteotomies** are the most difficult reorientation procedures. In each, the acetabulum is freed totally from any bony contact with the remainder of the pelvis and rotated into better position.

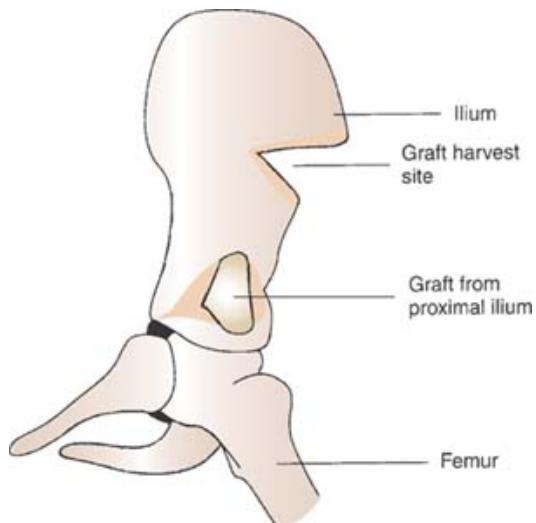


Figure 12.7-9. 9. Pemberton osteotomy: A triangular graft is cut from the proximal ilium, and the graft is carefully wedged into the osteotomy site. (Reproduced with permission from Chapman MW: *Chapman's Orthopaedic Surgery*, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

Usual preop diagnosis: Acetabular dysplasia due to congenital or developmental hip dislocation

Summary of Procedures

	Salter	Pemberton	Steel, Dial
Position	Supine or slightly lateral		
Incision	Oblique or longitudinal anterior hip		
Special instrumentation	Steinmann pins	Special curved, custom osteotomes	Steinmann pins
Unique considerations	Frequently follows previous unsuccessful open-hip surgery.		+ additional ischial incision
Antibiotics	Usually, cefazolin 25 mg/kg iv		
Surgical time	1.5–2 h	2–3 h	2–4 h
Closing considerations	Hip spica		
EBL	100–300 mL		200–600 mL
Postop care	PACU → room; care as needed for spica cast		
Mortality	Minimal Avascular necrosis of the hip: 5–6% Persistent hip subluxation: 5% Infection: 1%	—	—



Morbidity	Sciatic or perineal palsy: <0.1%		
	Excess bleeding from superior gluteal artery: Rare		Occasional
	Ileus: Rare		Occasional
Pain score	2–5	2–5	3–6

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Patient Population Characteristics

Age range	18 mo–6 yr, if dislocated 18 mo–10 yr, if only subluxated	18 mo–7 yr	12 yr
Male:Female	1:2		
Incidence	1/10,000	1/10,000	1/10,000
Etiology	Congenital and/or developmental hip dysplasia: 98% Perthes disease: 1% Torticollis: < 1% Other joint contractures in cases of neuromuscular dislocation: <1%		
Associated conditions			

Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, see p. 1389.](#)

Suggested Readings

1. Ganz R, Klaue K, Vinh TS, et al: A new periacetabular osteotomy for the treatment of hip dysplasias. *Clin Orthop Rel Res* 1998; 232:26–36.
2. Millis MB, Kaelin AJ, Schluntz K, et al: Spherical acetabular osteotomy for the treatment of acetabular dysplasia in adolescents and young adults. *J Pediatr Orthop* 1994;3:47–53.
3. Pogliacomi F, De Filippo M, Costantino C, et al: 2006: the value of pelvic and femoral osteotomies in hip surgery. *Acta Biomed* 2007;78(1):60–70.
4. Pemberton PA: Pericapsular osteotomy of the ilium for the treatment of congenitally dislocated hips. *Clin Orthop* 1974;98:41–54.
5. Salter RB, Duboi JP: The first fifteen years' personal experience with innominate osteotomy in the treatment of congenital dislocation and subluxation of the hip. *Clin Orthop* 1974;98:72–103.
6. Sanchez-Sotelo J, Trousdale RT, Berry DJ, et al: Surgical treatment of developmental dysplasia of the hip in adults: I. Nonarthroplasty options. *J Am Acad Orthop Surg* 2002;10(5):321–33.
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7. Staheli LT: Surgical management of acetabular dysplasia. *Clin Orthop* 1991;264:111–21.



8. Steel HH: Triple osteotomy of the innominate bone. *J Bone Joint Surg* 1973;55(2):343–50.
9. Tonnis D, Arning A, Block M, et al: Triple pelvic osteotomy. *J Pediatr Orthop* 1994;3:54–67.
10. Vitale MG, Skaggs DL: Developmental dysplasia of the hip from six months to four years of age. *J Am Acad Orthop Surg* 2001;9(6):401–11.
11. Waters P, Kurica K, Hall J, et al: Salter innominate osteotomies in congenital dislocation of the hip. *J Pediatr Orthop* 1988; 8 (6):650–5.

Acetabular Augmentation (Shelf) & Chiari Osteotomy

Surgical Considerations

Description: Acetabular augmentation is a “salvage” procedure used to deepen the hip socket when a realignment osteotomy of the pelvis and/or femur would not adequately cover the femoral head. This is accomplished by securing strips of cortical cancellous bone graft onto the proximal surface of the hip capsule. The surgical approach is anterior to the hip, elevating the gluteal muscles subperiosteally from the outer surface of the ilium. The reflected head of the rectus femoris tendon is elevated, and a domed-shaped slot is created just above the capsular attachment to the ilium. Abundant cortical cancellous strips of bone graft are then harvested from the upper two thirds of the outer wall of the ilium. These bone grafts have a natural curve and lie on the convexity of the hip capsule. No internal fixation, other than suture repair, is used to hold the bone graft in place. This creates a large bony augmentation (shelf) over the uncovered femoral capsule.

Variant procedure or approaches: The bone graft may be taken as a large, sculpted, solitary, cortical cancellous strut or wedge, or more commonly, as curved “shavings” anchored in a dome-shaped slot just above the hip capsule. In the **Chiari procedure**, a complete dome-shaped osteotomy allows lateral displacement of the ilium just above the proximal hip capsule ([Fig. 12.7-10](#)). The line of the osteotomy corresponds more or less with the slot of the shelf procedure. In either case, the result is abundant bony coverage over the hip capsule, which undergoes metaplasia into fibrocartilage.

Usual preop diagnosis: Acetabular dysplasia (shallow socket) due to congenital hip dislocation or developmental neurologic subluxation

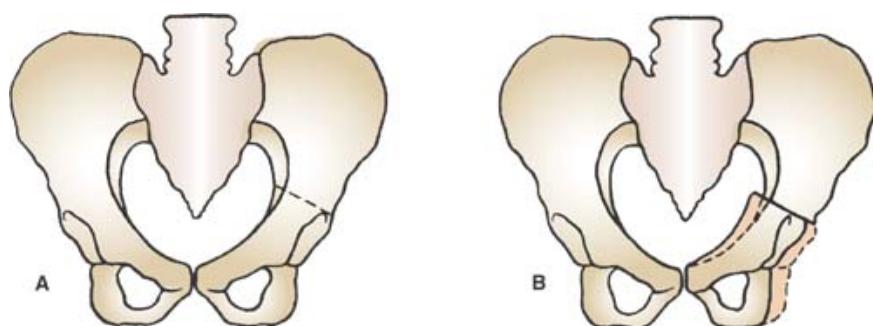


Figure 12.7-10. 10. Chiari osteotomy: (A) Line of osteotomy. (B) Completed osteotomy. (Reproduced with permission from Crenshaw AH, ed: *Campbell's Operative Orthopaedics*, 8th edition. Mosby-Year Book, St. Louis: 1992.)

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Summary of Procedures

	Acetabular Augmentation	Chiari Osteotomy
Position	Supine or slightly tilted up (reverse Trendelenburg)	or lateral decubitus
Incision	Oblique or longitudinal; anterior hip region	



Special instrumentation	Usually no internal fixation; I.I. or intraop x-ray	Two large screws or pins; I.I. or intraop x-ray
Antibiotics	Cefazolin 25 mg/kg iv	
Surgical time	1.5–3 h	
Closing considerations	Unilateral or 1.5 spica cast mandatory	Spica cast (optional)
EBL	100–500 mL	200–800 mL
Postop care	PACU → room. Care as necessary for cast.	
Mortality	Minimal	
Morbidity	Lateral femoral cutaneous nerve dysfunction: 30–50% Infection: 1%	Sciatic or peroneal palsy: 2% Possible need for later C-section: Rare
Pain score	4–6	4–6

Patient Population Characteristics

Age range	6–35 yr
Male:Female	1:1.5
Incidence	< 1/10,000 in general population; in neuromuscular population (e.g., cerebral palsy, poliomyelitis residuals): 5–10%
Etiology	Neuromuscular hip subluxation with shallow acetabulum; residual shallow acetabulum (poor coverage from congenitally dislocated hip)
Associated conditions	Cerebral palsy; polio; spina bifida; myopathy; congenital atrophies; Charcot-Marie Tooth disease

Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, see p. 1389.](#)

Suggested Readings

1. Betz RR, Kumar Si, Palmer CT, et al: Chiari pelvic osteotomy in children and young adults. *J Bone Joint Surg* 1988;70(2):182–91.
2. Chiari K: Medial displacement osteotomy of the pelvis. *Clin Orthop* 1974;98:55–69.
3. Fong HC, Lu W, Li YH, et al: Chiari osteotomy and shelf augmentation in the treatment of hip dysplasia. *J Pediatr Orthop* 2000;20(6):740–4.
4. Morrissey RT: *Atlas of Pediatric Orthopaedic Surgery*. JB Lippincott, Philadelphia: 1992.
5. Piontek T, Szulc A, Gowacki M, et al: Distant outcomes of the Chiari osteotomy 30 years follow up evaluation. *Ortop Traumatol Rehabil* 2006;8(1):16–23.
6. Staheli LT, Chew DE: Slotted acetabular augmentation in childhood and adolescence. *J Pediatr Orthop* 1992;12(5):569–80.
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7. Summers BN, Turner A, Wynn-Jones CH: The shelf operation in the management of late presentation of congenital hip dysplasia. *J*

Bone Joint Surg 1988;70(1):63–8.

8. White RE Jr, Sherman FC. The hip shelf procedure. A long-term evaluation. *J Bone Joint Surg* 1980;62(6):928–32.
9. Zuckerman JD, Staheli LT, McLaughlin JF. Acetabular augmentation for progressive hip subluxation in cerebral palsy. *J Pediatr Orthop* 1984;4(4):436–42.

Ober Fasciotomy, Yount-Ober Release

Surgical Considerations

Description: Ober's fasciotomy is performed to release flexion, abduction, and external rotation contracture at the hip. This contracture usually occurs as a result of profound flaccid paralysis → prolonged positioning in a so-called “frog” position of 90° flexion, abduction, and lateral rotation at the hips. This results in tightening of the iliotibial (IT) band (the greatly thickened lateral aspect of the fascia lata) and related structures. The operation is performed through an anterolateral incision just distal to the iliac crest. All of the fascial investments of the tensor, sartorius, and, at times, the rectus femoris and gluteus medius and minimus are divided, while preserving any normal-appearing muscle fibers. The limb is stretched into progressively more adduction and extension, until a neutral position can be obtained. The Yount procedure is added when the knee also is contracted in a flexed mode due to tightness of the IT band. The Yount procedure consists of further resection of a segment of the IT band and a lateral intermuscular septum through a separate distal mid-lateral longitudinal incision just above the knee. An oblique segment of the IT band and septum are removed and not repaired.

Usual preop diagnosis: Flaccid paralysis and “frog”-type contracture due to poliomyelitis, myelomeningocele, or myopathy

Summary of Procedures

	Ober Fasciotomy	Yount-Ober Release
Position	Supine; both legs must be prepped and draped to well above the iliac crest area for intraop stretching.	
Incision	Oblique iliac crest	Mid-lateral longitudinal above knee joint, 10 cm
Unique considerations	Patients with sensory and motor loss have a tendency to get pressure sores.	
Antibiotics	Usually none	
Surgical time	1 h/side	30 min/side
Closing considerations	Bilateral above-knee casts	
EBL	< 150 mL	< 50 mL
Postop care	PACU → room; extensive physical therapy program of stretching exercises. Myopathic patients at risk for postop respiratory compromise.	
Mortality	Minimal Hematoma: 1%	
Morbidity	Fracture of atrophied bone postop: < 1% Infection < 1% Pressure sores from positioning or casts: < 1%	
Pain score	3–4	3–4

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Patient Population Characteristics

Age range	2–15 yr
Male:Female	1:1
Incidence	Extremely rare in children born in the United States; however, polio is seen commonly in southeast Asian and Latin-American immigrants.
Etiology	Polio; myelomeningocele; myopathy or dystrophy
Associated conditions	Other contractures; incontinence; pressure sores in myelomeningocele

■ Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, see p. 1389.](#)

Suggested Readings

1. Beaty JH: Paralytic disorders. In *Campbell's Operative Orthopaedics*, 8th edition. Crenshaw AH, ed. Mosby-Year Book, St. Louis: 1992, 2412–16.
2. Irwin CE: The iliotibial band, its role in producing deformity in poliomyelitis. *J Bone Joint Surg* 1949;31:141–52.
3. Ober FR: The role of the iliotibial band and fascia lata as a factor in the causation of low-back disabilities and sciatica. *J Bone Joint Surg* 1936;18:105–19.
4. Yount CC: The role of the tensor fasciae femoris in certain deformities of the lower extremities. *J Bone Joint Surg* 1926; 8:171–82.

