

Genu Valgum in Children: Diagnostic and Therapeutic Alternatives

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Abstract

Genu valgum is a common orthopaedic problem in children. The vast majority of cases are physiologic variants, which resolve normally. However, there are pathologic entities due to both focal and systemic processes in which the deformity often progresses and usually requires treatment. Differentiating between the two forms is facilitated by a thorough understanding of the natural history of the development of the tibiofemoral angle in children. In this review, an approach to the evaluation and diagnosis of genu valgum is presented, and therapeutic alternatives are discussed.

J Am Acad Orthop Surg 1995;3:275-283

Genu valgum, or knock-knee, is a common condition affecting the lower limbs in children and adolescents that the orthopaedist is often called on to evaluate. As with genu varum, physiologic forms are most common; however, pathologic causes, which have the propensity to progress and may require treatment, do exist (Table 1). It is obviously important to distinguish between these entities. In this review, we will present an approach to the evaluation, diagnosis, and treatment of genu valgum in children.

Physiologic Genu Valgum

Evaluating angular malalignment is simplified if one is familiar with the normal development of the tibiofemoral angle. Salenius and Vankka¹ have shown in a radiographic study that the tibiofemoral angle in the newborn is characterized by maximal lateral bowing (genu varum angulation of 10 to 15 degrees). It straightens between the ages of 20

and 22 months and progresses into maximum valgus angulation (10 to 15 degrees) at around 3 years of age. The normal child then has a gradual resolution to physiologic knee valgus (7 to 8 degrees) over the ensuing years (Fig. 1). Using clinical techniques of measurement, Staheli et al^{2,3} have reported a similar pattern of development.

In the vast majority of children with genu valgum, the tibiofemoral angle is within the physiologic range of two standard deviations above or below the mean. They can be treated with observation and parental reassurance that the "deformity" is a variant of normal and not a disease.^{1,3} Staheli has suggested that such children are probably best described as having knock-knees.² Fat thighs, ligamentous laxity, and flatfoot, which often results in toed-out habitus, can accentuate the knock-kneed appearance⁴ and cause physiologic genu valgum to seem more severe. Torsional malalignment can have a similar effect. Children with excessive

femoral anteversion and compensatory external tibial torsion may have the appearance of valgus malalignment of the knee when, in fact, no frontal-plane deformity exists. The appearance of genu valgum in this situation is due to malalignment in the transverse (rotational) plane.

Pathologic Genu Valgum

Pathologic genu valgum is much less common than the physiologic type. However, numerous causes exist. Both focal and systemic processes may cause deformity that either is localized to a specific site within the bone or is more generalized, involving the whole bone. By definition, children with pathologic genu valgum have tibiofemoral angles that are outside two standard deviations of the mean.^{1,3} This measurement varies as a function of age

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Table 1
Classification of Genu Valgum

Physiologic
Knock-knees
Apparent genu valgum (fat thighs, rotational deformity)
Pathologic
Idiopathic
Unresolved physiologic valgus
Lateral femoral hypoplasia
Posttraumatic
Malunion
Physcal arrest
Metaphyseal tibial fracture
Metabolic
Rickets
Renal osteodystrophy
Neuromuscular
Cerebral palsy
Paralytic conditions (e.g., poliomyelitis)
Infectious (e.g., osteomyelitis)
Generalized disorders
Juvenile arthritis
Osteochondrodysplasia
Osteogenesis imperfecta

equate reduction or physeal injury and subsequent growth arrest. In the proximal tibia, as in other parts of the immature skeleton, Salter-Harris type III, IV, and V fractures pose the greatest risk of this occurrence. In contrast, several authors have shown that in the distal femur the fracture type is not predictive of future growth problems.⁵ Due to the large cross-sectional area and the convoluted anatomy of this growth plate, damage to the physeal cartilage is probably extensive despite the pattern of injury. Furthermore, the geometry of this physis may affect the ability to achieve an adequate, anatomic reduction.

It is worth mentioning that occult physeal injuries to the knee may occur concomitantly with more overt fractures of the metaphyseal and diaphyseal regions of the tibia and femur and can lead to pro-

gressive angular deformity.⁶ These injuries should be looked for diligently, and families should be informed of the potential consequences to avoid subsequent embarrassment, misunderstanding, and potential liability. Hresko and Kasser⁶ recommend that all patients with traumatic injury to the lower extremity undergo radiographic evaluation of the knee in addition to a thorough clinical evaluation.

