ANATOMICAL AND BIOMECHANICAL CONSIDERATIONS IN AXIAL DEVIATIONS OF LOWER LIMB

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Abstract

Planning for surgical correction of lower-limb deformity requires assessment of character and extent of the deformity. Angular deformities of tibia or femur in frontal plane lead to mechanical axis deviation of the lower limb and malorientation of the joints above and below the level of deformity. Accurate correction of the malalignment and of the joint orientation is important for function and to prevent joint degeneration. An awareness of the three dimensional nature of deformity is essential if correction is to be achieved. This applies to all aspects of orthopaedics, from total joint arthroplasty (the knee in particular) to fracture management. Mechanical axis deviations in the lower extremity are commonly seen in both paediatric and adult orthopaedic practice. This paper describes, for the trainee, the consequences of such deformity and the methods by which they are quantified.

Keywords: axial deviation, lower limb, children, deformities

Introduction.

Deformities in the lower limb comprise static and dynamic components and may occur in any plane, not just the "anatomical" sagittal or frontal planes. The concept of the weight bearing or "mechanical" axis was described by Pauwels in 1980 (1). It is a static weight bearing axis which can be drawn on a radiographic image of the limb. The mechanical axis of the lower limb in the frontal plane is defined as a line drawn from the centre of the femoral head to the centre of the ankle joint. In the sagittal plane the normal mechanical axis runs from the centre of gravity (in front of S2), to the centre of the ankle joint (1, 2, 3). The common situation is for deformity to occur between these anatomical planes, that are in an oblique plane (4, 5). Rotational deformity (internal or external) and translational deformity may coexist (1, 4, 6).

Development

On clinical examination most newborn infants present an external rotation tendency of the hips and mild internal tibial torsion. The hips rotate externally approximately 30° more than they rotate internally. This is known to be associated with approximately 35° to 40° of anteversion of the neck of the femur. This "physiologic" deformity is felt to be secondary to the marked knee-chest position which is present in the later months of pregnancy. If the intra-uterine positioning is severe or asymmetric, or if there is a congenital tendency for a rotational deformity, the usual physiologic rotation may be increased or decreased. In the course of normal development, most of these attitudes will correct themselves spontaneously so that in the adult the average rotation at the hips is approximately 40° internal and 45° external; the average ante torsion of the neck of the femur is 15°and the tibial torsion has changed to be approximately 20° of external rotation (1, 5, 7).

Types of deformities

Rotational deformities may be simple or mixed. By a simple deformity is meant that the several segments of the extremity are rotated in the same direction. By a mixed deformity is meant that there is an abnormal rotation in one segment in a given direction with an abnormal rotation in another segment in the opposite direction, such as increased anteversion of the femur with external tibial torsion or external rotation of the femur with internal tibial torsion. These deformities may be unilateral or bilateral. Also, the deformity may be located in only one segment-such as isolated internal torsion or isolated anteversion (8).

Internal rotation deformities

May be categorized broadly into congenital and acquired. The congenital form may be due to hereditary factors or intra-uterine positioning (table I). The acquired forms are usually due to abnormal postures (1). Such problems as tibia vara, dyschondroplasia, infantile or vitamin D resistant rickets, cerebral palsy and poliomyelitis may be etiologic factors in the production of these anatomic deformities. Frequently, as is the case with anteversion, as the patient matures, a compensatory external tibial torsion develops which gives him a superficial appearance of a normal gait. These children have a relatively high incidence of true or apparent bowleg and a certain amount of genu recurvatum which increases the apparent bowleg (4, 6, 7).

External rotation deformities

May be congenital, either on the basis of intra-uterine positioning or hereditary factors or they may be acquired (9). The most common cause of external rotation deformity in the lower extremity in the infant is at the hip, and this appears to be due to a constant frog-leg position, seen especially in the hypotonic infant.

This deformity is not uncommon and deserves treatment in infancy to avoid the persistent objectionable deformity of adulthood. These deformities may also be combined with internal tibial rotation deformity. Secondary internal tibial torsion is often seen as a compensatory deformity, which develops following attempt to walk with the toes pointed straight forward. Thus, a simple deformity may become a mixed deformity with growth (2, 5, 6).

