Lower limb deformity assessment and correction

Ross A Fawdington

Ben Johnson

Nigel T Kiely

Abstract

This paper draws on the work of Dror Paley et al and describes the basic principles of clinical and radiographic assessment of coronal plane lower limb deformity. It covers concepts of mechanical axis deviation and of the Centre of Rotation of Angulation (CORA) which influence the choice of corrective osteotomy shape and its location.

Keywords assessment; axes; correction; deformity; mechanical

Introduction

The word 'orthopaedics' is derived from the Greek *orthos* meaning "right" or "straight" and *paidion* meaning "child", therefore correction of deformity is fundamental to the speciality. Deformity can be defined as any departure from the normal bone or joint anatomy.[1] This paper describes how to analyze lower limb deformity and the principles and planning methods used in deformity correction.

A deformity may be described in relation to the coronal (frontal), sagittal (lateral) and axial (transverse) planes. Alternatively, deformity may be described as translation along and/or rotation around the *x, y and z* axes, hence there are six degrees of freedom. However, angular deformity only occurs in one true plane.

The most frequent cause of deformity varies with the age of the patient. In children the cause is likely to be congenital (e.g. fibular hemimelia, proximal femoral focal deficiency). In adolescents deformity may arise from trauma or pathology affecting the growth plate, such as infection, Blount's disease, diaphyseal aclasis, and rickets. In adults the majority of cases are secondary to mal- or non-union of fractures and in the elderly, metabolic conditions such as Paget's disease. Traumatic deformities are different to congenital deformities because there may be a translational component that may either compensate for or exaggerate the deformity.

***Ross A Fawdington** MBChB MRCS(Ed) Specialty Registrar Year 7, Trauma & Orthopaedics, Robert Jones & Agnes Hunt Orthopaedic Hospital, Oswestry, Shropshire, UK. Conflicts of interest: none declared.*

***Ben Johnson** MBChB FRCS(Orth) Specialty Registrar Year 8, Trauma & Orthopaedics, Robert Jones & Agnes Hunt Orthopaedic Hospital, Oswestry, Shropshire, UK. Conflicts of interest: none declared.*

***Nigel T Kiely** FRCS(Orth) Consultant Adult and Children's Orthopaedic Surgeon, Robert Jones & Agnes Hunt Orthopaedic Hospital, Oswestry, Shropshire, UK. Conflicts of interest: none declared.*

A lower limb deformity affects the mechanical axis of the limb i.e. how load is transferred through the bones and joints. A deformity may be well tolerated and not cause any functional problems initially, but to compensate for the deformity the arc of motion of adjacent joints may alter. This in turn can change the gait pattern and thus may present as muscle fatigue or pain as muscles work to maintain joint position and resist abnormal loads. As the joints are exposed to non-physiological loads, this may lead to early degenerative changes. Such secondary changes are usually inevitable in these circumstances, as the load on a joint is a function of the alignment of the bones relative to that joint.[2] The horizontal orientation of the joint lines at the hip, knee and ankle are essential anatomic determinants for all weight bearing functions.[3] If the joint line is tilted at any of these joints this generates shear forces across it, placing abnormal stress on the cartilage and ligamentous structures.[4]

The distance between the deformity and the compensating joint affects the deviation of the mechanical axis and thus the joint contact pressures. If the deformity affects the lower limb and is in the coronal plane the compensating joints are the hip and sub-talar joint. The knee cannot compensate in this plane therefore deformities of the distal femur or proximal tibia result in marked axis deviation and increased knee contact pressures. Deformity close to the hip or ankle joint does not give rise to a large axis deviation. However, it significantly changes the inclination of the joint, leading to a decrease in the contact area and a secondary increase in the contact pressure on the remaining load bearing articular cartilage.[1] As a sagittal plane deformity is compensated by the hip, knee and ankle joints, it is better tolerated. And finally, if a joint has a large multi-directional range of motion it has more capacity to accommodate a deformity.

Clinical assessment — standing

Clinical assessment should start with a standing examination of the patient. The patient should stand with their patellae facing forwards rather than rely on the foot position, as there may be a rotational component to the deformity. Inspection will reveal whether there is a deformity in the coronal (varus or valgus) or sagittal (apex anterior or posterior) planes. The patient may compensate for a leg length discrepancy by one of three mechanisms or a combination of them. The pelvis can tilt down towards the affected side, the ankle of the short limb may be held in equinus or the long limb can be flexed at the knee, which permits the knee of the short limb to be fully extended and the foot to be plantigrade.

Leg length assessment can be performed using blocks under the foot of the shorter limb combined with inspection and palpation of the posterior superior iliac spines (PSIS) with the patient bent forward slightly to make them more prominent [Figure 1a and b]. It should be recorded what thickness of block makes the patient feel level, balanced and comfortable and what thickness of block truly levels the pelvis; the two are not necessarily the same. The advantage of this technique is that the overall discrepancy from femur, tibia and foot is measured as a composite. The opportunity should also be taken to assess hip abductors by carrying out a Trendelenburg test.