Another common cause of genu valgum is tibia valga following fracture of the proximal tibial metaphysis (Fig. 3). Since the first description by Cozen⁷ in 1953, there have been many reports of this problem. Hosts of possible theories about etiology have been proposed, although the actual cause of the abnormality remains unknown. Cozen suggested that the problem was due to asymmetric stimulation

(Fig. 1). Deformity is more apt to be unilateral, and treatment is often necessary.

Idiopathic

Idiopathic genu valgum occurs when physiologic variants fail to resolve, leading to persistent or progressive deformity. Children with this diagnosis are often obese and flatfooted and characterized by ligamentous laxity.⁴ Hypoplasia of the lateral femoral condyle and stretching of the medial soft-tissue structures of the knee may develop in response to prolonged, excessive weight-bearing through the lateral half of the joint (Fig. 2).

Posttraumatic

Trauma is probably the most common cause of pathologic genu valgum. Fractures of the distal femur or proximal tibia can lead to valgus deformity due to either inad-

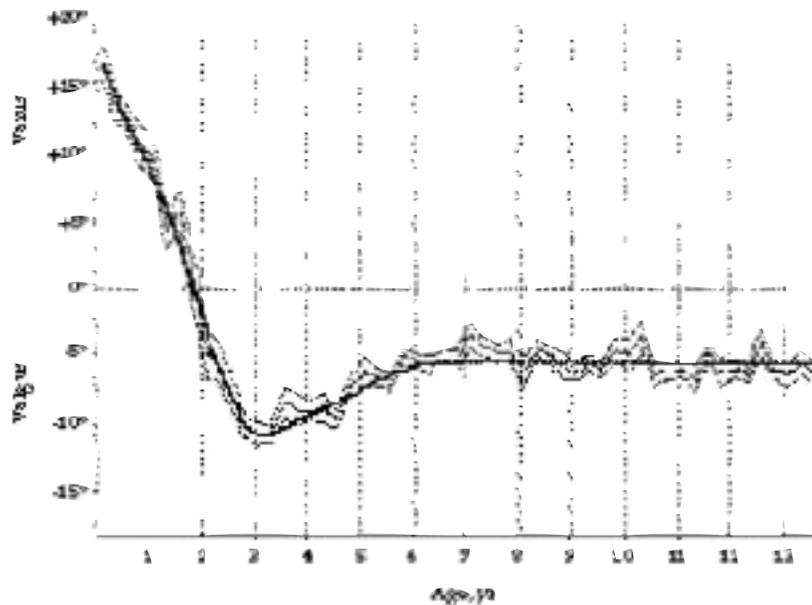


Fig. 1 Graph illustrating the development of the tibiofemoral angle in children during growth, based on measurements from 1,480 examinations of 979 children. Of the lighter lines, the middle one represents the mean value at a given point in time, and the other two represent the deviation from the mean. The darker line represents the general trend. (Adapted with permission from Salenius P, Vankka E: The development of the tibiofemoral angle in children. *J Bone Joint Surg Am* 1975;57:259-261.)



Fig. 2 Idiopathic genu valgum in an obese teenager in whom physiologic valgus failed to resolve. Note the asymmetric involvement (greater on the left) and the hypoplasia of the lateral femoral condyle, suggesting excessive lateral loading.

of the proximal tibial physis.⁸ Taylor⁹ attributed it to overgrowth of the tibia relative to the fibula. Salter and Best¹⁰ felt that malunion was the most important factor in the pathogenesis of the valgus angulation. Houghton and Rooker¹¹ experimentally produced tibia valga in rabbits by sectioning the pes anserinus and medial periosteum and postulated a tethering effect of the intact lateral periosteum as the mechanism. Weber¹² surgically explored two cases of posttraumatic valgus, found the pes anserinus trapped between the fracture fragments,

and postulated that medial soft-tissue interposition was the cause of the deformity.

