

Lower limb asymmetry: Imaging evaluation in children

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Abstract. Limb length discrepancy or anisomelia has long been objectified with imaging. The biomechanical implications for patients with a developing skeleton are more relevant than the cosmetic aspects, both in treatment and in follow-up. The aim of this publication is to review the most common causes of lower limb asymmetry in children, with emphasis on imaging findings, which are of great importance for clinical management. A retrospective review was performed on patients younger than 15 years, who required evaluation at our center for lower limb asymmetry, using simple X-ray, CT scan and /or MRI. The anatomical findings and morphometric analysis were recorded for each case. The causes of limb length discrepancy are many, including congenital and sequelae conditions. A knowledge and proper assessment of the imaging findings helps to improve and standardize the radiology report. Key words: Anisomelia, Asymmetry, Lower extremities.

Resumen. La asimetría de extremidades inferiores o anisomelia ha sido largamente objetivada con imágenes y posee implicancias biomecánicas para los pacientes con esqueleto en desarrollo que son más relevantes que los aspectos cosméticos, tanto en su tratamiento como en el seguimiento. El objetivo de esta publicación es revisar las causas más frecuentes de asimetría de extremidades inferiores en la edad pediátrica con énfasis en los hallazgos imaginológicos, que son de gran importancia para el manejo clínico. Se realizó una revisión retrospectiva de pacientes menores de 15 años que requirieron evaluación en nuestro centro por asimetría de extremidades inferiores mediante radiografía simple, tomografía computarizada y/o resonancia magnética, consignando los hallazgos anatómicos y el análisis morfométrico para cada caso. Las causas de anisomelia son múltiples, incluyendo trastornos congénitos y secuelas. Su conocimiento y la adecuada valoración de los hallazgos en imágenes permiten enriquecer y estandarizar el informe radiológico. Palabras clave: Anisomelia, Asimetría, Extremidades inferiores.

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Introduction

Anisomelia or lower limb length discrepancy is a common cause of radiographic study in children. While the discrepancy in length between the extremities is frequent in the population, with reports that refer to between 40 and 70%⁽¹⁾ being affected, the impact of these asymmetries is variable and there is no agreement in literature on the concept of significant discrepancy nor in treatment indications. Some authors define anisomelia with discrepancies above 20 or 30 mm, while others determine its importance in terms of functional outcome⁽²⁻⁴⁾. Among the results of asymmetry, McCaw describes stress fractures, back pain and osteoarthritis⁽⁵⁾.

With an outlook on the long term results for these

patients, it is reasonable to consider that the age at installation of the discrepancy will be a factor, in addition to the magnitude of the asymmetry. The possibilities for remodeling and compensation for children far outweigh that for adults faced with a discrepancy acquired at an older age, giving rise to different therapeutic interventions⁽⁵⁾. Moreover, the activity of the individual is also a determinant in deciding treatment and so for example, athletic children may have symptomatology with asymmetries of lower magnitude in relation to more sedentary children.

Imaging study

There are several clinical measurement methods that seek to objectify the asymmetry of lower limbs.

Among the most used are highlighted the difference found in the measurement from the anterior superior iliac spine to the medial malleolus, also known as true anisomelia and the attempt to match the limbs by placing blocks of known dimensions under the shorter leg while standing, called functional anisomelia. Both require pre-objectifying the absence of contractures and anomalous bending of the joints, allowing the true anisomelias to be distinguished from those considered as apparent.

The radiological study has been considered the gold standard in the evaluation of anisomelias. Throughout history different measuring techniques have been used:

- Scanogram, which uses three different exposures for hip, knee and ankle, with subsequent representation on a numbered grid. This technique has no magnification errors but increases the time and cost of the study as well as the radiation dose to the patient.
- Teleradiography (TLR) or lower extremities radiograph as it is called today, consisting of a single exposure, including from the hips to the ankles with a source distanced 1.80 m from the patient, which reduces magnification errors. Alignment of the extremities is achieved with kneecaps in the frontal position, as varus or valgus deformities could be masked by internal or external rotation of the limb. The three dimensional (3D) assessment of the limb is reserved for some particular deformities and requires additional lateral projection⁽⁷⁾. Projections obtained with "lifts" for the shorter limb prevent involuntary flexion of the contralateral knee, underestimating the asymmetry and minimizing the possibility of distortion by distraction of the beam towards the hip and ankles.
- Computed tomography (CT) scanogram or scout has also been used, with an increased cost and radiation dose, so its use is restricted to axial and torsional deformities.
- Magnetic resonance imaging (MRI) has been used as support to teleradiography due to the absence of ionizing radiation and the ability to characterize the abnormalities of associated soft tissue⁽⁸⁾.

Teleradiography has now emerged as the method of choice for analyzing anisomelia, because it allows visualization of the entire lower extremities, with few distortion alterations caused by movement of the patient. The advent of digital radiology has helped to reduce radiation doses by up to 12 times that of conventional radiography⁽⁶⁾, adding the possibility of subsequent information processing and significantly improving the methods of presentation and storage of the test, formerly

considered a major problem. Having the radiograph of the lower extremities then as the focus of our evaluation in these patients and having as the goal to objectify the anatomical differences between one segment and the contralateral, it is necessary to mention that there is no agreement on anatomical milestones considered as reference in the measurements. This creates potential inter-observer variations, which added to the patient's own variations could influence the therapeutic conduct⁽⁹⁾. However, all methods agree on the establishment of a dimension for each limb from the pelvis to the ankle, which eliminates the contribution of the foot in the total length of the limb. Used for measurement of the segments of the lower extremities at femur level was the tangent to the most proximal point of the proximal femoral epiphysis or the margin of the greater trochanter and the tangent to the most distal point of the medial femoral condyle or to the intercondylar notch. In the tibia was used the tangent to the tibial plateau or to the intercondylar eminence up to midpoint of the distal tibia, in the ankle⁽⁶⁾. Considering the variations of ossification of the pediatric patients, in our center we use the distance between the tangents to the most proximal point of the proximal femoral epiphysis and the intercondylar notch for the femur and the tangents to the intercondylar eminence and to the midpoint of the distal tibia for the tibial component (Figure 1).



Figure 1. Teleradiograph (TLR) of lower extremities, frontal projection. Measurement of anatomical segments of both limbs. The total length of each limb is the sum of the length of the femur and tibia of each side.

Causes

Causes of anisomelia can be divided into two groups: congenital and acquired (sequelae conditions). Within the congenital we find those related to structural defects such as aplasia or femoral hypoplasia, fibular hemimelia, posteromedial tibial deformity, hip dislocation among others and those non-structural such as hemihypertrophy, congenital vascular abnormalities (Klippel-Trenaunay-Weber Syndrome) and neurofibromatosis (NF). Among the sequelae causes are considered the aftermath of trauma (fracture malunion and Salter-Harris fractures types III, IV and V), infections, neurological conditions (cerebral palsy, spinal dysraphias), malignancies (bone tumors, radiotherapy) and alterations of the axis (Table I). We will revise some examples in the following section.

Distal femoral focal deficiency

The distal femoral focal deficiency (Figure 2), unlike its proximal counterpart, is an extremely rare clinical-radiological entity, of which there are isolated case reports in literature, mainly associated with tibial agenesis⁽¹⁰⁾. Clinical suspicion is established at birth, with the observation of a shorter lower extremity and is confirmed with imaging studies. Assumed as causes are the embryological alteration in the differentiation of the bud that originates the lower extremities (about the 5th to 7th weeks of gestation) and the lack of neurotrophic stimulus from nerve destruction, a finding related to diabetic mothers.

An association exists with fibular hemimelia and malformations of the tibia, although less evident than in the proximal femoral focal deficiency, suggesting that the distal deficiency would be part of a spectrum more than of an isolated entity⁽¹⁰⁾.