Table I. Causes of Rotation Deformities

Causes of Internal Rotation Deformities	Causes of External Rotation Deformities
Soft-tissue contracture	Soft-tissue contracture
Anteversion of the femur	Loss of the normal femoral anteversion
Spastic internal rotators of the femora	Paralysis of internal rotators
Genu varus	Genu valgus
Internal tibial torsion	External tibial torsion
Metatarsus varus	Calcaneo valgus feet or pes planus
Pes planus or pes equinus	

There is a relatively high incidence of knock knees with patients who have external rotation deformities of the hips. This is explained by the Heuter-Volkmann Law, which in turn is invoked by an abnormal foot strike and, to some degree, by a tight iliotibial band. These children have an abnormal foot strike, in that the pressure is distributed over the lateral calcaneal tubercle, thereby transmitting more pressure to the lateral knee epiphyses which are thus inhibited and result in a knock knee deformity (3, 7).

Mechanics of Deformities

A rationale of diagnosis and treatment is based on the understanding of forces which modify epiphyseal growth.

Epiphyseal growth: The direction of growth of an epiphysis is modified by many factors: gravity, muscle imbalance, joint contractures, hereditary factors, nutrition, blood supply, disuse, infection and trauma. The Heuter-Volkmann Law of epiphyseal pressure states that increase in pressure across an epiphysis will decrease its growth; conversely, decreasing the pressure will increase the rate of growth.

Angular deformities which originate in the epiphyses result from asymmetric pressures applied parallel with the plane of epiphyseal growth, that is, perpendicular to the epiphyseal plate. Torsional deformities result from torque forces applied perpendicular to the plane of epiphyseal growth, that is, parallel with the plane of the epiphyseal plate (1, 2).

Nature of forces: The force required to produce or correct rotational or angular deformities is directly proportional to the width of the bone, and this is related to the age of the patient. Total force must be considered in regard to magnitude of force and duration of force. Thus, the same energy on the epiphyseal plate can be expended by a large force for a short time as can be expended by a small force for a longer time. The force needed for correction is equal and opposite to the deforming force, but since this cannot be calculated in magnitude or duration, the end point of anatomic alignment must be the criterion for correction (1, 2).

Diaphyseal changes: The thickened cortices which are noted in the diaphysis of long bones are the result of changes in the internal architecture secondary to stress (Wolff's Law). With the correction of these abnormal stresses, the diaphyseal changes can be observed to revert to normal. These diaphyseal deformities are the result of stresses imposed by rotational or angular deformities which originate in the epiphyseal areas (8).

Clinical examination in children with rotational deformities.

When a child is presented for examination, it is of the greatest importance that the entire extremity be examined, regardless of the initial complaint. One should observe gait patterns with and without shoes and examine all segments of the extremity in the standing, the sitting and the lying positions (fig. 1) (6).

Fig. 1. Antetorsion of the neck of the femur – clinical aspect.

HIPS: The extended position is the best method for determining the torsional deformity of the femur. The range of motion of the hip joint is examined thoroughly, and careful attention is paid to the ability to rotate internally and externally. The extended limbs are supported in the hands of the examiner over the end of the table, and the extremities are rotated simultaneously, internally and externally, measuring the degree of rotation. An alternate method of measuring hip rotation is with the patient prone and the knees flexed 90°. An internal rotation deformity of the hip is diagnosed when internal rotation exceeds external rotation by 30° or more. Conversely, if external rotation exceeds internal rotation by 30° or more, external rotation deformity is diagnosed (6, 7).

TIBIA: Tibial torsion should be measured while the patient sits on the edge of a table. The knee joint is flexed 90° and, with the foot supported passively, and with 90° of flexion at the ankle, the axis of the knee joint is compared with the axis of the ankle joint. A simple method is to relate the tibial tubercle to the malleoli. Normally, there is from 0 to 40° of external tibial torsion, the higher numbers occurring in adults (6, 7).

FOOT: The lateral border of the foot is noted to determine whether or not it is convex or straight. Also, the relationship of the plane of the metatarsals to the plane of the ankle joint is noted both while walking and on passive examination. The structure of the longitudinal arch of the foot is also noted (2, 6).

Conclusions

Deformities of the lower extremity in children are most frequently the result of intra-uterine positioning and congenital deformities. Sleeping, sitting and play habits of infancy have a great effect on the persistence of these deformities. It is not possible to predict which deformity will correct spontaneously; therefore, consideration should be given to treatment of the objectionable deformities and to prevention of the development of secondary deformities. Rotation deformities of the hips in older age groups are associated with actual change of normal femoral torsion. Treatment of soft-tissue contractures and deformities in infants may prevent skeletal deformities later in life. Rotation deformities may cause secondary angular deformities or may prevent the spontaneous correction of angular deformities by the Heuter-Volkmann or Wolff's Law. External rotation deformity of the hips in infants deserves recognition and treatment to prevent a cause for later knock knee and objectionable gait patterns in the adult. The early recognition and treatment of these deformities is better than a wait-and-see policy.

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