More recently, Jordan et al¹³ reported on seven patients with this deformity, reviewed the major theories regarding the etiology of this problem, and concluded that the most likely primary mechanism is growth stimulation of the medial portion of the proximal tibia due to fracture hyperemia. This is currently the prevailing theory and is strongly supported by the findings in two case reports. Green¹⁴ reported a case of posttraumatic tibia valga in which the mechanism of medial overgrowth of the proximal tibia was supported by the finding of asymmetric growth-arrest lines. Zionts et al¹⁵ reported a case of tibia valga that showed increased radionuclide activity in the medial half of the proximal tibial growth plate on a bone scan.

Metabolic

Metabolic causes of pathologic genu valgum include the various forms of rickets and renal osteodystrophy. Although the metabolic effects on the physis are similar in these disorders, vitamin D-resistant and vitamin D-deficient rickets are more typically associated with varus deformity at the knee, and renal osteodystrophy is typically associated with valgus deformity.¹⁶ This difference is thought to be related to the pattern of mechanical loading of the physes as determined by the alignment of the knee at the time the metabolic process manifests itself.¹⁷

Most of the disorders that are responsible for vitamin D-resistant and vitamin D-deficient rickets are present from birth. Therefore, the metabolic abnormality is usually established when the child begins to stand. The physiologic tibiofemoral alignment at this age predisposes to progressive varus malalignment

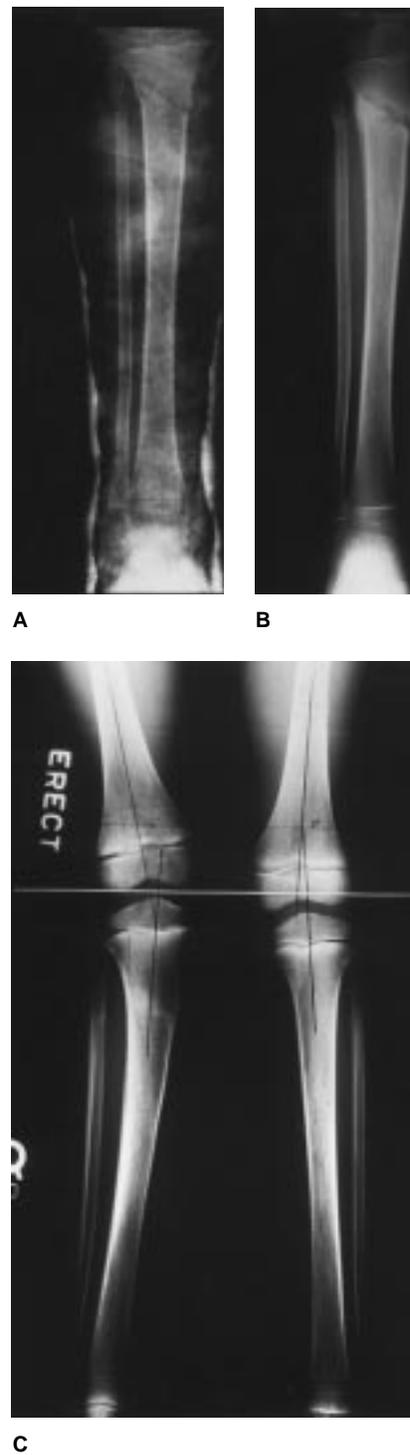


Fig. 3 Serial radiographs showing genu valgum due to inadequate initial reduction of a proximal metaphyseal tibial fracture in a 7-year-old child. **A**, Inadequate reduction. **B**, Malunion at the time of cast removal. **C**, Resultant valgus at 1-year follow-up.

according to the Heuter-Volkman principle, which states that epiphyseal growth is inversely proportional to the pressure applied to its longitudinal axis.

For similar reasons, renal osteodystrophy causes genu valgum because children are generally older when the metabolic effects become manifest. Valgus tibiofemoral alignment has usually developed, and subsequent mechanical forces acting across the epiphyseal plate predispose to the development of progressive valgus deformity (Fig. 4). Oppenheim et al¹⁸ have described changes in the lateral proximal tibia in children with renal osteodystrophy similar to those seen in the medial proximal tibia in Blount's disease.

