

Common Rotational Variations in Children

Todd L. Lincoln, MD, and Patrick W. Suen, MD

Abstract

Most rotational variations in young children, such as in-toeing, out-toeing, and torticollis, are benign and resolve spontaneously. Understanding the normal variations in otherwise healthy children is vital to identifying true structural abnormalities that require intervention. A deliberate assessment of the rotational profile is necessary when evaluating children who in-toe or out-toe. In-toeing is usually attributable to metatarsus adductus in the infant, internal tibial torsion in the toddler, and femoral anteversion in children younger than 10 years. Out-toeing patterns largely result from external rotation hip contracture, external tibial torsion, and external femoral torsion. Although congenital muscular torticollis is the most common explanation for the atypical head posture in children, more serious disorders, including osseous malformations, inflammation, and neurogenic disorders, should be excluded.

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Benign rotational variations such as in-toeing, out-toeing, and torticollis are seen in many healthy children. Although the physical appearance of these conditions may initially be alarming, spontaneous resolution occurs in most cases. A thorough understanding of the normal rotational variations that may occur in children younger than 10 years is essential to properly reassure and educate families, as well as to identify more serious underlying structural problems that might exist.

In-toeing and Out-toeing

Natural History

Limb buds appear in the fifth week in utero. The great toes develop in a preaxial position, rotating medially in the seventh week to bring the hallux to midline. Subsequent intrauterine molding causes external rotation at the hip, internal rotation of the tibia, and variable positioning of the foot. Thus, many infants are born with an

internal tibial torsion axis, an external contracture at the hip, or flexible foot deformities. The external hip contracture initially masks the high degree of femoral anteversion also characteristic of normal infants at birth. Postnatally, the lower extremities continue to rotate externally until adult values are reached (between ages 8 and 10 years). During this period of rapid growth, the tibia typically externally rotates 15° while femoral anteversion decreases an average of 25°.¹ Normal rotational profiles in childhood therefore are variable and age-dependent.

Evaluation

Normal variability in young children must be differentiated from more serious structural problems. The clinical history should delineate the onset and duration of a structural problem and any evidence of progression. Whereas the typical natural history of benign rotational conditions would suggest improvement over time, a progressive deformity sug-

gests a possible pathologic developmental or neurologic disorder. The physician should also determine whether the rotational problem has caused a functional impairment such as tripping, pain, or shoe wear difficulties. Perceived gait disturbances must be interpreted in the context of the normal immature pattern of walking that is characteristic of young children. Relevant birth history should be noted, including gestational age, length of labor, complications, Apgar scores, birth weight, and number of days in the hospital. These details may heighten the suspicion for possibility of cerebral palsy. The family history should include a careful assessment of rotational disorders in other family members and the presence of hereditary disorders (eg, vitamin D-resistant rickets, mucopolysaccharidoses, achondroplasia, epiphyseal or metaphyseal dysplasia) that may affect the rotational profile.

Evaluation of postural conditions requires both a static and a dynamic physical examination. The static ex-

Dr. Lincoln is Assistant Professor, Department of Orthopaedic Surgery, Stanford University Medical Center; Lucile Salter Packard Children's Hospital, Palo Alto, CA. Dr. Suen is in private practice at Kaiser Permanente, Oakland, CA.

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amination should begin with an evaluation of the overall appearance of the patient before focusing on the lower extremities. Short stature or disproportionate body-to-limb ratio may suggest skeletal dysplasia. The child's rotational profile, as described by Staheli,² should be recorded. The five components in this profile are internal and external hip rotation, thigh-foot axis, transmalleolar axis, heel-bisector angle, and foot progression angle during gait.

Hip rotation is most easily measured with the patient in the prone position. A parent can hold a fearful or uncooperative younger child face to face to soothe her or him during the examination. Infants have an average of 40° of internal rotation (range, 10° to 60°) and 70° of external rotation (range, 45° to 90°). By age 10 years, internal hip rotation averages 50° (range, 25° to 65°) and external rotation, 45° (range, 25° to 65°).² Internal rotation measuring 70°, 80°, or 90° is evidence respectively of a mild, moderate, or severe increase in femoral torsion.¹ Increased femoral torsion may be evident during gait, with medially facing patellar alignment.