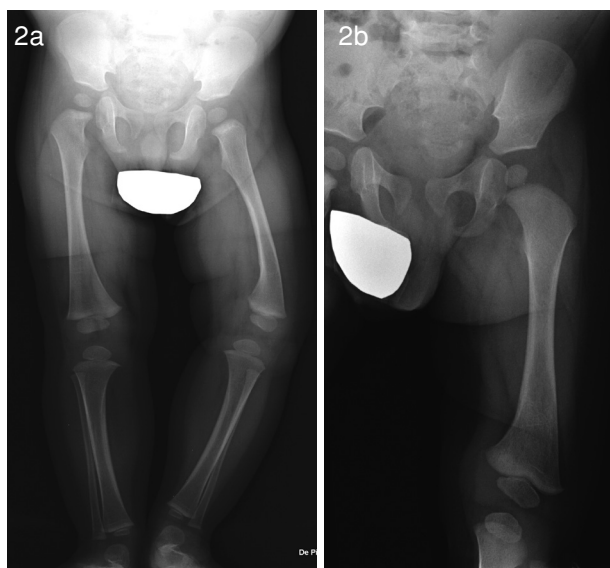


Figure 2. 9 month old patient, in study for pelvic inclination and shortening of left lower extremity. TLR shows left femur 6 mm shorter than the contralateral and marked genu varus. a) A localized projection of the femur. b) Showing discrete curvature of its distal third associated with oblique arrangement of the physis, suggestive of femoral focal deficiency.

Fibular Hypoplasia

Fibular hypoplasia or fibular hemimelia (Figure 3) is the deficiency that most commonly affects the long bones and includes a broad spectrum from the discrete shortening of the fibula to its complete absence⁽¹¹⁾.

Aplasias or fibular hypoplasias are often accompanied by tibial shortening, valgus or equinovalgus foot and tarsal synostosis. Severe cases may also be accompanied by shortening of the femur, describing association with proximal femoral focal deficiency^(11,12).

Table I. Causes of lower limb asymmetry in children.	
Causes of anisomelia	
Congenital malformative	Aplasia, Hypoplasia or femoral focal defect Hemimelia or fibular hypoplasia Posteromedial tibial deformity
Congenital non-malformative	Hemihypertrophy Vascular abnormalities (Klippel-Trenaunay-Weber Syndrome) Neurofibromatosis
Acquired	Trauma sequelae (Salter-Harris fractures III, IV, V) Infections Tumors Vascular alteration sequelae Axis deviation (Genu valgum, Genu varus) Neurological conditions



Figure 3. 1 year 6 months old patient with prenatal diagnosis of fibular hemimelia, in study for difficulty when starting to walk. The right lower extremity projects 2.2 cm shorter than the contra lateral with valgus deformity. The femur and tibia are also observed shortened.

Klippel-Trenaunay-Weber Syndrome

Klippel-Trenaunay-Weber Syndrome (KTWS) (Figure 5) is a congenital disorder characterized by capillary, venous, lymphatic or mixed malformations associated with bony and/or soft tissue hypertrophy that cause anisomelias. There is no predilection toward race or gender in its presentation and its cause is unknown, with an important embryological component in its pathogenesis. The condition involves increased blood flow that causes hypertrophy of the physis and the appearance of nevi, superficial varicose veins in response to hypoplasia of the deep venous system and venous stasis, determining hypertrophy of the affected segment (Figure 6). The conditions are usually unilateral, although there are isolated reports of bilateral involvement⁽¹²⁾. Asymmetry rarely increases after age 12, although the behavior of anisomelia is unpredictable⁽¹⁵⁾.

Hemihypertrophy

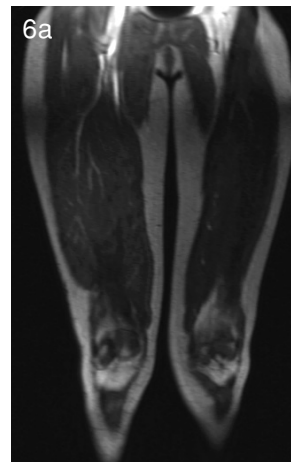
Hemihypertrophy (Figure 4) has been regarded by some authors as one of the rarest and fascinating developmental anomalies⁽¹³⁾. It consists of overgrowth of one side of the body, partially or completely, in the absence of neurological disorders, endocrine, vascular or another, so it is a diagnosis of exclusion. The event is evident at birth, but the severity develops gradually. It is associated with many birth defects such as mental retardation, renal and neoplastic disorders, among which stand out Wilms tumor, adrenal carcinoma and hepatoblastoma⁽¹⁴⁾. Its cause is unknown, but there is evidence of multifactorial alteration including embryological and chromosomal disorders. The main differential diagnosis of this disorder is hemiatrophy of neurological origin, so we need a thorough and comprehensive analysis from the neurological point of view in all these patients.