Neuromuscular

Genu valgum may be seen in children with neuromuscular disorders. Ambulatory children with cerebral palsy and other neuromuscular disorders often have pes valgus and/or excessive external tibial torsion, which causes the foot to be rotated externally relative to the knee (Fig. 5). As a result of this malalignment, valgus and external-rotation ground-reaction forces are generated against the knee during stance. With growth and continued weight-bearing, these abnormal forces can lead to progressive valgus deformity in the foot and at the ankle and knee.¹⁹ In children with spina bifida and other paralytic conditions, such as poliomyelitis, genu valgum is thought to be caused by contracture of the iliotibial band²⁰



Fig. 5 Ambulatory 11-year-old child with neuromuscular disorder. External rotation of the foot is due to pes valgus and external tibial torsion. As a consequence, the ground-reaction force passes lateral to the normal weight-bearing line, potentiating deformity in the foot and ankle and creating a valgus moment at the knee, which in time can lead to progressive deformity there as well.



A



B

Fig. 4 Clinical appearance (A) and standing anteroposterior radiograph (B) of a 12-year-old child with chronic renal failure. Note the distal femoral physeal irregularities. Genu valgum is the most common skeletal manifestation of renal osteodystrophy.

and by the cumulative effects of abnormal dynamic forces (valgus thrust) produced by walking with a Trendelenburg or other compensatory gait pattern.

Infectious

Osteomyelitis can cause genu valgum directly, by disrupting the growth plate, or indirectly, by inducing reactive hyperemia and asymmetric growth stimulation. The latter are the mechanisms by which genu valgum is presumed to occur in children with juvenile arthritides, in whom hyperemia due to chronic synovitis may asymmetrically stimulate the physes around the knee.²¹

Generalized Disorders

Genu valgum also occurs in children with hereditary skeletal disor-

ders, such as multiple epiphyseal dysplasia and pseudoachondroplasia, and in other generalized disorders characterized by severe osteopenia, such as osteogenesis imperfecta.

Evaluation

The assessment of genu valgum should include a thorough history, including inquiries about the birth history, gross motor developmental sequence, family history, and dietary history. Parental concerns are usually related to cosmesis, clumsiness, and future functional performance. Children with physiologic valgus usually have a normal gestational and birth history and have reached developmental milestones at appropriate intervals. However, the family history may reveal that there have been other siblings or family members for whom there were similar concerns and findings. The growth pattern and dietary history are usually normal. Children with pathologic genu valgum typically have a history of progressive deformity and, depending on the underlying cause, a history of trauma, infection, dietary deficiency, or systemic illness.

Physical examination should include an accurate assessment of the patient's stature to allow determination of the growth percentile. The location of the deformity should be noted, and the severity of the angulation should be documented by either goniometric measurement of the tibiofemoral angle or, more simply, by linear measurement of the distance between the medial malleoli with the patient supine and the knees together, as advocated by Howorth.⁴ Heath and Staheli³ have described a photographic technique of determining the knee angle, which uses the anterior superior iliac spine, the patella, and a point mid-

way between the malleoli to define two axes that closely approximate the tibiofemoral angle. The technique is simple and reproducible, and it provides an objective visual record of the deformity that other clinical techniques do not.

Rotational alignment (in particular, femoral anteversion and external tibial torsion) and ligamentous laxity should be assessed because of the potentially synergistic effect of these conditions on angular malalignment. Ligamentous laxity is defined clinically on the basis of the presence of joint hyperextensibility. Examination of rotational alignment is best done with the patient prone and the hips extended and knees flexed. In this position, hip rotation and the foot-thigh angle can be easily measured as estimates of femoral anteversion and tibial torsion, respectively.

Children with physiologic genu valgum are typically less than 7 years old, have symmetric involvement of the lower extremities, and are of normal stature. The tibiofemoral angle measures less than 15 degrees, and the intermalleolar distance is less than 8 cm.³ Gait is normal. Further diagnostic tests and radiographs are usually not necessary in this situation.

Radiographs are warranted, however, if pathologic genu valgum is suspected. Greene²² and Staheli²³ recommend them if the deformity is severe or asymmetric, if there are other musculoskeletal abnormalities, if the height is less than the 25th percentile value, or if the family history is positive. In general, children with short stature, asymmetric involvement, or a tibiofemoral angle greater than 15 to 20 degrees should be evaluated radiographically. A single weight-bearing anteroposterior radiograph of the lower extremities that includes the hips, knees, and ankles allows measurement of alignment and assessment of any osseous or physeal abnormality. Lateral

radiographs are helpful in assessing the sagittal plane if deformity is suspected or surgery is being considered. Tomograms are helpful in identifying the presence of a physeal bar.