The thigh-foot axis also is best examined with the child in the prone position and the knee flexed 90° (Fig. 1). This angle consists of the rotation of the tibia and hindfoot in relation to the longitudinal axis of the thigh and indicates the amount of tibial torsion present. In infants, the thigh-foot angle averages 5° internal (range, -30° to +20°). Excessive internal tibial torsion spontaneously resolves by age 3 or 4 years in most children. By age 8 years, the thigh-foot axis averages 10° external (range, -5° to +30°) and usually changes very little after that.²

Measurement of the transmalleolar axis also aids in determining the amount of tibial torsion. This axis is the angle formed at the intersection of an imaginary line from the lateral to the medial malleolus, and a second



Figure 1 The thigh-foot axis is best evaluated with the child in a prone position. The angle subtended by the longitudinal axis of the thigh and the foot defines the degree of internal or external tibial torsion present.

line from the lateral to the medial femoral condyles. At gestational age 5 months, the fetus has approximately 20° of internal tibial torsion. The tibia then rotates externally, and most newborns have an average of 4° of internal tibial torsion. As a child grows, the tibia continues to rotate externally. Adults have an average of 23° of external tibial torsion (range, 0° to 40°).¹

The foot should be examined for additional causes of apparent in-toeing or out-toeing. The heel-bisector line, the line drawn through the midline axis of the hindfoot and the forefoot, is helpful in evaluating forefoot adduction and abduction.³ In a neutral foot, the heel-bisector line passes through the second web space.

Assessment of the foot progression angle during gait is the fifth and final component of a child's rotational profile. The foot progression angle is the angle of the foot relative to an imaginary straight line in the patient's path. Patients who in-toe are assigned a negative angular value; patients who out-toe are given a positive val-

ue. This value represents the sum total effect of the child's structural alignment (ie, femoral torsion, tibial torsion, foot contour) as well as any dynamic torsion forces resulting from muscle forces. Some pathologic conditions will have characteristic gait patterns. For example, a patient with mild cerebral palsy may demonstrate mild equinus and in-toeing, whereas in-toeing with a Trendelenburg gait suggests hip dysplasia.

Children with rotational profiles two standard deviations outside the mean for their age are considered abnormal.¹ In such children, further diagnostic studies (eg, plain radiographs) should be considered, depending on the specific abnormality. For example, foot radiographs may help diagnose skewfoot in a child with severe in-toeing. Others have suggested extremity radiographs for children presenting with short stature (<25th percentile), a worrisome hip examination, marked limb asymmetry, or pain.¹ To rule out hip dysplasia, some advocate a pelvic radiograph for any patient presenting with a gait abnormality that is not easily explained by the rotational profile, asymmetric hip motion, or hip pain.²

In-toeing usually is caused by benign conditions such as metatarsus adductus, excessive internal tibial torsion, and excessive femoral torsion. Less frequently, patients have pathologic conditions such as clubfoot, skewfoot, hip disorders, and neuromuscular diseases. Metatarsus adductus, with or without internal tibial torsion, is the most common cause of in-toeing from birth to 1 year. In toddlers, internal tibial torsion causes most in-toeing. After age 3 years, in-toeing usually is caused by increased femoral anteversion. More severe in-toeing suggests a combination of deformities, such as internal tibial torsion and excessive femoral anteversion.⁴

Out-toeing typically is caused by external rotation contracture of the

hip, external tibial torsion, or external femoral torsion. External rotation contracture of the hip capsule is a common finding during infancy, whereas external tibial or femoral torsion is more commonly seen in older children and adolescents who out-toe.² Severe pes planovalgus also has been associated with out-toeing. More serious conditions, such as a slipped capital femoral epiphysis, hip dysplasia, or coxa vara, are less common but should be considered.