Figure 5. 10 yr 6 month old patient, Klippel-Trenaunay-Weber Syndrome carrier. Radiological study shows asymmetry of limbs with longer length in 27 mm to the right.



Figure 4. 6 yr old patient, carrier of hemihypertrophy, with intermittent monitoring for pelvic slope. TLR shows left lower extremity 23 mm longer, at the expense of the femoral component, with concordant pelvic slope. The soft tissue is prominent to the left.



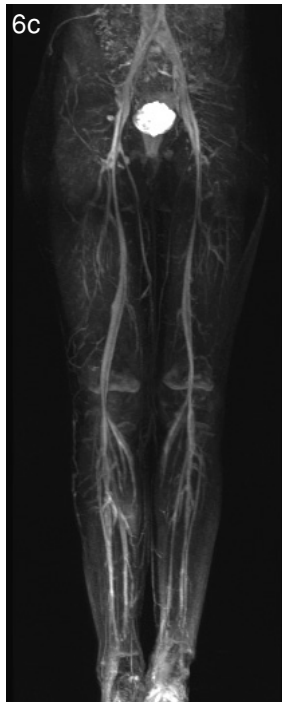


Figure 6. Klippel-Trenaunay-Weber Syndrome (same patient as Figure 5). MRI T1 gradient echo with contrast. a, b) subtraction angiography sequence c) Showing thicker muscular and adipose levels of the right leg with prominence of venous vascular structures in the thigh and leg.

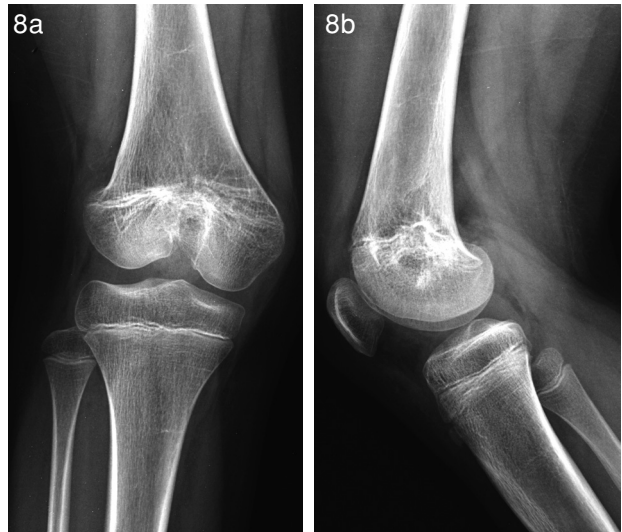


Figure 8. Fracture sequel (same patient as in Figure 7). a) Frontal projection. b) Lateral of knee. Deformity of distal femur with premature fusion of the physis, associated with coarse trabeculation and adjacent sclerosis, can be observed.

Sequelae of traumatismos

Traumatismos and their sequelae are common causes of anisomelia; in the majority of cases the asymmetry originates from bone shortening (Figure 7). In epiphyseometaphyseal lesions, shortening results from the presence of Salter-Harris III, IV and V type fractures that repair with bone bridges at the physis level and generate axis deviations of the affected bones and even of the extremity⁽¹²⁾ (Figure 8).



Figure 7. 10 year old patient, history of fall from a height at age 6 with direct impact on the right knee and Salter V fracture. TLR shows shortening of the right lower extremity of 5.4 cm and valgus deviation with respect to the contra lateral.