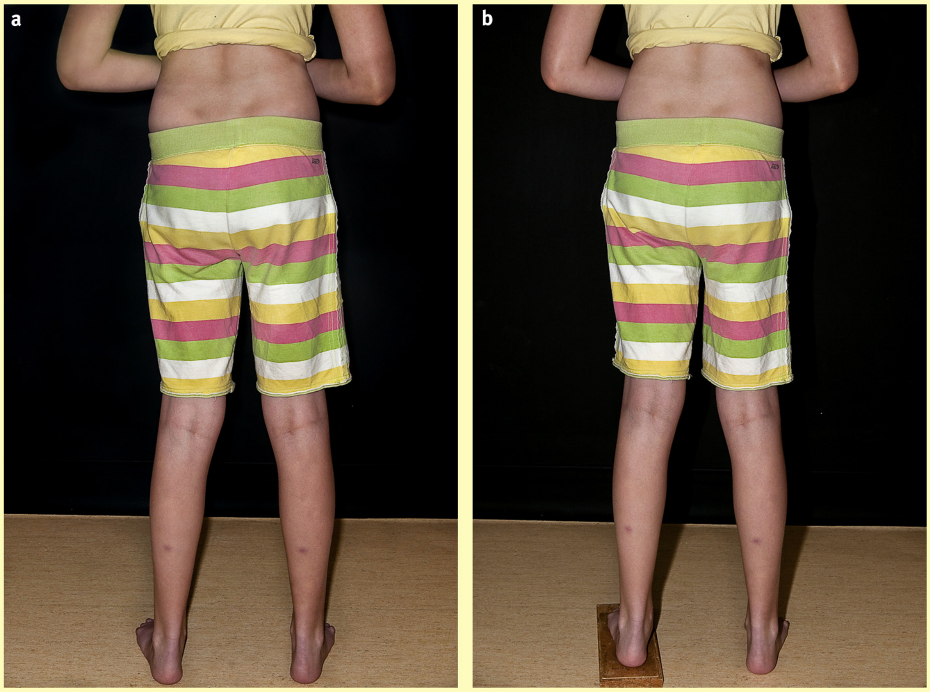

Figure 1 (**a**) A clinical photo demonstrating the unbalanced level of the posterior superior iliac spines (PSIS). (**b**) A clinical photo demonstrating the balanced posterior superior iliac spines (PSIS) using a wooden block under the short leg.

Clinical assessment — supine and prone

Examination with the patient supine on the couch should begin with levelling the pelvis relative to the long axis of the body. Each joint should then be examined to assess the range of movement and stability. While leg lengths can be assessed by tape measure, this method is often inaccurate and is not consistently reproducible. Additionally it does not measure shortening in the foot. A Galeazzi test should be performed to determine which segments are short. [Box 1]

With the patient prone, the rotational profile of the limb can be assessed. To measure the femoral anteversion (Gage test[5]), the knee should be flexed to 90° and the leg rotated while palpating the greater trochanter. When the trochanter is most prominent the femoral neck is in a horizontal orientation. The tibia can then be used as a goniometer, where the angle between the tibia and the vertical is the degree of femoral anteversion. This test assumes that there is no knee joint or tibial deformity.

To assess tibial torsion the knees are flexed to 90° and both tibiae are held vertical. An imaginary line connecting the medial and lateral malleoli is compared to the thigh axis to give the trans-malleolar axis. The foot-thigh angle is measured between a line that bisects the heel and the 2nd metatarsal and the longitudinal axis of the thigh. This can vary due to a subtalar joint deformity, tibial torsion or a mid-foot deformity. A mid-foot deformity will cause a break in the line between the calcaneal axis and the 2nd metatarsal, such as with metatarsus adductus.

How to perform a Galeazzi test

- The patient is supine on the examination couch
- Level the pelvis
- Flex both knees to 90° and place both medial malleoli together with the feet resting on the couch [Figure 2a]
- Inspect the knees from the side [Figure 2b]
- If the *end* of the distal femur is shorter/longer than the contra-lateral limb, there is a discrepancy in the femoral segment.
- If the *anterior* aspect of the distal femur is shorter/longer than the contra-lateral limb, there is a discrepancy in the tibial segment.

Box 1

Radiographic assessment

Plain radiographs must be standardized and if only assessing one segment, must include the joint above and below e.g. tibia including knee and ankle. With digital scaled radiographs leg lengths can be measured from standing films. Standard antero-posterior (AP) and lateral radiographs are usually sufficient and the beam must be centred on the bone or joint in question. Leg length and alignment are taken weight-bearing with the patellae facing forwards (centred on the femoral condyles) and any length inequality should be corrected using blocks to avoid compensatory mechanisms such as knee flexion, which would distort measurements. The plate and X-ray source should be sufficiently far away from each other to provide views of the joints without distortion due to parallax.[1] It is important to have views of the contra-lateral limb to act as a reference of normality. If the contra-lateral limb is abnormal, then standard reference measurements and angles can be used instead.