Hip, Open Reduction & Femoral Shortening

■ Surgical Considerations

Description: Open reduction of the hip replaces a dislocated femoral head into the anatomic acetabulum, at times after an unsuccessful attempt to reduce the hip by closed means. A developmental dislocation presents with a more normal acetabulum and occurs around birth or later. A teratologic congenital dislocation of the hip occurs early in utero, and, as a result, has a high-riding dislocation with a poorly developed acetabulum, presenting much more difficulty in obtaining and maintaining reduction. The most common surgical approach is through an extended anterior incision. The hip capsule is exposed circumferentially, after division and tagging of the origins of the rectus, femoris, and sartorius muscles, and retraction of the tensor and gluteal muscles. The iliopsoas tendon is either lengthened or divided. The capsule is opened in an oblique fashion, the ligamentum teres is excised, and any obstacle to reduction is removed. The femoral head is replaced in the socket, and the capsule is repaired in a “vest-over-pants” imbrication, with the hip reduced under direct visualization ([Fig. 12.7-11](#)). A medial approach through the adductor region can be used in very young children (<18 mo), but does not allow a capsular repair. If femoral shortening is necessary, the surgical excision is either extended anterolaterally, or a separate lateral incision is made longitudinally over the proximal femur.

Variant procedure or approaches: Most children < 2 years old can simply have the hip repositioned—closed or open—and subsequently have normal hip development. In older children, especially with a high dislocation, a segment of the femur is removed subtrochanterically to allow reduction without pressure (thus allowing “descent” of the femoral head). If the acetabulum is very shallow, a pelvic osteotomy may be added.

Usual preop diagnosis: Developmental dislocation of hip; teratologic congenital dislocation of hip

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Summary of Procedures

	Open Reduction	Open Reduction + Femoral Shortening
Position	Supine	
Incision	Oblique ("bikini") along the iliac crest or medial longitudinal over joint	+ anterolateral thigh over joint
Special instrumentation	None	Plates and screws
Unique considerations	Preliminary arthrogram and, often, attempted closed reduction. I.I. is used.	
Antibiotics	Usually cefazolin 25 mg/kg iv	
Surgical time	1.5–3 h	2–4 h
Closing considerations	Hip spica cast applied on child's spica frame. NB: Do not wake patient until last radiograph is taken, in case cast has to be reapplied.	
EBL	< 100 mL	100–400 mL
Postop care	PACU → room; care as necessary for spica cast	
Mortality	Minimal	
Morbidity	Avascular necrosis of femoral head Stiffness and late arthritis Limb-length discrepancy Marked scrotal or labial swelling: temporary Redislocation Infection	
Pain score	2–4	3–5

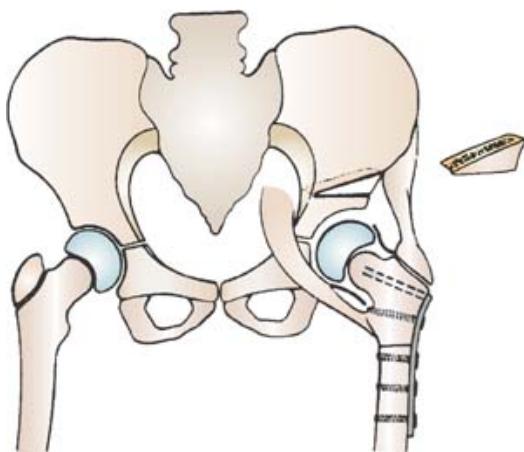


Figure 12.7-11. 11. Open reduction with femoral shortening. (Reproduced with permission from Crenshaw AH, ed: *Campbell's Operative Orthopaedics*, 8th edition Mosby-Year Book, St. Louis: 1992.)

(Print pagebreak 1369)

Patient Population Characteristics

Age range

Closed reduction: 3 mo–3 yr
Open reduction: 6 mo–10 yr

Male:Female

Incidence

Etiology

Associated conditions

Open reduction femoral shortening: 2–14 yr

1:5 (approximate)

1:10,000

Genetic background; breech presentation; first-born girl

Arthrogryposis; Larsen's disease; myelomeningocele; chromosomal anomalies; congenital torticollis; cerebral palsy

Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, see p. 1389.](#)

Suggested Readings

1. Coleman SS: *Congenital Dysplasia and Dislocation of the Hip*. Mosby-Year Book, St. Louis: 1978.
2. Ferguson AB: Primary open reduction of congenital dislocation of the hip using a median adductor approach. *J Bone Joint Surg* 1973;55:671–89.
3. Galpin RD, Roach JW, Wenger DR, et al: One-stage treatment of congenital dislocation of the hip in older children, including femoral shortening. *J Bone Joint Surg* 1989;71(5):734–41.
4. Hogan KA, Blake M, Gross RH: Subtrochanteric valgus osteotomy for chronically dislocated, painful spastic hips. Surgical technique. *J Bone Joint Surg* 2007;89(Suppl 2):226–31.
5. Moseley CF: Developmental hip dysplasia and dislocation: management of the older child. *Instr Course Lect* 2001;50:547–53.
6. Morrissey RT: *Atlas of Pediatric Orthopaedic Surgery*. JB Lippincott, Philadelphia: 1992:137–54.
7. Rab GT: Surgery for developmental dysplasia of the hip. In *Chapman's Orthopaedic Surgery*, 3rd edition. Chapman MW, ed. Lippincott Williams & Wilkins, Philadelphia: 2001:4241–58.
8. Schoenecker PL, Strecker WB: Congenital dislocation of the hip in children. Comparison of the effects of femoral shortening and of skeletal traction in treatment. *J Bone Joint Surg* 1984;66(1):21–7.
9. Wenger DR, Lee CS, Kolman B: Derotational femoral shortening for developmental dislocation of the hip: special indications and results in the child younger than 2 years. *J Pediatr Orthop* 1995;15(6):768–79.

Adductor Release or Transfer, Psoas Release

Surgical Considerations

Description: The adductor tendons and often the iliopsoas tendon are released in spastic and other neurologic conditions (especially cerebral palsy). The goal is to allow greater abduction by decreasing the strength of the adductors and flexors. The releases are also performed for other causes of hip contracture due to developmental hip dislocation, juvenile arthritis, etc. The procedure is performed with the patient supine, using a medial groin incision in which the tendons (usually the adductor longus, brevis, and gracilis) are isolated and divided by electrocautery. In the classic procedure, popularized by **Banks** and **Green**, the anterior branch of the obturator nerve is divided on the surface of the adductor brevis to affect more permanent adductor weakness. This procedure is now less popular, because the denervated muscles can undergo denervation fibrosis resulting in recurrent contracture. The iliopsoas tendon may be released at its insertion on the lesser trochanter, in the base of the adductor incision; or, just the tendinous



portion of the combined iliopsoas may be released at the pelvic rim, which produces a more modest degree of the flexor lengthening. Some surgeons transfer the adductor longus and gracilis muscles proximally and laterally, suturing them to the ischium to convert the adductors to hip extensors by changing their mechanics.

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Usual preop diagnosis: Adduction and flexion contracture of the hip with subluxation due to cerebral palsy, acquired encephalopathy, or progressive neurologic disorder.

Summary of Procedures

	Adductor Release	Adductor Transfer	Psoas Release
Position	Supine	Supine or lithotomy	
Incision	Medial proximal groin, longitudinal or transverse	Transverse medial groin	Anterior groin
Unique considerations	Frequently bilateral; often poor hygiene, especially if severe contracture; proximity to perineum		
Antibiotics	± cefazolin 25 mg/kg iv		
Surgical time	1 h	1.5 h	1 hr
Closing considerations	Bilateral leg casts or double spica cast		
EBL	< 100 mL		
Postop care	PACU → room; care as necessary for spica cast		
Mortality	Minimal		
Morbidity	Hematoma, drainage Infection: < 1% Recurrence of adduction deformity		
Pain score	2–4	2–4	2–4

Patient Population Characteristics

Age range	2–20 yr
Male:Female	1:1
Incidence	0 in general population; 30% of cerebral palsy patients (0.6–5.9/1,000)
Etiology	Cerebral palsy (90%); slowly progressive degenerative neurologic conditions (8–10%); head injury and drowning (1–2%)
Associated conditions	Multiple other contractures; GERD; poor general nutrition; mental retardation

Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, see p. 1389](#).

Suggested Readings



1. Banks HH, Green WT: Adductor myotomy and obturator neurectomy for the correction of adduction contracture of the hip in cerebral palsy. *J Bone Joint Surg* 1960;42:111–26.
2. Bleck EE: The hip in cerebral palsy. *Orthop Clin North Am* 1980;11(1):79–104.
3. Kalen V, Bleck EE: Prevention of spastic paralytic dislocation of the hip. *Dev Med Child Neurol* 1985;27(l):17–24.
4. Miller F, Cardoso Dias R, Dabney KW, et al: Soft-tissue release for spastic hip subluxation in cerebral palsy. *J Pediatr Orthop* 1997;17(5):571–84.
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5. Presedo A, Oh CW, Dabney KW, et al: Soft-tissue releases to treat spastic hip subluxation in children with cerebral palsy. *J Bone Joint Surg* 2005;87:832–41.
6. Reimers J, Poulsen S: Adductor transfer versus tenotomy for stability of the hip in spastic cerebral palsy. *J Pediatr Orthop* 1984;4(1):52–4.
7. Rinsky LA: Surgery for cerebral palsy. In *Chapman's Orthopaedic Surgery*, 3rd edition. Chapman MW, ed. Lippincott Williams & Wilkins, Philadelphia: 2001, 4485–504.
8. Root L, Spero CR: Hip adductor transfer compared with adductor tenotomy in cerebral palsy. *J Bone Joint Surg* 1981;63 (5):767–72.

Pinning of Slipped Capital Femoral Epiphysis (SCFE)

Surgical Considerations

Description: Slipped capital femoral epiphysis is a mechanical failure of the proximal femoral growth plate. During the rapid growth period, the shearing stress of the body weight on the proximal femoral growth plate may cause the femoral head (capital epiphysis) to gradually move relative to the femoral neck through the physis or growth cartilage. The displacement occurs over weeks-to-months, with the head appearing to move posteriorly and inferiorly on the neck. Percutaneous **in situ pinning** (no reduction) is the most common treatment. The goal is to prevent further slipping and subsequent arthritis by causing closure of the growth plate. The procedure must be performed under radiographic control (usually I.I.), using a variety of threaded pins or screws which are passed through the neck into the femoral head. Currently, the favored technique uses one cannulated screw, which is passed percutaneously over a guide wire from the anterolateral aspect of the proximal femur.

Variant procedure or approaches: Although most slips are chronic, occasionally following mild trauma, an acute slip will supervene. Following severe trauma, a previously normal hip with an open physis (growth plate) may suffer an acute displacement. In such acute slips, some degree of reduction may be possible, and two pins are usually necessary. Because pin-related complications are common, some surgeons prefer to close the growth plate by open drilling and curettage, with bone grafting across the cartilaginous plates. This is performed through an anterior incision, opening the hip capsule widely from an oblique groin incision. No pins are used, but an iliac bone graft is placed across the physis. A body spica cast is frequently needed. After the physis is closed, if there is severe residual deformity, a corrective osteotomy is performed in the trochanteric region (see [Proximal Femoral Osteotomy, Southwick procedure, p. 1375](#)).