Children with idiopathic genu valgum may have flattening of the lateral femoral condyle. Those with genu valgum of posttraumatic origin will have evidence of a malunited fracture, a physeal bar, or asymmetric growth-arrest lines. In children with rickets or renal osteodystrophy, widening and irregularity of the physes will be seen, and there may be changes in the lateral proximal tibia. Children with genu valgum due to chronic disease processes usually have generalized osteopenia. Those with osteochondrodystrophies will have changes of disordered growth and ossification in the epiphyses or metaphyses at multiple sites. These findings will usually be identified on the standing radiograph and can be delineated further by a more directed radiographic investigation, if necessary.

In most cases, measurement of the tibiofemoral angle (anatomic axis) will reasonably reflect the magnitude of the valgus deformity and can be used to track progression. However, as pointed out by Davids et al,¹⁷ this angle, which primarily measures the relative diaphyseal alignment of the two bones, may not accurately reflect the site or severity of deformity, particularly when there is more generalized involvement of the long bones. For this reason, measurement of hip, knee, and ankle-joint orientation relative to the weight-bearing axis (mechanical-axis alignment) is considered a more accurate way to characterize the deformity (Fig. 6).^{17,22-24}

Treatment

Children with physiologic genu valgum, by definition, do not require treatment. Braces are impractical,

poorly tolerated, and totally unnecessary for a condition with a benign natural history.^{22,23} Orthotics and shoe modifications do not affect the biomechanics of growth and alignment at the knee.²² Moreover, these modalities are expensive and can be physically and psychologically stressful to children and their parents. Instead, the child should be evaluated thoroughly, and the parents should be given a timely explanation of their child's diagnosis, the expected resolution of the "problem," and the impropriety of nonoperative treatment. Despite the generally favorable natural history, some cases of knock-knees will progress.

Children who are less than 10 years old and have a tibiofemoral angle greater than 15 to 20 degrees and/or an intermalleolar distance of more than 8 cm,^{1-4,22,23} those of short stature or with asymmetric involvement, and those with progressive deformity after age 4 years should be evaluated radiographically and followed up clinically to rule out developmental or metabolic causes. If a tibiofemoral angle of more than 15 degrees or an intramalleolar distance of 10 cm persists after age 10 years, spontaneous correction is unlikely to occur, and operative treatment is likely to be necessary.^{3,4,25}

The goal of operative treatment of pathologic genu valgum is restoration of normal mechanical-axis alignment and joint orientation. Operative correction of genu valgum can be accomplished by partial epiphysiodesis,²⁵ hemiepiphyseal stapling,^{4,21,26,27} or osteotomy.^{16,22,23}

Partial Epiphysiodesis

Partial epiphysiodesis, as advocated by Bowen et al,²⁵ is the simplest procedure. It can be performed through a standard incision that exposes the growth plate, or it can be done percutaneously, with fluoroscopic guidance. Either way, the goal is to create a bridge crossing the