Active treatment of childhood rotational disorders is unnecessary in most cases. Prudent care consists of reassurance and education about the natural history of the condition. Bracing and shoe modifications are unnecessary and should be actively discouraged for these normal children. Many published studies have shown that such interventions have no demonstrable effect on the natural history or on spontaneous resolution.⁵ One study even indicated an association of brace use for benign torsional variations during childhood with lower self-esteem scores during adulthood.⁶

Other Postural Conditions

Metatarsus Adductus

Metatarsus adductus consists of medial deviation of the forefoot on the hindfoot with a neutral or slightly valgus heel (Fig. 2). This condition, described by Henke in 1863, is the most common pediatric foot problem referred to orthopaedic surgeons. It occurs in 1:5,000 live births and in 1:20 siblings of patients with metatarsus adductus. The rate of metatarsus adductus is higher in males, twin births, and preterm babies.⁷ Earlier studies suggested a relationship between metatarsus adductus and hip dysplasia, but recent studies indicate no such correlation.⁸

Although the exact cause of metatarsus adductus is unknown, numerous theories exist. One is that in utero

positioning causes the deformity. This theory is supported by the high rate of spontaneous resolution of metatarsus adductus as well as its association with twin pregnancies.⁹ Sleeping position also may contribute to the development of metatarsus adductus. Many babies sleep in a prone position with the hip and knees flexed and the feet adducted. Other authors have proposed anatomic differences as the primary cause. Surgical findings have indicated that a muscle imbalance from a tight anterior tibial tendon or an anomalous insertion of this tendon could cause metatarsus adductus. However, others were unable to reproduce metatarsus adductus in still-born fetuses by using traction on the anterior tibial tendon.¹⁰ Furthermore, in patients with cerebral palsy, a spastic anterior tibial tendon leads to hindfoot varus. Such findings challenge the muscle imbalance concept. Another theory is that the medial cuneiform is abnormally shaped in patients with metatarsus adductus. Morcuende and Ponseti¹¹ found a trapezoid-shaped medial cuneiform with a broadened and medially tilt-

ed articular surface at the metatarsal-medial cuneiform articulation in fetuses with metatarsus adductus.

Metatarsus adductus usually is seen in the first year of life and occurs more frequently on the left side. Presenting complaints include cosmesis, an in-toeing gait, or excessive shoe wear. On physical examination, the foot appears C-shaped, with a concave medial border and a convex lateral border (Fig. 2). Pressure sites during shoe wear may include the medial border of the first metatarsophalangeal joint or a prominent lateral border at the base of the fifth metatarsal. Hyperactivity of the abductor hallucis muscle also may contribute an additional dynamic component to this foot position, particularly in children younger than 18 months. The hindfoot will be neutral or in valgus, but never in varus. Range of motion of the ankle and subtalar joint will be normal.

Metatarsus adductus has been classified by Smith et al³ as mild, moderate, or severe, depending on the heel-bisector angle. Greene¹² also developed a classification scheme



Figure 2 Typical clinical appearance of a child with metatarsus adductus.

based on the heel-bisector angle and the visual appearance of the lateral border of the foot. However, because flexibility appears to correlate more closely with treatment and prognosis, classification systems based on flexibility of the deformity may be preferable.¹³ A later classification system described by Bleck¹⁴ designated a flexible forefoot as one that could be abducted beyond the midline heel-bisector angle, a partially flexible forefoot as one that could be abducted to midline, and a rigid forefoot as one that could not be abducted to midline. The classification system of Crawford and Gabriel¹⁵ also is based on flexibility of the forefoot.

Routine imaging studies are not necessary in infants with metatarsus adductus but may be indicated in children older than 4 or 5 years with unresolved deformity and pain. The usefulness of radiographs before age 4 years is limited by the lack of sufficient ossification in the bones of the foot. In older children, forefoot adduction, excessive medial deviation at the tarsal-metatarsal joint, and a neutral or valgus heel will be evident on a standing radiograph. Although classification systems of metatarsus adductus based on radiographic criteria exist, they have poor intraobserver and interobserver agreement and no prognostic significance.¹⁶

Most cases of flexible metatarsus adductus resolve spontaneously and do not require use of splinting, braces, or special shoes. Rushforth¹⁷ did a prospective study of 83 children with 130 cases of flexible metatarsus adductus. At follow-up with no treatment (mean, 7 years), 58% had no residual deformity, 28% had mild deformity, 10% had moderate deformity, and 4% had severe adductus.¹⁷ Ponseti and Becker¹⁸ studied 335 children with flexible metatarsus adductus who received no treatment. All patients improved in 3 to 4 years. In a series of 21 patients (31 feet) with partly flexible or inflexible metatarsus adductus treated with serial cast-

ing, 20 patients (95% [29 feet]) had painless normal feet as adults; 1 patient (5% [2 feet]) had residual adductus and pain only after strenuous activity.¹³ Most evidence indicates that flexible metatarsus adductus commonly resolves without treatment and that even when it does not, it rarely leads to pain in adulthood.