Usual preop diagnosis: Acute or chronic SCFE

Summary of Procedures

	Pinning of SCFE	Variant Open Epiphysiodesis
Position	Supine	
Incision	Short, proximal thigh or stab incision	Anterolateral groin



Special instrumentation	Guide wires; cannulated screws; I.I.; fracture table	I.I. (recommended)
Unique considerations	Frequently bilateral ($\geq 20\%$); often obese	
Antibiotics	Cefazolin 1 g iv	
Surgical time	0.5–2 h	1–3 h
Closing considerations	None	Frequently needs spica cast
EBL	Negligible	200–500 mL
Postop care	PACU → room	Body spica cast, occasionally
Mortality	Minimal	
	Unsuspected pin penetration: $\geq 37\%$	
	Avascular necrosis: $\geq 33\%$ (in acute slip cases)	
Morbidity	Chondrolysis, hip stiffness: 1–28%	
	Fracture after pin removal: <1%	
	Infection: < 1%	
Pain score	2–3	2–3

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Patient Population Characteristics

Age range	10–16 yr
Male:Female	2–3:1
Incidence	1–3/100,000 (higher in African Americans)
	Excessive loading of the growth plate (obesity or increased angle of inclination of the physis)
Etiology	Insufficient tensile strength of collagen and proteoglycans around the femoral neck
	Increased thickness of the physis as from excessive growth hormone, hypogonadism, hypothyroidism, hyperparathyroidism, renal osteodystrophy, almost any other significant endocrinopathy
	Radiation therapy
Associated conditions	Obesity; endocrinopathies; renal osteodystrophy

Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, see p. 1389.](#)

Suggested Readings

1. Aadalen RJ, Weiner DS, Hoyt W, et al: Acute slipped capital femoral epiphysis. *J Bone Joint Surg*; 1974;56(7):1473–87.
2. Aronsson DD, Loder RT, Breur GJ, et al: Slipped capital femoral epiphysis: current concepts. *J Am Acad Orthop Surg* 2006; 14:666–79.
3. Asnis SE: The guided screw system in slipped capital femoral epiphysis. *Contemp Orthop* 1985;11:27–31.
4. Dobbs MB, Weinstein SL: Natural history and long-term outcomes of slipped capital femoral epiphysis. *Instr Course Lect* 2001; 50:571–5.



5. Lee FY, Chapman CB: In situ pinning of hip for stable slipped capital femoral epiphysis on a radiolucent operating table. *J Pediatr Orthop* 2003;23(1):27–9.
6. Lehman WB, Menche D, Grant A, et al: The problem of evaluating *in situ* pinning of slipped capital femoral epiphysis: an experimental model and a review of 63 consecutive cases. *J Pediatr Orthop* 1984;4(3):297–303.
7. Loder RT: Unstable slipped capital femoral epiphysis. *J Pediatr Orthop* 2001;21(5):694–9.
8. Loder RT, Aronsson DD, Dobbs MB, et al: Slipped capital femoral epiphysis. *Inst Course Lect* 2001;50:555–70.
9. Morrissey RT: *Atlas of Pediatric Orthopaedic Surgery*. JB Lippincott, Philadelphia: 1992, 212–44.
10. O'Brien ET, Fahey JJ: Remodeling of the femoral neck after *in situ* pinning for slipped capital femoral epiphysis. *J Bone Joint Surg*: 1977;59(1):62–8.

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Flexible Intramedullary Nailing of Long-Bone Fractures

Surgical Considerations

Description: The purpose of flexible nailing of long bones is to obtain stability with minimal surgical risk. This method is applicable to both lower- and upper-extremity fractures. Casting is unnecessary in many cases because of the balanced dynamic forces exerted by the elastic memory of the implanted precontoured nails. This is particularly appealing when treating femur fractures that otherwise would require spica casting and prolonged immobility. This technique results in a high rate of fracture union, promoted by the implant load-sharing characteristics with a modulus of elasticity that is close to bone, thereby avoiding stress shielding. The flexible nailing technique for treatment of femur fractures in children also avoids the risk of avascular necrosis of the femoral head because of a more distal entry point on the bone, compared to standard rigid intramedullary nails that enter the medullary canal at the base of the femoral neck, where the primary vascular supply to the femoral head is located.

The child is placed supine on a radiolucent operating table, although some surgeons prefer to use a fracture table when treating femur fractures with this method. The surgeon performs a closed reduction of the fracture with fluoroscopy assistance, proceeding to an open incision and reduction only if an acceptable fracture reduction cannot be achieved with closed techniques. After the fracture is aligned, a small incision for each nail is made on the extremity proximal to the physis at the knee. A drill is used to create an entry point in the cortex of the bone, and each nail is contoured before insertion through this entry point. No intramedullary reaming is performed before nail insertion. The rare need for cast application is judged by intraop imaging for rotational and angular stability.

Usual preop diagnosis: Fracture

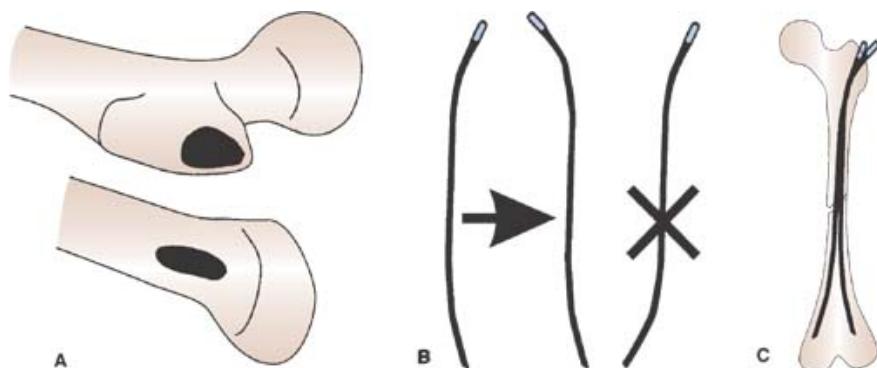


Figure 12.7-12. 12. Intramedullary nailing. (A) Nail entry site through greater trochanter (antegrade) or distal metaphysis (retrograde). (B) Nails are contoured before insertion. (C) Fracture stabilized with two antegrade nails. (Reproduced with permission from Chapman MW: *Chapman's Orthopaedic Surgery*, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)



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Summary of Procedures

	Closed Reduction	Open Reduction
Position	Supine; may be performed on fracture table if femoral.	
Incision	2–3 cm at entry site for each nail	Incision at fracture site and 2–3 cm at entry site for each nail
Instrumentation	Intramedullary nails, power drill, I.I.	
Unique considerations	Blood loss from fracture; muscle relaxation may be necessary to obtain reduction.	
Antibiotics	Cefazolin 25 mg/kg	
Surgical time	45–60 min	60–90 min
Closing considerations	May supplement with cast.	
EBL	Minimal	50–200 mL
Postoperative care	PACU → room	
Mortality	Rare, except in multitrauma Nonunion, malunion Shortening Infection Painful instrumentation	
Morbidity		
Pain score	4–7	4–7

Patient Population Characteristics

Age range	6–14 yr
Male:Female	2.6:1
Incidence	19/100,000 for femoral shaft
Etiology	Trauma
Associated conditions	Usually normal, healthy child

Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, see p. 1389](#).

Suggested Readings

1. Hedlund R, Lindgren U: The incidence of femoral shaft fractures in children and adolescents. *J Pediatr Orthop* 1986;6(1):47–50.
2. Hinton RY, Lincoln A, Crockett MM, et al: Fractures of the femoral shaft in children. Incidence, mechanisms, and sociodemographic risk factors. *J Bone Joint Surg* 1999;81(4):500–9.
3. Mazda K, Khairouni A, Pennecot GF, et al: Closed flexible intramedullary nailing of femoral shaft fractures in children. *J Pediatr Orthop* 1997;6(3):198–202.
4. Rathjen KE, Riccio AI, De La Garza D: Stainless steel flexible intramedullary fixation of unstable femoral shaft fractures in children. *J Pediatr Orthop* 2007;27:432–41.



5. Vrsansky P, Bourdelat D, Al Faour: Flexible stable intramedullary pinning technique in the treatment of pediatric fractures. *J Pediatr Orthop* 2000;20(1):23–7.

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Proximal Femoral Osteotomy

Surgical Considerations

Description: Femoral osteotomy is performed in the inter- or subtrochanteric area to redirect the femoral head more superiorly (valgus) or inferiorly (varus) and/or for rotational correction of excessive medial/femoral torsion (anteversion). A plate and screws are commonly used, but an **external fixator** and/or spica cast may be placed instead. The usual surgical approach is direct lateral over the proximal shaft of the femur, beginning at the greater trochanter. The deep fascia is split and the underlying vastus muscle is elevated subperiosteally to expose the femoral shaft. Normally, a power saw is used to make the osteotomy; and, depending on the correction desired, there are a variety of internal fixation devices which can be used.

Variant procedure or approaches: Different named plates (e.g., AO blade, Coventry screw, Richards screw, Wagner, etc.) may be used to affix the proximal to the distal femoral segments. A 1–4-cm segment of femur may be removed in cases of superior hip dislocation to allow soft-tissue relaxation and descent of the femoral head into the socket. Most proximal femoral osteotomies are performed in the subtrochanteric area, but some are performed in the intertrochanteric or base of the neck (**Kramer compensating**). The **Southwick osteotomy** is a more complicated example of a subtrochanteric osteotomy, which corrects for three directions (varus, lateral rotation, and extension).

Usual preop diagnosis: Developmental hip subluxation; excessive hip anteversion; residual deformity from Perthes disease; coxa vara; slipped capital femoral epiphysis (SCFE); residual deformity

Summary of Procedures

	Varus Derotation Osteotomy + Plate and Screws	External Fixator	Southwick or Kramer
Position	Supine		
Incision	Lateral thigh or, occasionally, long anterior thigh		
Special instrumentation	Plate and screws; power drill and saw; I.I.	External fixator; multiple pins; Plate and screws; power drill and saw; I.I.	
Unique considerations	Fracture or radiolucent table		
Antibiotics	± Cefazolin 25 mg/kg iv		
Surgical time	1.5–2.5 h	2–4 h	
Closing considerations	Spica cast, frequently	± Spica cast	Spica cast, occasionally
EBL	250–750 mL		500–1,000 mL
Postop care	PACU → room. Spica cast; Nonweight-bearing 6 wk; no full weight-bearing, 3 mo.		
Mortality	Minimal Persistent hip dysplasia: 5–20% (depending on etiology) Excess blood loss from a perforating branch of the profunda femoris: < 1%		
Morbidity	Infection: < 1% Loss of fixation, instrument failure: < 1%		

Nonunion: < 1%			
Persistent hip stiffness: < 1%			
Avascular necrosis: Rare			
Pain score	6–8	6–8	6–8

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Patient Population Characteristics

Age range	2–21 yr
Male:Female	1:1
Incidence	Depending on Dx
Etiology	Coxa varum, coxa valgum due to muscle imbalance; hip dislocation; excessive medial femoral torsion (anteversion); osteochondrodystrophies (dwarfing syndromes); Perthes disease; SCFE
Associated conditions	Cerebral palsy; myelomeningocele, neuromyopathies; congenital hip dislocation; occasionally, hypothyroidism as a cause of SCFE

Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, see p. 1389.](#)

Suggested Readings

1. Beauchesne R, Miller F, Moseley C: Proximal femoral osteotomy using the AO fixed-angle blade plate. *J Pediatr Orthop* 1992; 12(6):735–40.
2. Hau R, Dickens DR, Nattrass GR, et al: Which implant for proximal femoral osteotomy in children? A comparison of the AO (ASIF) 90 degree fixed-angle blade plate and the Richards intermediate hip screw. *J Pediatr Orthop* 2000;20(3):336–43.
3. Kramer WG, Craig WA, Noel S: Compensating osteotomy at the base of the femoral neck for slipped capital femoral epiphysis. *J Bone Joint Surg* 1976;58(6):796–800.
4. Morrissy RT: *Atlas of Pediatric Orthopaedic Surgery*. JB Lippincott, Philadelphia: 1992, 264–304.
5. Raney EM, Grogan DP, Hurley ME, et al: The role of proximal femoral valgus osteotomy in Legg-Calve-Perthes disease. *Orthopedics* 2002;25(5):513–17.
6. Southwick WO: Osteotomy through the lesser trochanter for slipped capital femoral epiphysis. *J Bone Joint Surg* 1967;49 (5):807–35.

Epiphysiodesis

Surgical Considerations

Description: Epiphysiodesis is performed in skeletally immature adolescents to eliminate or retard growth of the longer limb in cases of leg-length discrepancy (anisomelia). The timing of the procedure is critical, based on the child's bone age and discrepancy,

which are plotted on a graph or computer program. The procedure is most commonly performed through small incisions (1") about the knee, centered on the growth plate (physis) of the distal femur or proximal tibia. The original **Phemister technique** ([Fig. 12.7-13](#)) is an approach in which a $\frac{3}{4}$ – $1\frac{1}{4}$ square or rectangular block of bone is removed using a box chisel centered on the physis, visualized directly. The bone block is rotated 90° or 180° and reinserted, causing a bony bridge across the physis. **Blount** subsequently used stout, reinforced staples to bracket the physis and “lock it.” This provides a theoretical advantage of reversibility (i.e., if staples are removed, growth may resume if the procedure was performed at too early an age). More recently, a **percutaneous technique** of simply drilling directly across the cartilaginous physeal growth plate, causing a bony bridge, has been used. This is accomplished through small stab incisions, under fluoroscopic control.