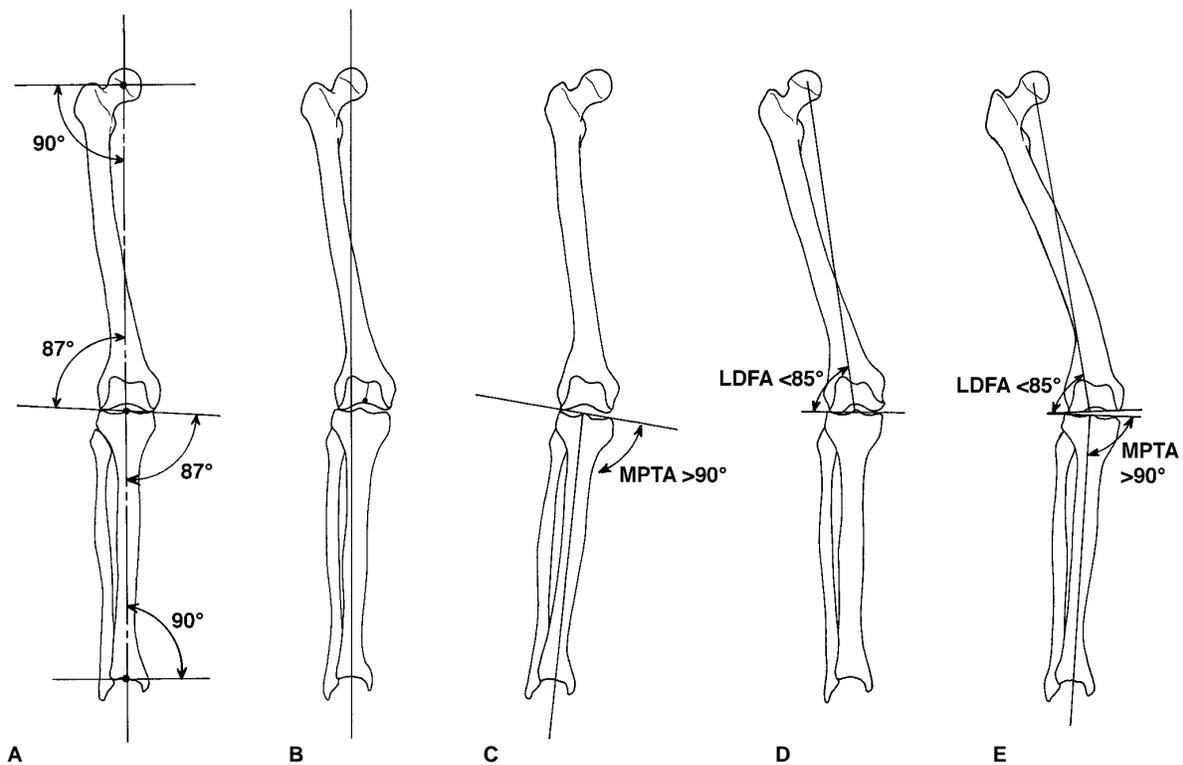


Fig. 6 A, Mechanical-axis and joint-orientation angles that define normal frontal plane alignment. A line drawn from the center of the femoral head to the center of the ankle defines the mechanical axis. The line normally passes 1 cm medial to the center of the knee. These relationships can be used to characterize the source and severity of valgus malalignment, as advocated by Paley et al.²⁸ B, A mechanical-axis line passing through the lateral half of the knee joint defines valgus malalignment. C, Valgus deformity in the tibia is characterized by a medial proximal tibial angle (MPTA) greater than 90 degrees. D, Valgus deformity in the femur is characterized by a lateral distal femoral angle (LDFA) less than 85 degrees. E, Combined deformity. (Parts B-E adapted with permission from Paley D, Herzenberg JE, Tetsworth K, et al: Deformity planning for frontal and sagittal plane corrective osteotomies. *Orthop Clin North Am* 1994;25:428.)

physis opposite the apex of the deformity, around which angulation can be corrected.

Correction is predicated on continued growth in the contralateral half of the physis. Thus, the ability to predict remaining growth and its effect on angular deformity is crucial to achieving a successful outcome. Bowen et al²⁵ developed a method that allows correction of angular deformity to be correlated with linear growth with use of the Green-Anderson growth-remaining charts to help determine the appropriate timing for surgery. Using this method of prediction, they reported successful results in 10 of 12 patients treated by partial epiphysiodesis.

Hemiepiphysal Stapling

When growth is predictable, partial epiphysiodesis is an excellent option. However, the procedure is not reversible, and in conditions in which growth may be atypical, mistiming surgery can lead to undercorrection or overcorrection of the deformity. Therefore, when skeletal growth is not predictable, as in renal osteodystrophy, rickets, and other metabolic conditions that cause generalized bone involvement, epiphysal stapling may be a better option. First described by Blount and Clarke²⁶ in 1949, this procedure is intended to halt physal growth by creating a peripheral bracket around the physis that mechanically impedes longitudinal growth.²⁷ Unlike epiphysiodesis, stapling does not ablate the growth plate. If there is overcorrection, the effect is theoretically reversible by removing the staples, if bar formation has not occurred and if staple removal can be done without damaging the growth plate in the process.