Patients with rigid metatarsus adductus deformities should undergo early casting. Although some authors claim that below-knee casting is less effective than long leg casting, no data support this claim.¹² In a study of 37 feet with inflexible moderate metatarsus adductus and 48 feet with severe metatarsus adductus, Katz et al¹⁹ demonstrated that below-knee casting can improve metatarsus adductus deformities. Correction of the foot deformity was achieved by 6 to 8 weeks in all cases. At 2- to 6-year follow-up, moderate deformity had recurred in six feet with initial severe inflexible deformity; one additional patient had developed a severe deformity.

Uncommonly, resistant cases of inflexible metatarsus adductus may require surgery because of painful shoe wear. Surgical options include release of the abductor hallucis tendon, medial midfoot capsulotomy, tarsometatarsal joint capsulotomy and release of the intermetatarsal ligaments, or osteotomy at the metatarsal bases and cuneiforms. Lengthening of the abductor hallucis with medial capsulotomy of the naviculocuneiform and cuneiform first metatarsal joints is technically simple and was shown to be effective in a recent series of 29 feet in 18 children.²⁰ Capsulotomy of the tarsometatarsal joints and release of intermetatarsal ligaments (the Heyman-Herndon procedure) has a 41% failure rate and complications such as skin slough, osteonecrosis of the cuneiforms, dorsal prominence of the first metatarsal-cuneiform joint, and early degenerative arthritis.²¹ Osteotomy at the metatarsal bases is associated with shortening of the first metatarsal in 5% to 30% of patients.²²

In contrast, an opening wedge osteotomy of the medial cuneiform, combined with a closing wedge osteotomy of the cuboid or osteotomies at the base of the second through fourth metatarsals, has been shown to be safe and effective.²³ Thus, this appears to be the most effective surgical option in patients older than 3 years with persistent rigid metatarsus adductus deformities.

Metatarsus Primus Varus

Metatarsus primus varus is an isolated adducted first metatarsal. In contrast with simple metatarsus adductus, in metatarsus primus varus the lateral border of the foot has a normal alignment, and there is often a deepened vertical skin crease on the medial border of the foot at the tarsometatarsal joint. In general, metatarsus primus varus is a more rigid deformity than simple metatarsus adductus, and early casting is recommended. Persistent deformity in childhood is associated with progressive hallux valgus. Opening medial cuneiform osteotomy has been described for selective use in children with a severe deformity.²²

Dynamic Hallucis Abductus

Dynamic hallux abductus, otherwise known as the wandering or atavistic toe, also can cause in-toeing. The great toe deviates medially during ambulation while the remainder of the forefoot remains straight. Dynamic hallucis abductus usually presents after a child begins walking and is thought to be caused by an imbalance of the great toe abductor and adductor muscles. Dynamic hallux abductus usually resolves with age and subsequent fine motor coordination development.

Skewfoot

Skewfoot, also called congenital metatarsus varus or serpentine metatarsus adductus, is characterized by adducted metatarsals combined with a valgus deformity of the heel and

plantarflexion of the talus (Fig. 3). Little is known of the pathogenesis of this disorder. Improper casting of metatarsus adductus or clubfoot deformities may result in a skewfoot because of failure to support the hindfoot while abducting the forefoot in the cast. However, most cases are thought to be idiopathic.²⁴

The amount of hindfoot valgus necessary to classify a foot as a true skewfoot rather than as the more common metatarsus adductus is not strictly defined. As a result, limited epidemiologic information about this deformity is available. Determining hindfoot valgus in infants is difficult because of their small size; commonly, skewfoot is not diagnosed until later in childhood. Pain or callus formation under the head of the talus and the base of the fifth metatarsal may be reported, and uneven shoe wear may develop. Standing radiographs confirm the presence of an adducted forefoot and a valgus hindfoot.