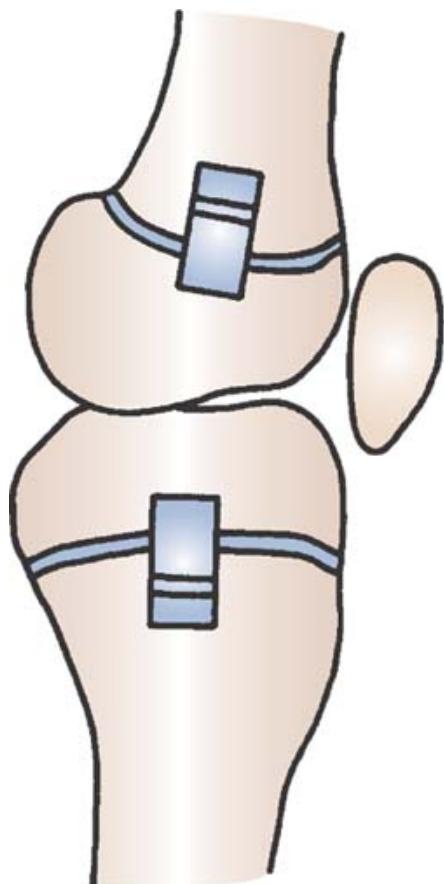


Figure 12.7-13. 13. Phemister method of epiphysiodesis (block of bone reversed, then reinserted to form osseous bar). (Reproduced with permission from Chapman MW: *Chapman's Orthopaedic Surgery*, 3rd edition. Lippincott Williams & Wilkins, Philadelphia: 2001.)

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Usual preop diagnosis: Limb-length discrepancies of 2–5 cm in adolescents (willing to accept a slight diminution in adult stature)

Summary of Procedures

	Open Epiphysiodesis	Percutaneous Epiphysiodesis	Epiphyseal Stapling
Position	Supine, with tourniquet	Supine	Supine, with tourniquet
Incision	3–4 cm longitudinal incision, medial and laterally centered incisions over distal femoral and/or proximal tibial epiphysis	1 cm, same area as open epiphysiodesis	4–5 cm, same area as open epiphysiodesis
Special instrumentation	Box chisel	Drill point and sleeve	Heavy, reinforced staples
Unique considerations	Tourniquet used	I.I. control mandatory; tourniquet (optional)	
Antibiotics	± Cefazolin 25 mg/kg iv		



Surgical time	1 h		
Closing considerations	Cylinder cast or knee immobilizer		
EBL	< 50 mL		
Postop care	PACU → room; crutches for comfort		
Mortality	Minimal		
	Under- or overcorrection with regard to length: 5–10%		
	Wound problems: < 5%		
	Asymmetric growth arrest → valgus or varus deformity: 2–5%		
Morbidity	Anterior or lateral compartment syndrome: 1 %	—	—
	Fracture: 1 %	—	—
	Peroneal palsy: < 1 %	—	—
Pain score	3–5	2–3	3–5

Patient Population Characteristics

Age range	9–14 yr (adolescents, usually healthy with limb-length discrepancy 2–6 cm)
Male:Female	1:1
Incidence	< 1/1,000
Etiology	Idiopathic hemihypertrophy; neurologic (e.g., polio, hemiplegia); congenital deformities of the lower extremities (e.g., congenitally short femur, fibular hemimelia); osteomyelitis; development of tumorous conditions (e.g., enchondromatosis); traumatic growth plate injuries occurring near puberty; epiphyseal problems related to hip (slipped epiphysis, sequelae of Perthes disease); Klippel-Trenaunay-Weber syndrome
Associated conditions	Other contractures in neurologic conditions (e.g., polio); neurofibromatosis, AV fistulae; Wilms' tumor (rare)

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~ Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, see p. 1389.](#)

Suggested Readings

1. Blair VP III, Walker SJ, Sheridan JJ, et al: Epiphysiodesis: a problem of timing. *J Pediatr Orthop* 1982;2(3):281–4.
2. Blount WP, Clarke GR: Control of bone growth by epiphyseal stapling. *J Bone Joint Surg* 1949;31:464–78.
3. Bowen JR, Torres RR, Forlin E: Partial epiphysiodesis to address genu varum or genu valgum. *J Pediatr Orthop* 1992;12(3):359–64.
4. Johnston CE II, Beuche MJ, Williamson B, et al: Epiphysiodesis for management of lower limb deformities. *Instr Course Lect*

1992;41:437–44.

5. Kemnitz S, Moens P, Fabry G: Percutaneous epiphysiodesis for leg length discrepancy. *J Pediatr Orthop* 2003;12(1):69–71.
6. Liotta FJ, Ambrose TA II, Eilert RE: Fluoroscopic technique vs Phemister technique for epiphysiodesis. *J Pediatr Orthop* 1992; 12(2):248–51.
7. Moseley CF: A straight line graft for leg length discrepancies. *Clin Orthop* 1978;136:33–40.
8. Phemister DB: Operative arrestment of longitudinal growth of bones in the treatment of deformities. *J Bone Joint Surg* 1933; 15:1–15.
9. Scott AC, Urquhart BA, Cain TE: Percutaneous vs modified Phemister epiphysiodesis of the lower extremity. *Orthopedics* 1996;19(10):857–61.
10. Waseem M, Fischer J, Paton RW. Partial percutaneous epiphyseodesis in patients with congenital abnormalities of the growth plates. *J Pediatr Orthop B* 2004;13:39–42.

Sofield Procedure

Surgical Considerations

Description: The **Sofield procedure**, or “**fragmentation rodding**,” is most commonly performed for deformity of the long bone, and to prevent recurrent fracture, usually a result of osteogenesis imperfecta. The procedure involves exposure of at least one end and a varying amount of the bony shaft. If the deformity is severe, the entire shaft is exposed via a longitudinal incision, usually laterally. The bone is divided (osteotomized) into the minimum number of segments that will allow a straight intramedullary rod to traverse the segments (usually 2–4 osteotomies). The construct is justly referred to as a “shish kebab.” It is needed less frequently in the upper extremities.

Variant procedure or approaches: Because a growing bone will elongate beyond the end of a simple intramedullary rod after 1–2 years, the resulting unsupported portion of the bone will be liable to fracture or new deformity. To obviate this problem, **Bailey** and **Dubow** developed an **elongating rod system**, consisting of an outer tubular rod sleeve (the female portion) and an inner obturator portion (male). Both ends of the telescoping rod are anchored in the ends of the bones. The system elongates much like a car radio antenna and decreases the need for frequent revisions. The surgical technique is, however, identical to any fragmentation rodding, except that both ends of the bone must be exposed.

Usual preop diagnosis: Osteogenesis imperfecta; fibrous dysplasia (occasionally); rickets; congenital pseudarthrosis of the tibia

Summary of Procedures

Position	Supine
Incision	Lateral for femur; anterolateral for tibia
Special instrumentation	± fluoroscopy (I.I.) table
Unique considerations	Tendency to hyperthermia; other bones may fracture in more severe cases, even as a result of a BP cuff. If dentinogenesis imperfecta is present, extreme care should be taken during intubation to prevent tooth trauma. In these patients, neck motion is often limited.
Antibiotics	Cefazolin 25 mg/kg iv
Surgical time	1–1.5 h/tibia; 1.5–2.5 h/femur (often done sequentially on the same day)



Closing considerations

EBL

Postop care

Mortality

Morbidity

Pain score

Double spica cast if femur is rodded.

Depending on patient age and size, as well as use of a tourniquet for the femur, 50–250 mL; for the tibia, 50–100 mL
PACU → room; avoid trauma to teeth, mouth, or other bones in PACU.

< 1% (usually related to severe restrictive lung disease, in the most severely involved cases)

Intraop hyperthermia: common

Intraop fracture of other bones or teeth

Late rod migration: common

Late refracture: common

Nonunion: rare

Exuberant callus simulating osteosarcoma: rare

Infection: < 1% of rodding

Radial nerve palsy (in cases of humerus or radius rodding)

2–3 (It is surprising how little discomfort these children have, especially the 2nd or 3rd time a bone is rodded.)

(Print pagebreak 1379)

Patient Population Characteristics

Age range

2–25 yr

Male:Female

1:1

Incidence

1/20,000 (osteogenesis imperfecta); other etiologies much less common

Etiology

Congenital (hereditary deficit in collagen synthesis), most commonly as autosomal dominant or spontaneous mutation:
All cases

Dentinogenesis imperfecta; diminished vital capacity due to associated kyphoscoliosis ↓ hearing due to otosclerosis and impingement of the 8th cranial nerve; pelvic distortion causing chronic constipation; basilar impression and other C-spine abnormalities causing brain stem compression or even hydrocephalus (rare)

Associated conditions

Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, see p. 1389](#).

Suggested Readings

1. Bailey RW, Dubow HE: Evolution of the concept of an extensible nail accommodating to normal longitudinal bone growth: clinical considerations and implications. *Clin Orthop* 1981;159:157–70.
2. Gamble JG, Strudwick WJ, Rinsky LA, et al: Complications of intramedullary rods in osteogenesis imperfecta: Bailey-Dubow rods versus non-elongating rods. *J Pediatr Orthop* 1988;8(6):645–9.
3. Marafioti RL, Westin GW: Elongating intramedullary rods in the treatment of osteogenesis imperfecta. *J Bone Joint Surg* 1977; 59(4):467–72.
4. Peluso A, Cerullo M: Malignant hyperthermia susceptibility in patients with osteogenesis imperfecta. *Paediatr Anaesth* 1995;5



(6):398–9.

5. Pozo JL, Crockard HA, Ransford AO: Basilar impression in osteogenesis imperfecta. A report of three cases in one family. *J Bone Joint Surg* 1984;66(2):233–8.
6. Rodriguez RP, Bailey RW: Internal fixation of the femur in patients with osteogenesis imperfecta. *Clin Orthop* 1988;159:126–33.
7. Sofield HA, Millar EA: Fragmentation, realignment and intramedullary rod fixation of deformities of the long bones in children. A ten-year appraisal. *J Bone Joint Surg* 1959;41:1371–91.
(Print pagebreak 1380)
8. Stockley I, Bell MJ, Sharrad WJ: The role of expanding intramedullary rods in osteogenesis imperfecta. *J Bone Joint Surg* 1989;71(3):422–7.
9. Wilkinson JM, Scott BW, Clarke AM, et al: Surgical stabilization of the lower limb in osteogenesis imperfecta using the Sheffield Telescopic Intramedullary Rod System. *J Bone Joint Surg* 1998;80(6):999–1004.

Limb Lengthening

Surgical Considerations

Description: Limb lengthening usually is performed in the lower extremity for congenital or acquired leg-length discrepancies of at least 5 cm. Lesser discrepancies are dealt with by bone shortening or epiphysiodesis of the long side. The basic principles include: (a) application of an adjustable, external fixator; (b) “low-energy,” transverse bone cut (osteotomy without use of a power saw) through a small, longitudinal incision over the involved bone; (c) preservation of the periosteal sleeve; (d) gradual lengthening, usually 1 mm/day in fractional adjustments; and (e) when the desired limb length is obtained, either use bone graft and plate acutely or leave until the bone gap fills in and stabilizes (average 38 d/cm gained).

Limb lengthening dates back to the early 1900s, but it fell into disfavor because of the high rate of major complications. **Wagner** improved the technique by introducing a simplified, unilateral, large-pin fixator, but performed the osteotomy in the midshaft and began lengthening immediately ([Fig. 12.7-14](#)). This technique usually requires a bone graft and later plating as a second operation to obtain healing. **DeBastiani** uses a similar large-pin fixator (**Orthofix**), but performs the osteotomy more toward the end of the bone (metaphysis) and waits a week before beginning the lengthening. Spontaneous healing is usual. **Ilizarov** introduced a more complex, but more adaptable, small-pin transfixation system with a circular fixator. In a similar fashion, the Ilizarov method stretches the healing callus (callotasis). Typically, 4–10 cm/bone are gained with any of the above techniques.

Usual preop diagnosis: Congenital or acquired anisomelia (limb-length discrepancy) due to overgrowth or growth retardation > 5 cm.

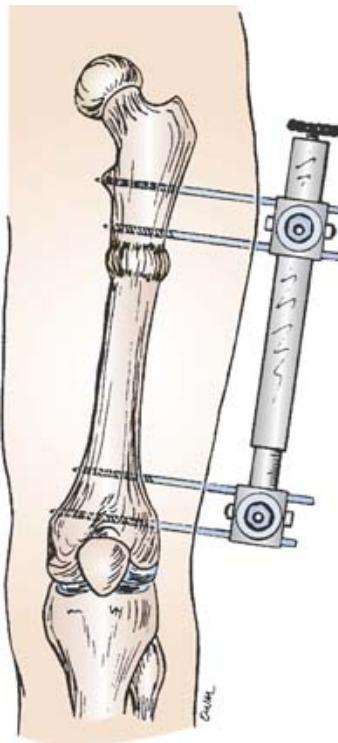


Figure 12.7-14. 14. Wagner apparatus for leg lengthening. (Reproduced with permission from Chapman MW, ed: *Operative Orthopaedics*, 2nd edition. JB Lippincott, Philadelphia: 1993.)