Restoration of growth is usually attended by a rebound phenomenon caused by growth acceleration on the previously stapled side of the physis. Although this is partially

compensated for by premature closure of the physis on the same side, overcorrection by approximately 5 degrees is recommended to achieve the desired effect if staple removal is necessary. Adolescent girls with a skeletal age of 11 years and boys with a skeletal age of 12 years are generally the most suitable candidates for this procedure. Epiphysal stapling is not recommended for children less than 10 years old because of the uncertainty of the effects of rebound overgrowth and concerns about premature physal closure.²⁷ Since both epiphysal stapling and hemiepiphysiodesis result in some shortening of the limb, they are ideal surgical options when the angular deformity is due to a process that causes chronic hyperemia and overgrowth of the affected limb.

Osteotomy

Osteotomy is probably the most common method of correction of angular deformity. While osteotomy may be done at any age, it is usually reserved until patients are near skeletal maturity. As with the other methods of correction of valgus deformity, the goal of osteotomy is restoration of physiologic mechanical-axis alignment. If osseous deformity is generalized, correction at multiple sites within the extremity and occasionally even within a single bone may be necessary. Generally, correction can be achieved by dome, oblique-plane, closing-wedge, or opening-wedge osteotomies. Concomitant sagittal- and/or transverse-plane deformities should be identified and corrected simultaneously.

The specifics of realignment osteotomies are beyond the scope of this discussion. The important concept is that correction should be established as close to the center of rotation of angulation of the deformity as possible to avoid introducing a translational deformity in the bone.²⁸

Typically, the apex of deformity in genu valgum is at the level of the physis or closer to the joint. Osteotomy at this level in either the distal femur or the proximal tibia is generally not feasible in skeletally immature individuals. Thus, the osteotomy must be performed at a level different from that of the deformity. Therefore, it must be designed not only to correct angulation but also to compensate for translation in order to properly realign the extremity.

After osteotomy, stable internal fixation augmented by a cast or external fixation should be used to maintain correction until healing is complete. Alternatively, angular deformity may be gradually corrected with use of the principles of distraction osteogenesis.²³ Using an external fixator allows the osteotomy to be adjusted postoperatively to fine-tune alignment or to be repositioned in the event of neurovascular compromise.

As pointed out by Steel et al,²⁹ neurovascular complications after osteotomy are probably more common than recognized. They include compartment syndromes, ischemia due to stretch or compression of the anterior tibial artery, and neuroparaxia due to traction on the peroneal nerve. The risks can be reduced by avoiding acute valgus-to-varus realignment when deformity is particularly severe, routinely performing prophylactic anterior-compartment fasciotomy, draining surgical wounds, and diligently monitoring neurovascular status postoperatively.

Relative Merits of Surgical Procedures

Both epiphysal stapling and partial epiphysiodesis can be performed with less morbidity than is associated with osteotomy.^{25-27,29} Correction is gradual, reducing the risk of neurovascular complications. Furthermore, because valgus deformity

about the knee is typically in the juxtaphyseal region of either the distal femur or the proximal tibia, correction occurs at the appropriate level opposite the center of rotation of the deformity, resulting in restoration of mechanical-axis alignment.

Posttraumatic genu valgum after a proximal tibial metaphyseal fracture generally corrects spontaneously over the course of 2 to 4 years,²⁹ and early osteotomy should be avoided.³⁰ Residual deformity can be effectively treated in adolescence by hemiepiphyseal stapling or arthrodesis or by osteotomy, depending on the severity and the level of deformity.

Genu valgum associated with long-standing metabolic disorders is generally a complex deformity and

usually needs to be treated by osteotomy. The patient's metabolic profile must be stabilized as a prerequisite to surgical treatment.^{16,17}

Summary

Genu valgum is a common condition in children. Physiologic variants predominate and do not require treatment. Pathologic genu valgum is much less common, is more likely to progress, and usually requires treatment. Knowledge of the natural history of the development of the tibiofemoral angle is necessary to distinguish between the two forms. Nonoperative treatment has no place in the management of either physiologic or

pathologic genu valgum; it is unnecessary in the former and ineffective in the latter. Children more than 10 years old with a tibiofemoral angle greater than 15 degrees or an intermalleolar distance of more than 10 cm are unlikely to improve spontaneously and usually require operative treatment. The goal of treatment is restoration of normal mechanical-axis alignment, which, depending on the underlying cause and the site and severity of the deformity, can be achieved by epiphyseal stapling, partial epiphysiodesis, or osteotomy.

Acknowledgments: The authors are grateful to Dorothy Cochrane, Debbie Chessor, and Holly Quick for their assistance in the preparation of the manuscript.

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