The natural history of this deformity is unclear. Although some feet undergo spontaneous correction, others clearly continue to have pain, callosities, and problems with shoe wear. Surgery is indicated for children with

a persistently symptomatic foot deformity. Mosca²⁵ reported successful outcomes in 9 of 10 children treated after age 6 years with an opening wedge osteotomy on the calcaneus and the medial cuneiform.

Positional Calcaneovalgus

Positional calcaneovalgus is a flexible foot deformity characterized by dorsiflexion at the ankle and mild subtalar joint eversion. It may be the most common pediatric foot deformity, with an estimated incidence ranging from 0.1% to 50% in some series.⁸ Positional calcaneovalgus is most common in girls, first-born children, and children of young mothers. Intrauterine malpositioning is thought to cause this deformity. Imaging studies are not necessary for diagnosis but may help rule out the presence of a more serious underlying disorder, such as congenital vertical talus or posteromedial bowing of the tibia. Treatment of positional calcaneovalgus does not alter the natural history of this deformity.²⁶ All cases appear to resolve spontaneously, with or without manipulation and bandaging. Therefore, no treatment is recommended for positional calcaneovalgus.

Rotational Deformities of the Lower Extremity

Tibial Torsion

Internal tibial torsion is the most common cause of in-toeing from ages 1 to 3 years. In two thirds of affected children, the increased torsion is bilateral. When unilateral, internal tibial torsion usually affects the left side. Most cases are thought to be caused by intrauterine positioning. Accurate clinical recognition relies on measurement of the thigh-foot and transmalleolar axes. Although most children with increased tibial torsion are normal, excessive internal tibial torsion is also associated with tibia vara, while increased external tibial torsion is often associated with neuromuscular conditions such as myelodysplasia and polio.

Parents of children with increased internal tibial torsion often report that the child is clumsy and trips frequently. Treatment with splinting, shoe modifications, exercises, and braces has proved to be ineffective.⁵ Because the natural history of internal tibial torsion strongly favors spontaneous resolution by age 4 years, expectant observation is recommended instead. Disability from persistent residual internal tibial torsion is rare, and it is not a risk factor for degenerative joint disease. Some have even suggested that in-toeing improves sprinting ability.²⁷

In contrast to internal tibial torsion, excessive external tibial torsion tends to increase with age. It is usually discovered in late childhood or adolescence, tends to be unilateral, and more often affects the right side.² Disability from external tibial torsion is more common and includes patellofemoral pain and patellofemoral instability.^{2,28} Some have found an association between external tibial torsion and degenerative joint disease in the knee, but most believe it is not a risk factor.²⁸

Surgical treatment of tibial torsion is rarely indicated and should be re-

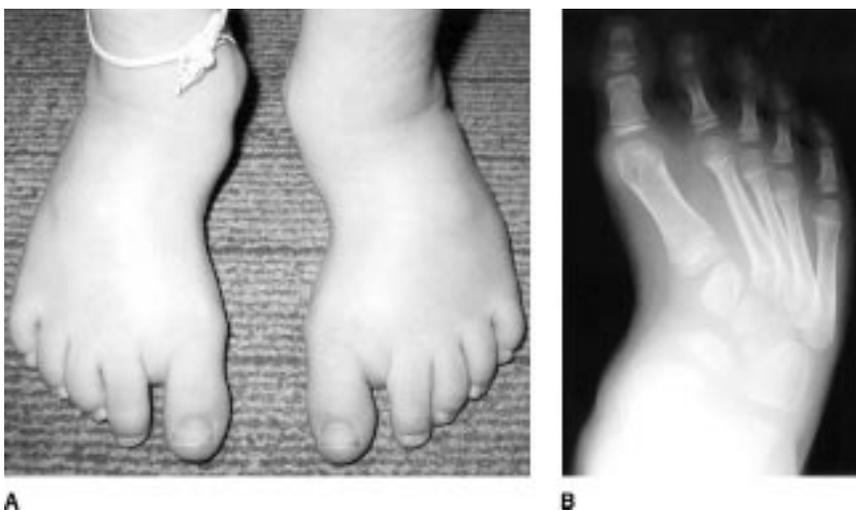


Figure 3 A, Clinical appearance of a skewfoot. B, Anteroposterior radiograph of a skewfoot showing hindfoot valgus, talar plantarflexion, midfoot abduction, and forefoot adduction.