Summary of Procedures

	Wagner	Orthofix	Ilizarov
Position	Supine		
Incision	Longitudinal midshaft	Longitudinal proximal shaft (metaphyseal)	
Special instrumentation	I.I.; Wagner device (Fig. 12.7-13); large bone pins	I.I.; Orthofix device; large bone pins	Ilizarov frame (“Erector set”); multiple 1.5–1.8 mm small-diameter wires
Unique considerations	Acute lengthening may cause ↑ BP.	—	Frame should be prepped prior to surgery because of “fiddle factor.”
Antibiotics	Cefazolin 25 mg/kg iv		
Surgical time	1–2 h		
EBL	< 100 mL		
Postop care	PACU → room; early initiation of physical therapy and/or CPM machine		
Mortality	Minimal While the device remains in place, at least one of the following complications is usual; frequently, several occur before healing is complete: <ul style="list-style-type: none">• Joint stiffness or localized pin infection: Very common (50% temporary)• Edema, swelling, pressure sores: Common		

Morbidity	<ul style="list-style-type: none">•Joint subluxation: Common•Psychological decompensation due to pain: Common•Premature consolidation: Common•Skin necrosis: Common•Wound infection: Common•Localized osteomyelitis: Common•Axial deviation of the bone: Common•Delayed union, nonunion, late fracture: Common•Pin penetration of a vessel or nerve: Rare•Compartment syndrome: Rare Sudeck's atrophy: Rare		
Pain score	7–8	7–8	7–8

(Print pagebreak 1381)

Patient Population Characteristics

Age range	10–30 yr
Male:Female	1:1
Incidence	Dependent on underlying Dx (common in polio) Congenital deficiencies of the lower extremities (e.g., proximal focal femoral deficiency, congenitally short femur, fibular hemimelia, etc.); osteomyelitis, traumatic growth plate injury, fracture; asymmetric neurologic conditions (e.g., polio or cerebral palsy); congenital hemihypertrophy
Etiology	Hip and knee contractures; in cases of polio, other deformities, and weaknesses; AVM; congenital or developmental hip dislocation
Associated conditions	

(Print pagebreak 1382)

Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, p. 1389.](#)

Suggested Readings

1. Abbott LC: The operative lengthening of the tibia and fibula. *J Bone Joint Surg* 1927;9:128–52.
2. Aronson J: Limb-lengthening, skeletal reconstruction, and bone transport with the Ilizarov method. *J Bone Joint Surg* 1997;79(8):1243–58.
3. DeBastiani G, Aldegheai R, Renzi-Briviol, et al: Limb lengthening by callus distraction (callotasis). *J Pediatr Orthop* 1987;7(2):129–34.



4. Friend L, Widmann RF: Advances in management of limb length discrepancy and lower limb deformity. *Curr Opin Pediatr* 2008;20(1):46–51.
5. Murray JH, Fitch RD: Distraction histiogenesis: principles and indications. *J Am Acad Orthop Surg* 1996;4(6):317–27.
6. Noonan KJ, Leyes M, Forriol F, et al: Distraction osteogenesis of the lower extremity with use of monolateral external fixation. A study of two hundred and sixty-one femora and tibiae. *J Bone Joint Surg* 1998;80(6):793–806.
7. Wagner H: Operative lengthening of the femur. *Clin Orthop* 1978;136:125–42.

Patellar Realignment

Surgical Considerations

Description: Patellar realignment encompasses over 100 procedures designed to prevent lateral subluxation and dislocation of the patella. These disorders include a spectrum of malalignments of the patella, ranging from simple excess lateral tilt, recurrent partial subluxation, and recurrent episodic dislocation, to irreducible chronic dislocation. As such, the surgical procedures also encompass a spectrum of complexities, depending on the degree of instability. Nowadays, an arthroscopic inspection often is performed first. The basic principles of the repair include both proximal and distal realignment. **Proximal realignment** includes: (a) lateral release, which is the division of the contracted lateral patellar retinacular joint capsule and other tight lateral tissue—the first step in all surgical repair; (b) medial tightening, including reefing and/or advancement of the medial capsule and vastus medialis muscle insertion; and (c) distal realignment, consisting of redirection of the patellar tendon more medially (and sometimes more anteriorly).

Variant procedure or approaches: **Arthroscopic or open lateral release** is the simplest and first-step procedure. It may be sufficient when there is only subluxation and not true dislocation; and it has the advantage of being an outpatient procedure. For frank dislocation, an open “proximal realignment” also includes the medial tautening. If this is not sufficient to hold the patella centralized and if the patient has open epiphyses (< 16 yr), the lateral half of the patellar tendon may be released (distal realignment) and reattached medially (**Roux-Goldthwait**) or the patella may be held medially by tenodesing the semitendinosus tendon to it. In skeletally mature patients, the bony insertion of the patellar tendon is osteotomized and transferred medially (**Trillat**) or anteriomedially (**Macquet**). The **Hauser procedure** of distal and medial transfer of the tibial tubercle has had a very poor long-term outcome and is seldom performed.

Usual preop diagnosis: Lateral patellar subluxation; recurrent dislocation; congenital or chronic lateral patellar dislocation

Summary of Procedures

	Proximal Realignment	Trillat	Macquet
Position	Supine, with tourniquet		
Incision	Anterior transverse or longitudinal or oblique, about the knee, or arthroscopic	Anterior longitudinal	Transverse or oblique
Special instrumentation	None	Single bone screw	
Unique considerations	Tourniquet		May use iliac or bank bone graft.
Antibiotics	Optional, cefazolin 25 mg/kg iv	Usually, cefazolin 25 mg/kg iv	
Surgical time	1.5 h	1–2 h	
Closing considerations	Cylinder cast		Skin closure may be difficult, depending on elevation of tibial tubercle.
Postop care	PACU → home, if arthroscopic	PACU → room	

EBL	< 100 mL		
Mortality	Minimal		
	Recurrence: 5–10%		
	Late stiffness or ↑ knee pain: 5%		
	Superficial wound dehiscence or infection: ≥ 5%	<5%	≤5%
Morbidity	Anterior compartment syndrome of the leg (Hauser procedure): 1–5%		
	Deep infection: 1–2%		
	Peroneal palsy: < 1%		
Pain score	4–6	4–6	4–6

(Print pagebreak 1383)

Patient Population Characteristics

Age range	2–20 yr (most commonly, 13–20 yr)
Male:Female	1:3
Incidence	Subluxation: Very common Recurrent dislocation: Rare Congenital dislocation: Very rare
Etiology	Generalized ligamentous laxity; familial tendency; congenital hypoplasia at a lateral femoral condyle; abnormal attachment or contracture of the IT band; medial femoral torsion or genu valgum; trauma
Associated conditions	Diffuse hyperlaxity syndromes (Ehlers-Danlos, Marfan, etc.); nail patella syndrome (hypoplastic nails and dislocated radial heads, as well as hypoplastic patellae)

■ Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, see p. 1389.](#)

Suggested Readings

1. Baker RH, Carroll N, Dewar FP, et al: The semitendinosus tenodesis for recurrent dislocation of the patella. *J Bone Joint Surg* 1972;54(l):103–9.
 2. Chrisman OD, Snook GA, Wilson TC: A long-term prospective study of the Hauser and Roux-Goldthwait procedures for recurrent patellar dislocation. *Clin Orthop* 1979;144:27–30.
 3. Cox JS: Evaluation of the Roux-Elmslie-Trillat procedure for knee extensor realignment. *Am J Sports Med* 1982;10(5):303–10.
- (Print pagebreak 1384)
4. Fondren FB, Goldner JL, Bassett FH III: Recurrent dislocation of the patella treated by the modified Roux-Goldthwait procedure. A prospective study of forty-seven knees. *J Bone Joint Surg* 1985;67(7):993–1005.
 5. Hughston J, Walsh WM: Proximal and distal reconstruction of the extensor mechanism for patellar subluxation. *Clin Orthop* 1979;144:36–42.



6. Maquet P: Mechanics and osteoarthritis of the patellofemoral joint. *Clin Orthop* 1979;144:70–3.
7. Morrissey RT: *Atlas of Pediatric Orthopaedic Surgery*. JB Lippincott, Philadelphia: 1992, 425–38.
8. Mulford JS, Wakeley CJ, Eldridge JD: Assessment and management of chronic patellofemoral instability. *J Bone Joint Surg Br* 2007;89(6):709–16.
9. Tachdjian MO: *Pediatric Orthopaedics*. WB Saunders, Philadelphia: 1990, 1551–95.
10. Trillat A, DeJour H, Louette A: Diagnostic et traitement des subluxations récidivantes de la rotule. *Rev Chir Orthop* 1964; 50:813–24.
11. Wall JJ: Compartment syndrome as a complication of the Hauser procedure. *J Bone Joint Surg* 1979;61(2):185–91.

Tendon Transfer, Lengthening (Posterior Tibial)

Surgical Considerations

Description: Extremity tendons may be lengthened (for contracture) or transferred to change the muscle force vector and compensate for paralysis or paresis of other muscle groups. Originally used for the treatment of poliomyelitis sequelae, these lengthenings and transfers are now used for a variety of deformities 2° more common neuromuscular disorders, such as cerebral palsy, muscular dystrophies, Charcot-Marie-Tooth disease, traumatic nerve palsies, etc. Basic principles are that the muscles to be transferred should be at least grade 4/5 strength, and that the loss of normal function should be well compensated. The posterior tibial muscle (PTM) is a representative example, but many extremity muscles have one or more described lengthenings or transfers. Such procedures frequently are combined with other transfers or fusions.

For moderate spastic ankle varus, the simplest procedure, **PTM lengthening**, is accomplished by an intramuscular myotendinous “slide.” This refers to simply cutting the tendinous fibers well within the distal muscle belly and leaving a small gap in the tendon, while the surrounding muscle fibers remain intact. An alternative for spastic varus is the **split posterior tibial transfer** of the PTM. Four short, 2–3-cm incisions are used to expose and dissect half of the posterior tibia tendon at its insertion on the navicular. Then half of the tendon is passed proximally up its sheath to a second incision just posterior to the distal tibial shaft medially. The freed half tendon is passed laterally to the peroneal tendon sheath just distal to the lateral malleolus, where, through a final incision, the tendon is anastomosed to the peroneus brevis.

For complete flaccid foot drop (e.g., peroneal nerve palsy), the entire posterior tibial tendon is transferred. First, it is detached at its medial insertion, delivered proximally at the distal tibia posteriorly, passed **anteriorly** through a window in the interosseous membrane, and then subcutaneously passed to the mid-dorsal surface of the foot, where it is fixed into the middle cuneiform by a pull-out stitch.

Usual preop diagnosis: Flaccid or spastic developmental deformity, such as varus or valgus foot neuromuscular disease

Summary of Procedures

	Lengthening	Split Transfer	Anterior Transfer
Position	Supine		
Incision	Longitudinal posteromedial calf	Medial foot; posteromedial calf; lateral ankle; lateral foot	Medial foot; posteromedial calf; anterior ankle; dorsal foot
Special instrumentation	None	Tendon passer	Pull-out suture; buttons
Unique considerations	Underlying neurologic disease. Usually added to other procedures (e.g., Achilles tendon lengthenings).		



Antibiotics	Usually none	
Surgical time	30 min	1 h
Closing considerations	Below-knee cast	
EBL	< 20 mL	< 50 mL
Postop care	PACU or room	
Mortality	Rare	
Morbidity	Over- or undercorrection Hematoma Drainage: < 1%	
Pain score	1–3	3–4
		3–4

(Print pagebreak 1385)

Patient Population Characteristics

Age range	3–30 yr
Male:Female	1:1
Incidence	Dependent on Dx
Etiology	Poliomyelitis; cerebral palsy, spina bifida; traumatic peroneal nerve injury; neuropathies, myopathies (e.g., Charcot-Marie-Tooth disease)
Associated conditions	Multiple other contractures

Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, see p. 1389.](#)

Suggested Readings

1. Barnes MJ, Herring JA: Combined split anterior tibial-tendon transfer and intramuscular lengthening of the posterior tibial tendon. Results in patients who have a varus deformity of the foot due to spastic cerebral palsy. *J Bone Joint Surg* 1991;73(5):734–8.
2. Green NE, Griffin PP, Shiavi R: Split posterior tibial-tendon transfers in spastic cerebral palsy. *J Bone Joint Surg* 1983;65(6):748–54.
3. Greene WB: Cerebral palsy. Evaluation and management of equinus and equinovarus deformities. *Foot Ankle Clin* 2000;5(2):265–80.
4. Hoffer MD, Barakat G, Koffman M: 10-year follow-up of split anterior tibial tendon transfer in cerebral palsied patients with spastic equinovarus deformity. *J Pediatr Orthop* 1985;5(4):432–4.
5. Miller G, Hsu JD, Hoffer MM, et al: Posterior tibial tendon transfer: a review of the literature and analysis of 74 procedures. *J Pediatr Orthop* 1982;2(4):363–70.
6. Morrissey RT: *Atlas of Pediatric Orthopaedic Surgery*. JB Lippincott, Philadelphia: 1992, 645–68.
7. Richards BM: Interosseous transfer of tibialis posterior for common peroneal nerve palsy. *J Bone Joint Surg* 1989;71(5):834–7.
8. Rinsky LA: Surgery for cerebral palsy. In *Chapman's Orthopaedic Surgery*, 3rd edition. Chapman MW, ed. Lippincott Williams

& Wilkins, Philadelphia: 2001, 4485–504.