In the case of diaphyseal fractures, it is possible to observe bone growth stimulation during the repair process of the lesion, which causes difficulty when sketching the final prognosis for the bone remodeling process, although it has been considered that if there is an asymmetry of less than 3 cm in the three years following the fracture, bone growth should be stable until puberty⁽¹²⁾.

Electrical or burns traumas and the prolonged immobilization from musculoskeletal injuries can lead to alterations in growth and also generate anisomelia.

Infections

Osteoarticular infections could alter growth areas through various mechanisms: localization of bacteria in bone microcirculation, epiphyseal detachment and contributing to the appearance of fractures.

Septic arthritis affects in a variable way the growth cartilage, causing asymmetries and alterations in the axial axis (Figure 9), more severe in infants with septic arthritis of the hip⁽¹²⁾. If the affected area is only the long bone diaphysis, osteomyelitis usually causes modest shortening, but if the condition compromises the physis, shortening may be more significant. Some disorders require special care, for example purpura fulminans since its microthrombotic-microembolic septic behavior can lead to amputations⁽¹²⁾.

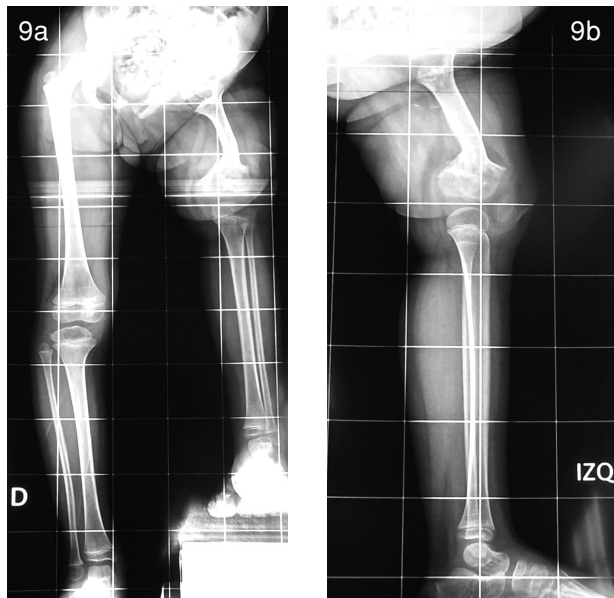


Figure 9. 4 year 10 months old patient with a history of neonatal sepsis and septic arthritis of the left hip, currently under evaluation for gait alterations. TLR frontal projection (a) and lateral (b) show severe asymmetry of lower limbs with shortening of 9 cm in the left lower extremity, at expense of the femoral component, which is observed deformed and widened in its proximal aspect.

Tumors

Tumors are an important and common cause of anisomelia. Tumors of cartilage origin and benign, either isolated enchondromas or as part of a multiple enchondromatosis syndrome (Figure 10), can cause bone deformities and anisomelia when located near the growth cartilages (Figure 11) and may also have malignant transformation⁽¹⁶⁾. Other tumors can stimulate temporal limb growth such as osteoid osteoma, or delay bone growth as occurs after the administration of corticoids in bone cysts⁽¹²⁾.



Figure 10. 7 year 6 months old patient, in study for pelvic slope and discomfort with gait. The length of the right lower extremity is 34 mm less, associated with the presence of radiolucent lesions with sclerotic borders in proximal femur, distal and proximal tibia, whose biopsy showed multiple enchondromas.

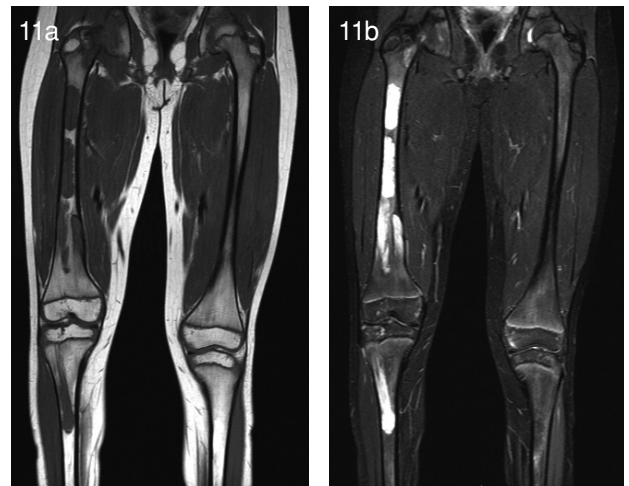


Figure 11. Enchondromatosis (same patient as in Figure 10). MRI T1 spin echo (a) and T2 STIR (b) show non-aggressive looking multiple lesions hypointense on T1, hypointense on T2, without calcifications.