served for children older than 8 years with marked functional or cosmetic deformity and a thigh-foot angle greater than three standard deviations beyond the mean (eg, thigh-foot angle $>15^\circ$).² Both proximal and supramalleolar tibial derotational osteotomies have been used to manage tibial torsion. However, most surgeons prefer the supramalleolar osteotomy because of its lower complication rate.²⁹ In the skeletally mature adolescent, derotational osteotomy with intramedullary fixation is also an option.

Femoral Torsion

Femoral torsion is the angular difference between the femoral neck axis and the transcondylar axis of the knee. At birth, neonates have an average of 40° of femoral anteversion. By age 8 years, average anteversion decreases to the typical adult value of 15° . Most cases of femoral torsion are idiopathic, although a familial association is identified in some patients.

Increased femoral anteversion is the most common cause of in-toeing in early childhood, tends to occur in females, and is symmetric. Children with excessive femoral anteversion characteristically sit with their legs in the W position (Fig. 4) and run with an eggbeater-type motion (because of internal rotation of the thighs during swing phase). In-toeing from excessive femoral anteversion usually increases until age 5 years and then resolves by age 8. On physical examination, internal hip rotation is increased and external hip rotation decreased. No association between increased femoral anteversion and degenerative joint disease has been proved; however, some association with knee pain has been suggested.³⁰ Knee pain may be particularly prevalent in children with concomitantly increased femoral anteversion and external tibial torsion (so-called miserable malalignment syndrome).³¹

No treatment is necessary for most cases of femoral torsion. Surgical in-

tervention may be indicated in a child older than 8 years with a marked cosmetic or functional deformity, anteversion $>50^\circ$, and internal hip rotation $>80^\circ$. Surgeries to correct femoral torsion include proximal and distal femoral osteotomies. A proximal femoral osteotomy may be considered if the patient has a concomitant varus or valgus deformity. Otherwise, a distal femoral osteotomy through a lateral approach is the preferred treatment. A small compression plate may be used to treat skeletally immature patients and a blade plate for skeletally mature patients.³²

Torticollis

Torticollis is any deformity in which the head is tilted and abnormally rotated. The differential diagnosis of torticollis includes typical congenital muscular torticollis as well as torticollis secondary to osseous malformations, inflammation, and neurogenic

disorders. In a series of 288 children with torticollis, congenital muscular torticollis was the cause in 82% of cases.³³ Of the remaining 18%, most had Klippel-Feil syndrome or a neurologic disorder. Klippel-Feil syndrome is characterized by congenitally fused cervical vertebrae and a short neck. Osseous malformations that cause torticollis include basilar impression; atlanto-occipital anomalies; and a unilateral absence of C1, familial cervical dysplasia, and atlantoaxial rotatory displacement. Any of a variety of neurologic disorders may be the etiologic agent, including posterior fossa tumors (Fig. 5) and cervical tumors, syringomyelia, Arnold-Chiari malformations, ocular dysfunction, and paroxysmal torticollis of infancy. A formal ophthalmologic examination frequently is indicated when the sternocleidomastoid muscle is not clearly tight on examination. Acute-onset torticollis in the setting of a pharyngitis or recent adenoidectomy may indicate Grisel's syndrome. Ballock and



Figure 4 Characteristic ability of a 6-year-old child with increased femoral anteversion to sit in the W position. The child's patellas are outlined by the dotted circles.



Figure 5 Axial computed tomography image of a large posterior fossa tumor (astrocytoma) (arrow) in a 4-year-old child who presented for evaluation of torticollis and recent change in gait.

Song³³ outlined a useful diagnostic algorithm in 1996 based on their retrospective review of children with non-muscular causes of torticollis.