9. Woo R: Spasticity: Orthopedic perspective. *J Child Neurol* 2001;16(1):47–53.

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Triple Arthrodesis and Grice Procedure (Extra-Articular Subtalar Arthrodesis)

Surgical Considerations

Description: Triple arthrodesis is used to realign the hind foot of skeletally mature patients with significant fixed or flexible deformities of multiple etiologies. The technique involves denuding the cartilaginous surfaces of the talonavicular, talocalcaneal (subtalar), and calcaneocuboid joints and fusing them. The approach is always through an oblique lateral sinus tarsi incision and often an additional short medial incision over the talonavicular joint. For supple (passively correctable) deformities, the fusion is performed easily in situ. Fixed deformities are more difficult; but, basically, any deformity (valgus, varus, planus, cavus, etc.) can be corrected by resecting appropriate wedges of bone. Fixation is usually internal with pins, screws, or staples, in addition to an external cast.

Variant procedure or approaches: Because the triple arthrodesis removes growth cartilage, it is unsuitable in growing children (< 12–14 yr). Grice developed an **extraarticular subtalar fusion** which can be performed as early as age 3. It is basically a block of autologous bone graft placed between the talus and the calcaneus to stabilize a valgus heel. Tibial, fibular or, preferably, iliac autologous graft is used through the same lateral sinus tarsi incision as for a triple arthrodesis.

Usual preop diagnosis: Varus or cavovarus foot deformities; severe valgus or equinovalgus

Summary of Procedures

	Triple Arthrodesis	Grice Procedure
Position	Supine, slightly tilted up on the operative side	
Incision	2 oblique over the sinus tarsi; optional medial incision	
Special instrumentation	Pins, screws, or rods	Pin or screw
Unique considerations	Intraop x-ray to confirm pin position	Iliac or tibial autologous graft
Antibiotics	Usually, cefazolin 25 mg/kg iv up to 1 gm	Cefazolin 25 mg/kg iv up to 1 gm
Surgical time	1–2 h	1.5 h
Closing considerations	Above-the-knee cast	
EBL	< 100 mL	< 50 mL
Postop care	PACU → room	
Mortality	Rare	
Morbidity	Superficial skin slough Superficial infection Nonunion of at least one arthrodesis site (usually talonavicular) Aseptic necrosis of the talus: Rare	
Pain score	6–8	4–5

Patient Population Characteristics

Age range	> 12 yr (triple arthrodesis); 3–10 yr (Grice)
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Male:Female	1:1
Incidence	< 1% (depends on diagnosis and severity of deformity) Neuromuscular imbalance (most cases); congenital malformations (e.g., coalitions, severe pes planus); incompletely treated or overcorrected clubfoot; postfracture of calcaneus or talus
Etiology	Poliomyelitis; cerebral palsy (\uparrow GERD, \downarrow airway protective reflexes, \uparrow postop pulmonary complications); myelomeningocele; Charcot-Marie-Tooth disease (\uparrow sensitivity to muscle relaxants); congenital tarsal coalition
Associated conditions	

(Print pagebreak 1387)

Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, see p. 1389.](#)

Suggested Readings

1. Dennyson WG, Fulford GE: Subtalar arthrodesis by cancellous grafts and metallic internal fixation. *J Bone Joint Surg* 1976;58(4):507–10.
2. Duncan JW, Lovell WW: Hoke triple arthrodesis. *J Bone Joint Surg* 1978;60(6):795–8.
3. Grice DS: An extra-articular arthrodesis of the subastragalar joint for correction of paralytic flat feet in children. *J Bone Joint Surg* 1952;34:927–40.
4. Mann RA, Mann JA: Arthrodesis of the foot and ankle. In *Chapman's Orthopaedic Surgery*, 3rd edition. Chapman MW, ed. Lippincott Williams & Wilkins, Philadelphia: 2001, 3057–72.
5. Morrissey RT: *Atlas of Pediatric Orthopaedic Surgery*. JB Lippincott, Philadelphia: 1992, 589–99.

Surgical Correction of Clubfoot

Surgical Considerations

Description: **Turco** popularized the one-stage surgical correction of resistant (uncorrected by casting) clubfoot (talipes equinovarus) in 1971. The orthopedic literature, however, is replete with reports of varying techniques for surgical correction of clubfoot. The three components of the deformity are: (a) hindfoot equinus (back of the heel is up); (b) varus (rolled inwardly); and (c) forefoot adductus (medial deviation). Beyond this, however, there exists considerable disagreement as to the pathologic anatomy, ideal skin incision, position, and which structures to release. Most surgeons vary the degree of release in proportion to the degree of deformity, often performing release of the same deep structures through totally different skin incisions. The most important structures released include: the entire posterior capsule of the ankle and subtalar joint; capsule of the subtalar, talonavicular, and calcaneal cuboid joints; tendo-Achilles, posterior tibial tendon, and usually the toe flexors; and origin of the abductor, hallucis, and the plantar fascia. The navicular is repositioned on the talus and usually held with a small pin.

Variant procedure or approaches: **Turco's procedure** is essentially a posteromedial procedure only and is performed through one incision on the medial aspect of the foot. **Crawford** described a much more extensile approach through an incision (**Cincinnati**) that runs from anteromedial, around the back of the tendo-Achilles, and then anterolateral to the calcaneal cuboid joint. This approach is also used by **McKay**, **Simons** and others for a more complete release. If there is severe equinus deformity, however, the incision is difficult to close posteriorly when the foot is brought up. **Carroll** accomplishes much the same correction using a separate medial and posterolateral incision.

Usual preop diagnosis: Resistant idiopathic clubfoot; secondary clubfoot due to paralysis

Summary of Procedures

	Turco	Cincinnati/McKay/Simons	Carroll
Position	Supine	Prone or supine	Supine
Incision	Straight medial foot	Transverse from the navicular bone medially posteriorly across the heel cord, then laterally to the cuboid	Medial zigzag and posterolateral longitudinal
Special instrumentation	Usually loupe magnification; small K wires to hold reduction		
Unique considerations	Tourniquet mandatory and often bilateral		
Antibiotics	Cefazolin 25 mg/kg iv		
Surgical time	1–2 h/foot		
Closing considerations	Well padded, loose-fitting, above-the-knee cast × 10–14 d		
EBL	< 30 mL		
Postop care	PACU → room		
Mortality	Rare		
	Mild, persistent deformity: very common		
	Hematoma: 2%		
	Superficial infection: 1–2%		
	Avascular necrosis		
	Overcorrection valgus, planus		
Morbidity	Pressure changes of the navicula		
	Wound dehiscence or necrosis		
	Transection of posterior tibial nerve or artery branch: Rare (except in patients who have had multiple operations)		
Pain score	2–5	2–5	2–5

(Print pagebreak 1388)

Patient Population Characteristics

Age range	3 mo–6 yr
Male:Female	2:1 (idiopathic type)
Incidence	1.2/10,000 live births (idiopathic type)
Etiology	Genetic, or hereditary effects; neuromuscular defects of the calf muscles; primary defect of formation of the talus and/or other tarsal bones; shortened ligaments and muscles Arthrogryposis (difficult intubation; ±VSD, other CHD); Larsen's syndrome (difficult intubation, ± ↑ICP); Freeman-Sheldon syndrome (difficult intubation); osteochondral dystrophies (e.g., diastrophic dwarfism); spinal dysraphism; tethered spinal cord; congenital constricting bands; poliomyelitis
Associated conditions	

Anesthetic Considerations

See [Anesthetic Considerations for Pediatric Orthopedic Surgery of the Pelvis and Lower Extremities, see p 1389.](#)

Suggested Readings

1. Beat JH: Congenital anomalies of the lower extremity. In *Campbell's Operative Orthopaedics*, 8th edition. Crenshaw AH, ed. Mosby-Year Book, St. Louis: 1992, 2075–91.
(Print pagebreak 1389)
2. Carroll NC: Congenital clubfoot: pathoanatomy and treatment. *AAOS Instr Course Lect* 1987;36:117–21.
3. Crawford AH, Marxen JL, Osterfeld DL: The Cincinnati incision: a comprehensive approach for surgical procedures of the foot and ankle in childhood. *J Bone Joint Surg* 1982;64(9):1355–8.
4. Cummings RJ, Davidson RS, Armstrong PF, et al: Congenital clubfoot. *J Bone Joint Surg* 2002;84A(2):290–308.
5. Lichtblau S: A medial and lateral release operation for clubfoot. *J Bone Joint Surg* 1973;55(7):1377–84.
6. McKay DW: New concept of and approach to club foot treatment: section II—correction of the club foot. *J Pediatr Orthop* 1983;3(1):10–21.
7. Morrissey RT: *Atlas of Pediatric Orthopaedic Surgery*. JB Lippincott, Philadelphia: 1992, 523–8.
8. Simons GW: Complete subtalar release in clubfeet: part I—a preliminary report. *J Bone Joint Surg* 1985;67(7):1044–55.
9. Simons GW: Complete subtalar release in clubfeet: part II—comparison with less extensive procedures. *J Bone Joint Surg* 1985;67(7):1056–65.
10. Turco VJ: Resistant congenital club foot—one-stage posteromedial release with internal fixation. A follow-up report of a fifteen-year experience. *J Bone Joint Surg* 1979;61(6A):805–14.
11. Turco VJ: Surgical correction of the resistant club foot. One-stage posteromedial release with internal fixation: a preliminary report. *J Bone Joint Surg* 1971;53(3):477–97.

Anesthetic Considerations for Pediatric Orthopedic Surgery of The Pelvis and Lower Extremities

(Procedures covered: pelvic osteotomy; acetabular augmentation & Chiari osteotomy; Ober fasciotomy; Yount Ober release; hip, open reduction; adductor release and/or transfer; psoas release; pinning of SCFE; femoral osteotomy; epiphysiodesis; Sofield procedure; limb lengthening; tendon transfer or lengthening; triple arthrodesis, Grice procedure; correction of clubfoot)

Preoperative

Children undergoing orthopedic procedures of the lower extremities typically fall into two groups: (a) post-trauma but otherwise healthy, and (b) those with a variety of chronic medical problems, including cerebral palsy, congenital hip dislocation, limb deformities, osteogenesis imperfecta, juvenile rheumatoid arthritis, epidermolysis bullosa, and various myopathies and muscular dystrophies. The anesthesiologist should review the anesthetic implications of these various syndromes or diseases (see [Table 12.7-2](#)). Many of these patients will have cardiac, respiratory, endocrine, and metabolic derangements, as well as airway abnormalities that may affect anesthetic management. In addition, the surgical procedures may run the gamut from a simple syndactyly repair of the

toes with little blood loss to pelvic osteotomies (in small children) with blood loss approaching the patients blood volume. Many patients with slipped capital femoral epiphysis (SCFE) are obese and require anesthetic techniques that minimize the risk of aspiration.

Respiratory

Patient's preop activity level is a good indication for baseline respiratory function. Careful assessment is necessary as associated anomalies may affect airway or lungs. Chronic otitis 2° eustachian tube dysfunction is common. Postpone surgery (2–3 wk) if Sx of acute URI (e.g., runny nose, fever, sore throat, cough) are present.

Tests: As indicated from H&P (although PFTs are not currently recommended as a routine part of the preanesthetic evaluation of the scoliosis patient).

Some pediatric patients with congenital musculoskeletal anomalies presenting for orthopedic procedures have coexisting cardiovascular anomalies. Preop review of patient's H&P is essential. Patients should not be accepted for orthopedic surgery and anesthesia until they are in the best possible physical and emotional condition. For children with CHD or who require cardiac medication, it is advisable to consult with a pediatric cardiologist before surgery.

***NB:** The consequences of VAE may be disastrous (e.g., cerebral or myocardial embolization) in patients with R→L shunt lesions. All iv lines, injection ports, and syringes should be air-free.

Tests: EKG; Hct; baseline SaO₂; CXR, as necessary

For patients with cerebral palsy presenting for orthopedic surgery, preop understanding of their intellectual functional capacity is necessary. Information about patient's behavioral or intellectual abilities is usually best obtained from parents or guardian. If patient is on seizure-control medication, it is recommended that the medication be continued until surgery. All patients who require Ober fasciotomy or Yount release will have profound weakness of lower extremities, if not of the entire body. Must be careful in choice of muscle relaxant (generally avoid depolarizing agents). Many patients with muscular dystrophy present for repeated orthopedic procedures. Patients with congenital muscular dystrophy (especially Duchenne's or Becker's) can have significant associated cardiac dysfunction. A pediatric cardiologist should be involved in the preanesthetic evaluation of their LV function, size, LV ejection fraction, shortening fraction, and ECHO exam. It is important to note that asymptomatic carriers of these X-linked muscular dystrophies can have associated ECHO and EKG abnormalities.

Complications of blood loss remain a major anesthetic consideration in pelvic osteotomies, especially in small children or those who have ↑ bleeding 2° osteogenic bone or bleeding disorders. There is no hard-and-fast rule for an acceptable amount of blood loss before transfusion therapy begins; each case must be individualized. Patients who need ↑ O₂ carrying capacity (e.g., congenital heart disease, sickle cell anemia (SSA), evidence of V/Q mismatch from preexisting pulmonary disease) will require transfusion at lower levels of blood loss than otherwise healthy children. Blood transfusion therapy must be considered after the loss of 15–20% of the patient's total blood volume. Predonation is limited by age, size, and level of cooperation with blood-collecting techniques. Hemodilution is not used frequently in pediatrics. Cell salvaging can introduce both intracellular and surgical debris back into circulation.

Tests as indicated from H&P.

Cardiovascular

Neurological

Hematologic

Laboratory

Premedication

Premedication for separation anxiety (e.g., midazolam) and facilitating induction. Care must be taken if premedication is used in patients with respiratory or cardiac dysfunction. Dosage must be individualized (see [p. E-4](#)). Children with valvular disease, prosthetic valves, and/or most forms of CHD, as well as postcardiac-correction patients, should receive antibiotics for bacterial endocarditis prophylaxis preop.

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Table 12. 7-2. Preop Anesthesia Considerations for Pediatric Orthopedic Diseases

General Considerations	Pediatric orthopedic patients may present with a spectrum of congenital and acquired problems. Congenital malformations and deformations include clubfoot, developmental dislocation of hip, and congenital limb deficiencies. Acquired conditions include trauma, infections, and growth disturbance. A variety of patients with neuromuscular disorders present for orthopedic procedures and present special challenges to the anesthesiologist (e.g., cerebral palsy, spina bifida, muscular dystrophy). Other syndromes and chronic conditions with orthopedic manifestations include osteogenesis imperfecta, juvenile rheumatoid arthritis, and epidermolysis bullosa. The anesthesiologist should review and understand the anesthetic implications of these various syndromes.
Specific Disease	Anesthetic Considerations
Achondroplasia	± Unstable spine: preop neuro and ortho exams are critical. Careful positioning necessary; prevent compression of cervicomедullary junction by placing a bolster under shoulders. Difficult iv access. ± GERD 2° obesity. Anticipate difficult mask fit and intubation. Possible choanal stenosis/narrow nasopharynx; may preclude nasal airway/nasal intubation and placement of NG tube. Smaller ETTs are needed. ± Restrictive lung disease and chronic respiratory infections common. C-spine fusion and small nasopharynx. Hypoplastic maxilla, prominent mandible/cleft palate. Difficult laryngoscopy and ET intubation. ± Tracheal stenosis/abnormal tracheal cartilage. Possible choanal stenosis/atresia; may preclude nasal airway, nasal ETT, and NG tube placement. Difficult vascular access. ± Craniosynostosis → ↑ ICP. ± CHD.
Apert syndrome	Poor cervical mobility; TMJ ankylosis; possibility of difficult intubation. IV access and positioning difficult 2° flexion or contracture deformity. 10% incidence of CHD.
Arthrogryposis	Communication difficulties. Scoliosis → restrictive lung disease. ± GERD. ↑ sensitivity to succinylcholine. ↑ resistance to NMRs. MAC decreased. Contractures → restricted access for examination and positioning. ± Latex allergy. Difficult iv access.
Cerebral palsy	Poor cervical mobility; TMJ ankylosis; possibility of difficult intubation. ± Restrictive pulmonary disease. ± Restrictive pericarditis and tamponade.
Juvenile rheumatoid arthritis	Limited C-Spine mobility → difficult intubation. Impaired renal drug excretion.
Klippel-Feil syndrome	Atlantoaxial instability: Evaluate C-spine before laryngoscopy. Care in positioning needed. May require larger than normal doses of spinal epidural anesthesia 2° height. Aortic dilatation → aortic insufficiency ± aortic dissection/aneurysm. Avoid → BP. Anticipate difficult intubation 2° narrow palate. Lung cysts → pneumothorax.
Marfan syndrome	

Muscular dystrophy

Possible cardiomyopathy: Avoid cardiac depressant drugs. ↑ sensitivity to muscle relaxants. MH susceptibility. ↓ gastric emptying and weak laryngeal reflexes. Avoid succinylcholine. May have MVR and cardiac conduction abnormalities. May require postop ventilation.

Myopathies

Avoid all muscle relaxants and respiratory depressants. Postop ventilation may be necessary.

Osteogenesis imperfecta

Bones fracture easily (e.g., with BP cuff): Use extreme care in positioning and intubation. Hypermetabolic fever may occur during anesthesia. Plt dysfunction: Difficult airway. Use atropine with caution as it may exacerbate pyrexia. CHD may require antibiotic prophylaxis. ± Difficult airway. ± Restrictive lung disease. Deafness may make communication difficult.

Septic arthritis

Infection/systemic toxicity slows gastric emptying; requires rapid-sequence intubation ([Appendix B-4](#)). Dehydration 2° ↑ T and ↓ fluid intake → hypovolemia/hemodynamic instability. Rx: adequate fluid resuscitation with balanced salt solution.

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Intraoperative

Anesthetic technique: As indicated in the preop considerations, these patient populations cover a vast spectrum, from fit and healthy children to those suffering from a variety of clinical syndromes with airway and cardiorespiratory problems. Thus, anesthesia needs to be tailored to the individual patient. Some older children may benefit from regional anesthesia with sedation. Some may do well with a combined regional/GA technique, whereas still others with difficult airways may require awake FOB (see [p. B-5](#)). The following sections address some of these concerns.

Otherwise healthy: Standard pediatric (< 12 yr) (see [p. D-1](#)) or adult induction (see [p. B-2](#)). **Difficult airway:** A mask induction and FOL during spontaneous respiration should be considered. Alternatives include use of LMA/intubating LMA, FOL or light wand stylet, retrograde wire intubation, and tracheostomy.

Muscle abnormalities: These patients may be very sensitive to muscle relaxants, have gastric hypomotility, and may be predisposed to MH. Induction should be accomplished by nontriggering agents (e.g., propofol 1–2 mg/kg and rocuronium 0.5–1 mg/kg) if necessary for intubation. Succinylcholine usually is contraindicated in these patients. Dantrolene must be available, but it need not be administered prophylactically. A study of MH patients showed that 32 out of 89 had preexisting musculoskeletal abnormalities.

Cardiorespiratory compromise: Inhalational induction, when administered cautiously, may be used safely in this group of patients. Intramuscular (e.g., ketamine 4–8 mg/kg im) inductions are usually safe and effective in neonates and infants with severe cardiac disease.

Otherwise healthy: Standard pediatric maintenance (see [p. D-3](#)). **Muscle abnormalities:** Maintenance of anesthesia with a nontriggering agent (e.g., N₂O, opiates) and short-acting NMRs is prudent. A peripheral nerve stimulator should be used to monitor muscle relaxation, as the effects of muscle relaxants may be unexpectedly prolonged.

Cardiorespiratory compromise: The maintenance of anesthesia in this group most commonly is accomplished by use of inhalational agents, additional narcotics, or other iv agents, depending on patient tolerance and postop plans for ventilatory management.

Induction

Maintenance

Emergence

Otherwise healthy: If a muscle relaxant is used, reverse with neostigmine (0.07 mg/kg) and glycopyrrolate (0.01 mg/kg iv) or edrophonium (0.5 mg/kg) and atropine (0.015 mg/kg iv). Make sure patient is awake and able to protect airway. A vital capacity of >15 mL/kg is considered an adequate sign of recovery of respiratory reserve.

Muscle abnormalities: Anticipate postop respiratory impairment. Suction airway carefully. The response to neostigmine is unpredictable and may precipitate myotonia. Continued postop mechanical ventilation may be required.

Cardiorespiratory compromise: Tourniquet release may cause significant. ↓ CO and ↓ BP, requiring temporary inotropic support. Otherwise, emergence as in normal patients.

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Regional anesthesia: Used in patients undergoing lower extremity surgery.

In young children, the epidural space can be reached easily by the caudal epidural approach, with less risk of dural puncture than with thoracic or lumbar epidural approaches. There is minimal risk of cord injury at the level of the sacrococcygeal ligament. The dural sac, however, can extend to the level of the third or fourth sacral vertebra in the newborn; therefore, care must be taken to avoid an inadvertent intrathecal injection. Bupivacaine or leobupivacaine provide reliable, long-lasting anesthesia and postop analgesia when given via the caudal epidural route. Bupivacaine 0.25% with epinephrine 1:200,000 (1 mL/kg) provides 3–6 h of analgesia for all procedures below the umbilicus. In infants (< 2.5 kg), a more dilute solution is used (0.125% or 0.175%) and the volume can be increased to remain below the toxic dose range (2.5 mg/kg). Intraop anesthesia with bupivacaine 0.25% with epinephrine 1:200,000 is given as a bolus with volumes determined by level desired (0.05 mL/kg/segment, not to exceed 1 mL/kg). Preservative-free clonidine (1–2 mcg/kg) as an additive to bupivacaine caudal anesthesia has been shown to increase the efficacy and duration of the analgesia.

Use bupivacaine 0.1–0.125% at rate of 0.1 mL/kg/h in patients < 5 yr; thereafter, patients may require 0.05–0.15 mL/kg/h.

Use of ultrasonography helps to improve the efficacy and safety of these blocks. Femoral, obturator and lateral cutaneous nerve of thigh can be blocked by doing a lumbar plexus block at the level of the L4 vertebra or by doing a 3-in-1 block at the groin. Sciatic nerve can be blocked in the posterior thigh at the apex of the popliteal fossa. If used in combination, these blocks can provide excellent post-operative analgesia for most of the lower limb procedures with minimal side effects. Catheters can be left in place for providing continuous post-operative analgesia. With the availability of safer and less expensive programmable pumps, most of the blocks can be done even for outpatient procedures and the children can be sent home on these pumps.

There may be rapid fluid shifts in pediatric patients undergoing orthopedic procedures. Close monitoring and adequate fluid replacement will ensure hemodynamic stability. In hip or pelvis surgery, blood loss may be substantial, and adequate iv access is important as blood transfusion may be required.

IV: 22 ga or greater × 1–2

Blood and fluid requirements

NS/LR

4 mL/kg/h: 0–10 kg
+ 2 mL/kg/h: 11–20 kg
+ 1 mL/kg/h: >20 kg (e.g., 25 kg = 65 mL/h)

Warm fluids for long cases.

Use of pneumatic tourniquets has become common practice in peripheral orthopedic

Control of blood loss	Tourniquet: 120-min limit	
Monitoring	Standard monitors (see p. D-1). ± Arterial line ± CVP line Temperature	procedures. They reduce intraop blood loss; however, they cause pain and, upon removal, and release products of anaerobic metabolism.
Positioning	and pad pressure points. eyes.	Most pediatric patients presenting for extremity surgery do not require invasive monitoring. An arterial or CVP line may be helpful, depending on patient's medical condition, length of surgery, and anticipated blood loss.
Complications	MH	Patients with osteogenesis imperfecta or osteoporosis are at risk for fractures and joint dislocations and require special care in positioning.

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Postoperative

Complications	MH Respiratory insufficiency	For MH considerations, see above.
Pain management	PCA Parenteral opiates Spinal/epidural opiates	(see p. E-4).

Suggested Readings

1. American Heart Association: Prevention of bacterial endocarditis. AHA Committee on Rheumatic Fever; Endocarditis and Kawasaki Disease of the Council on Cardiovascular Disease in the Young. *JAMA* 1990;264(22):2919–22.
2. Baum VC, O'Flaherty JE: *Anesthesia for Genetic, Metabolic, and Dysmorphic Syndromes of Childhood*. Lippincott Williams & Wilkins, Philadelphia: 1999.
3. Bell C, Kain Z: Acute pediatric pain management. In *The Pediatric Anesthesia Handbook*. Mosby, St. Louis: 1997.
4. Bernstein R, Rosenberg AD: *Manual of Orthopedic Anesthesia and Related Pain Syndromes*. Churchill Livingstone, New York: 1993.