Congenital muscular torticollis, a painless deformity associated with contracture of the sternocleidomastoid muscle, is the most common cause of torticollis and typically is identified in the first 2 months of life. This contracture of the sternocleidomastoid muscle leads to a head tilt toward the involved side and head rotation toward the opposite side. It is associated with breech and difficult deliveries as well as other musculoskeletal disorders, such as metatarsus adductus, hip dysplasia (Fig. 6), or talipes equinovarus. The authors of one clinical study reported a 7% to 20% incidence of developmental dysplasia of the hip in patients with congenital muscular torticollis.³⁴ Multiple theories regarding the etiology of congenital muscular torticollis have been proposed, including fibrosis of the sternocleidomastoid muscle after a peripartum intramuscular bleed, fibrosis caused by a compartment syndrome of the sternocleidomastoid

muscular compartment,³⁵ intrauterine crowding, and primary myopathy of the sternocleidomastoid muscle.³⁶

Congenital muscular torticollis is more commonly seen on the right side. A painless mass may be palpable in the sternocleidomastoid region in the first 2 weeks of life, reaching maximum size in 4 weeks, then regressing. By age 4 to 6 months, torticollis and contracture of the sternocleidomastoid are the only clinical findings. Persistent torticollis may lead to skull and facial deformities (ie, plagiocephaly). A child who sleeps prone usually lies 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.³³

Treatment usually is nonsurgical. For infants younger than 1 year, a program of sternocleidomastoid muscle stretching is recommended. The parents should be taught to stretch the child's contralateral ear to the shoulder and gently push the chin to touch the shoulder on the same side as the contracted sternocleidomastoid. Ninety percent of cases resolve with such treatment.³⁷ After age 2 years, nonsurgical treatment is unlikely to be effective. It is preferable to surgically treat children with persistent torticollis and an unacceptable amount of facial asymmetry before age 3 years.³⁸ However, some improvement in facial asymmetry has been shown even in children surgically treated as late as 8 years.³⁹

Current surgical options are unipolar or bipolar release. Middle third transection and complete resection are no longer recommended because of risk to the spinal accessory nerve. Unipolar release consists of division of the distal portion of the sternocleidomastoid muscle and typically is done for a mild deformity. Bipolar release entails division of both the sternocleidomastoid origin and insertion for more notable involvement. In



Figure 6 Torticollis in an infant with developmental dysplasia of the hip. (Courtesy Texas Scottish Rite Hospital for Children, Dallas, TX).

one series, 11 of 12 patients had a satisfactory result with a bipolar procedure combined with Z-plasty of the sternal attachment.³⁸ In another series of 55 patients, >50% had satisfactory improvement of their plagiocephaly and a 2% recurrence rate.⁴⁰ Potential surgical complications include injury to the spinal accessory nerve, jugular veins, carotid vessels, and the facial nerve. In the postoperative period, patients may do some simple stretching exercises, but they often require bracing to maintain corrected alignment.

Summary

Understanding the spectrum of postural variations that can occur in children younger than 10 years is requisite to avoid the needless treatment of benign conditions as well as to distinguish true pathologic structural abnormalities. Referral of a child to an orthopaedic surgeon for in-toeing or out-toeing is commonplace; for most of these children, the etiology of the complaint can be quickly diagnosed by a systematic assessment of the

child's rotational profile. Knowledge of the natural history of metatarsus adductus, tibial rotation, and femoral anteversion is the basis for the appropriate education and reassurance of families and primary care providers who are unnecessarily worried about children with such physiologic conditions. A need for diagnostic imaging or active intervention is rel-

atively uncommon and should be reserved for children who fall two standard deviations outside the mean rotational profile for their age. A second common source of orthopaedic referral consists of a wide variety of postural pediatric foot abnormalities. Familiarity with these conditions, ranging from the routine infant with a calcaneovalgus foot posture to the

rare child presenting with a skewfoot deformity, is needed to properly select those children who require treatment. Similarly, recognition of the high prevalence and clinical findings of congenital muscular torticollis, along with awareness of other, less common etiologies of torticollis in children, assists the proper selection of diagnostic studies and treatment.

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