5. Britt BA, Kalow W: Malignant hyperthermia: a statistical review. *Can Anaesth Soc J* 1970;17(4):293–315.
6. Brownell AK, Paasuke RT, Elash A, et al: Malignant hyperthermia in Duchenne muscular dystrophy. *Anesthesiology* 1983;58(2):180–2.
7. Brustowicz RM, Moncorgé C, Koka BV, et al: Metabolic responses to tourniquet release in children. *Anesthesiology* 1987; 67(5):792–4.
8. Ceviz N, Alehan F, Alehan D, et al: Assessment of left ventricular systolic and diastolic functions in children with merosin-positive congenital muscular dystrophy. *Int J Cardiol* 2003;87(2–3):129–33.
9. Glassman SD, Rose SM, Dimar JR, et al: The effect of postoperative nonsteroidal anti-inflammatory drug administration on spinal fusion. *Spine* 1998;23(7):834–8.
10. Grain L, Cortina-Borja M, Forfar C, et al: Cardiac abnormalities and skeletal muscle weakness in carriers of Duchenne and Becker muscular dystrophies and controls. *Neuromuscul Disord* 2001;11(2):186–91.
11. Howell TK, Patel D: Plasma paracetamol concentrations after different doses of rectal paracetamol in older children. A comparison of 1 g vs. 40 mg × kg(-1). *Anaesthesia* 2003;58(1):69–73.
12. Lemos J, Helay W: Blood transfusion on orthopedic operations. *J Bone Joint Surg* 1996;78:1260–70.
(Print pagebreak 1394)
13. Loder RT, Aronson DD, Greenfield ML: The epidemiology of bilateral slipped capital femoral epiphysis. A study of children in Michigan. *J Bone Joint Surg [Am]* 1993;75(8):1141–7.
14. Melacini P, Fanin M, Danieli GA, et al: Cardiac involvement in Becker muscular dystrophy. *J Am Coll Cardiol* 1993;22(7):1927–34.
15. Pullerits J, Holzman R: Pediatric neuraxial blockade. *J Clin Anesth* 1993;5(4):342–54.
16. Salem MR, Klowden AJ: Anesthesia for orthopedic surgery. In *Pediatric Anesthesia*, 4th edition. Gregory GA, ed. Churchill Livingstone, New York: 2001, 617–62.
17. Shimada Y, Yoshiya I, Tanaka K, et al: Crying vital capacity and maximal inspiratory pressure as clinical indicators of readiness for weaning of infants less than a year of age. *Anesthesiology* 1979;51(5):456–9.
18. Tait AR, Knight PR: The effects of general anesthesia on upper respiratory tract infections in children. *Anesthesiology* 1987;67(6):930–5.
19. Takasaki M, Dohi S, Kawabata Y, et al: Dosage of lidocaine for caudal anesthesia in infants and children. *Anesthesiology* 1977; 47(6):527–9.
20. Tetzloff JE, ed: *Clinical Orthopedic Anesthesia*. Butterworth-Henemann, Boston: 1995.
21. Wedel DJ: *Orthopaedic Anesthesia*. Churchill Livingstone, New York: 1993.
22. Wongprasartsuk P, Stevens J: Cerebral palsy and anesthesia. *Ped Anesth* 2002; 12:296–303.



Surgery for Epidermolysis Bullosa

Surgical Considerations

Description: Epidermolysis bullosa (EB) is a disabling inherited condition affecting the skin and submucosa. Recessive dystrophic EB is the most common type requiring surgical treatment. Children develop lesions associated with minimal trauma, which most commonly result in contractures of the hands and feet, mouth, and esophagus. Special care is required in handling patients with EB, because minor trauma from iv or EKG lead placement can cause severe blistering. Hand surgery typically involves opening up the contracted fingers by removing the cocoon of epidermis. The defects are grafted with full-thickness skin grafts, typically taken from the abdomen. Following sedation or anesthesia, the affected extremity is gently sponged with dilute chlorhexidine solution. A tourniquet is not applied since it is typically not required. A wrist block is administered by the surgeon. The cocoon of scar tissue is removed, the fingers manipulated to expose the defects, and a full-thickness skin graft is harvested. Generous Bactroban ointment and nonadhesive dressings are placed on the hand and a well-padded cast is applied at the end of the procedure. Adhesive tape is avoided throughout the procedure.

Usual preop diagnosis: EB

Summary of Procedures

Position	Supine
Incision	As necessary to relieve skin contractures on the hands
Antibiotics	Cefazolin 20–40 mg/kg iv up to 1 gm.
Surgical time	1–2 h. Positioning, iv placement and sedation/anesthesia are time-consuming, often longer than the procedure itself.
EBL	< 100 mL
Postop care	PACU → home. Return in 2 wk for intraop removal of cast, dressing change, and first splint application. Splinting and special gloves are the mainstay of postop treatment.
Mortality	None associated with procedure
Morbidity	Trauma from positioning and monitoring → new blisters
Pain score	7–9 (similar to 2nd-degree burns)

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Patient Population Characteristics

Age range	1–20 yr; older patients with precancerous or cancerous hand lesions
Male:Female	2–3:1
Incidence	Extremely rare
Etiology	Inherited
Associated conditions	Malnutrition; esophageal strictures; generalized skin contractures; malignant transformation of skin lesions

Anesthetic Considerations

Preoperative

EB is a heterogenous group of rare hereditary disorders characterized by blister formation in the skin in response to minor trauma, friction, or pressure. The most minor form of EB is EB simplex, in which the blisters heal without scarring. The junctional form often is diagnosed at birth, with blisters caused by the physical trauma of delivery. These patients develop severe scarring and have



a short life expectancy. Patients with the recessive dystrophic form may have strictures of the oropharynx, larynx, and esophagus. Patients may be on long-term corticosteroid treatment. Periop hydrocortisone treatment may be required to compensate for adrenal suppression.

Airway

A careful airway evaluation is essential, since these patients may have a difficult airway 2° mucous membrane and skin involvement in the area of the oropharynx, face, and neck. Patients with EB also may have limited mouth opening and neck movement as the result of scarring and contractures. Poor dentition: for loose teeth.

Skin

Because of the fragility of skin and mucous membranes in patients with EB, the anesthetic plan should be designed to prevent even the slightest trauma to skin and mucous membranes. The most common sites of involvement are the oropharynx, esophagus, and anus. Dysphagia, esophageal stricture and constipation are common, and are the major causes of morbidity, nutritional deficiencies, and growth retardation. Esophageal dilatation, insertion of NG feeding tubes, gastrostomy, and colonic interposition have been performed in patients with EB. Esophageal stricture increases the risk of regurgitation and aspiration, and precautions to avoid aspiration should be taken. Skin lesions can be painful, and some patients will be on chronic opiate medication for pain management.

Gastrointestinal

Chronic blood loss from denuded skin can → anemia and hypoalbuminemia.

Musculoskeletal

Tests: CBC

Other tests as indicated from H&P.

Laboratory

Adequate premedication is essential to minimize movement during induction. An orally administered combination of midazolam (0.6 mg/kg) and ketamine (3.5 mg/kg) facilitates theatraumatic placement of iv lines in the OR. Glycopyrrolate 0.01 mg/kg can be given as antisialagogue. EMLA cream can be applied without adhesive dressing.

Premedication

Intraoperative

Patients are placed on sheepskin to cushion pressure points. The following should be available: Albolene liquefying cleanser, Surg-O-Flex (flexible tubular bandage), Vaseline gauze, Zeroform, Kerlix, Webril, cotton umbilical tape, and Coban wrap. No adhesive tape is used. Adhesive portions of EKG leads and electrocautery dispersion plates are removed; the leads and plates are secured to the patient, using Webril or Surg-O-Flex. BP cuff must be applied over multiple layers of cotton padding. Carefully trim the adhesive off the pulse oximetry probe, wrap around the palm or finger, and wrap Coban around the probe. Alternatively, use adult clip-on probe. Anesthesia masks, ETTs, (*Print pagebreak 1396*) temperature probes, and all attached monitoring equipment are lubricated with Albolene. Venipuncture can be difficult, and the iv lines are secured with Vaseline gauze and Coban.

Anesthetic technique: GETA is the preferred method of anesthesia when upper airway manipulation is required or airway protection is compromised. Anticipate difficult airway. Planned FOL is safer than DL. Use smaller ETT to avoid formation of laryngeal bullae. ETT and laryngoscope blade, if used, should be well lubricated. Smaller than normal LMA has been used, with the shaft and cuff lubricated. Secure tube with umbilical tape. James, et al, reported 309 anesthetics performed on 73 patients with recessive dystrophic EB without the occurrence of laryngeal bullae, postop stridor, or "airway embarrassment." The safety of GETA, however, is not well documented in junctional EB patients, where columnar epithelium can be involved. Avoid succinylcholine 2° risk of ↑ K⁺ 2° muscle atrophy. NMRs prolong duration of action 2° ↓ muscle mass and changes in volume of distribution 2° hypoalbuminemia, which results from ill health and poor nutritional status.

IV anesthesia: Ketamine has been utilized for patients with EB undergoing surgical procedures. For iv anesthesia, use a loading dose of midazolam 0.1–0.2 mg/kg with ketamine 0.25–0.5 mg/kg, followed by a continuous infusion of ketamine (1 mg/kg/h) and midazolam (0.1 mg/kg/h). Glycopyrrolate can be used as an antisialagogue in these patients. Alternatively, propofol (50–100 mg/kg/h) with remifentanil (0.05–0.1 mg/kg/h) infusions may be used. Titrate both medications according to patient's response to the surgical stimulation.



Local anesthesia: At our institution, local anesthetic infiltration has not been associated with any serious sequelae; however, Kubota, et al, have recommended against the use of local anesthetic infiltration.

Regional anesthesia: In some patients with EB, regional anesthesia techniques allow maintenance of airway patency, involve minimal epidermal/dermal damage, and can offer prolonged postop pain relief. Brachial plexus anesthesia, epidural anesthesia, and spinal anesthesia have been used successfully in patients with EB.

Emergence

Adequate postop analgesia and parental presence in the PACU may help prevent excessive struggling and skin trauma during emergence and recovery. Plastic O₂ delivery masks should be avoided as they have sharp edges. Avoid rectal route for pain management, as it may cause perianal trauma and blistering. Acetaminophen, ketorolac, and opiates can be used for postop analgesia. PONV should be avoided by using combination antiemetic therapy. Pruritus, a common side effect of opiates, should be treated promptly.

Suggested Readings

1. Lin YC, Golianu B: Anesthesia and pain management for pediatric patients with dystrophic epidermolysis bullosa. *J Clin Anesth* 2006;18(4):268–71.
2. Borgeat A, Blumenthal S: Postoperative pain management following scoliosis surgery. *Curr Opin Anaesthesiol* 2008;21(3):313–6.
3. Broster T, Placek R, Eggers G: Epidermolysis bullosa: anesthetic management for cesarean section. *Anesth Analg* 1987;66:341–3.
4. Campiglio GL, Pajardi G, Rafanelli G: A new protocol for the treatment of hand deformities and recessive dystrophic epidermolysis bullosa (13 cases). *Ann Chir Main Memb Super* 1997;16(2):91–100, discussion 101.
5. Ergun G, Lin A, Dannenberg A, et al: Gastrointestinal manifestations of epidermolysis bullosa: a study of 101 patients. *Medicine* 1992;71(3):121–7.
6. Farber N, Troshynski T, Turco G: Spinal anesthesia in an infant with epidermolysis bullosa. *Anesthesiology* 1995;83:1364–7.
7. Herod J, Denyer J, Goldman A, et al: Epidermolysis bullosa in children: pathophysiology, anaesthesia and pain management. *Paediatr Anesth* 2002;12:388–97.
8. Iohom G, Lyons B: Anaesthesia for children with epidermolysis bullosa: a review of 20 years' experience. *EUJ Anesthesiology* 2000;18:745–54.
9. Fine JD, Johnson LB, Weiner M, et al: Tracheolaryngeal complications of inherited epidermolysis bullosa: cumulative experience of the national epidermolysis bullosa registry. *Laryngoscope* 2007;117(9):1652–60.
10. Kelly R, Koff H, Rothaus K, et al: Brachial plexus anesthesia in eight patients with recessive dystrophic epidermolysis bullosa. *Anesth Analg* 1987;66:1318–20.
11. Kubota Y, Norton M, Goldenberg S, et al: Anesthetic management of patients with epidermolysis bullosa undergoing surgery. *Anesth Analg* 1961;40(2):244–50.
12. Ladd AL, Kibele A, Gibbons S: Surgical treatment and postoperative splinting of recessive dystrophic epidermolysis bullosa. *J Hand Surg [Am]* 1996;21(5):888–97.

13. Patch MR, Woodey RD: Spinal anaesthesia in a patient with epidermolysis bullosa dystrophica. *Anaesth Inten Care* 2000; 28:446–8.
14. Spielman F, Mann E: Subarachnoid and epidural anaesthesia for patients with epidermolysis bullosa. *Can Anaesth Soc J* 1984; 31(5)549–51.
15. Yee C, Gunter J, Manley C: Caudal epidural anesthesia in an infant with epidermolysis bullosa. *Anesthesiology* 1989;70:149–51.
16. Yonker-Sell A, Connolly L: Twelve-hour anaesthesia in a patient with epidermolysis bullosa. *Can J Anaesth* 1995;42(8):735–9.