Radiation therapy is used in treatment of malignant tumors can lead to injury of the physis, especially when tumors are located adjacent to this, a frequent situation in this type of tumor lesions.

Acquired vascular disorders

Vascular disorders, among which include ischemia, arteriovenous fistulas, Perthes disease and some non-malformative causes such as Klippel-Trenaunay-Weber Syndrome are a group of clinical entities that can produce moderate anisomelias, with a discrepancy usually lower than 5 cm (Figure 12).

There are few reports in literature of congenital vascular causes for anisomelia such as Klippel-Trenaunay-Weber Syndrome, and rarer still are the descriptions of its vascular manifestations, only case reports exist. The description of ischemic causes are also unusual, very small series being available in literature, where the most frequently described etiologies are iatrogenic injuries⁽¹⁷⁾ (Figure 13). Femoral artery catheterization for diagnostic and monitoring purposes is one of the most important causes and its complications are to be expected given the small vessel diameter in children (Figure 14). A 33% growth retardation of lower limbs secondary to ischemia installed for more than 30 days has been described; behavior in these cases is controversial because of the limited experience found. Opinions from experts recommend early reperfusion when the proximal arterial area is altered and heparin therapy in distal obstructions or those that are outside the range of early intervention⁽¹⁷⁾.

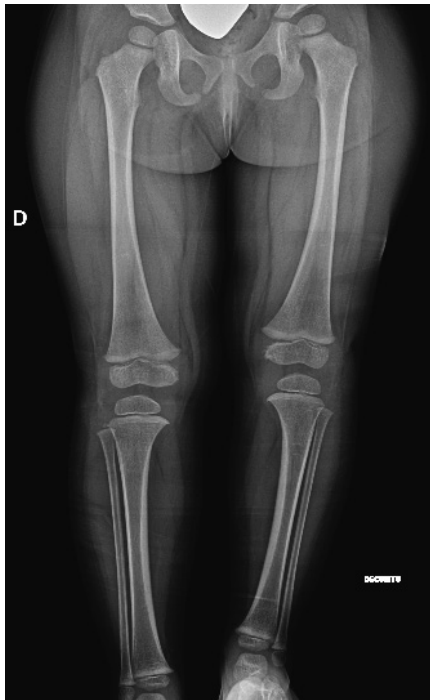


Figure 12. 2 year old patient, with a history of hospitalization for prematurity with surfactant deficiency illness and necrotizing enterocolitis and a history of multiple punctures to install catheters. Under evaluation for suspected overgrowth syndrome. TLR shows left lower extremity 1.3 cm shorter, at the expense of the tibial segment, without obvious deformity. Indicated treatment is shoe lift, well tolerated. In control at 2 years 8 months, alteration persists and Doppler ultrasound of right lower extremity is sought for suspected overgrowth.

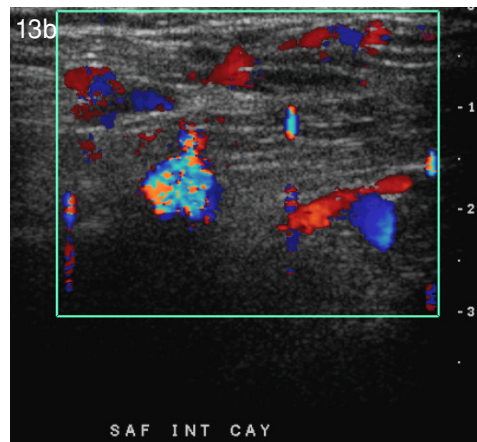
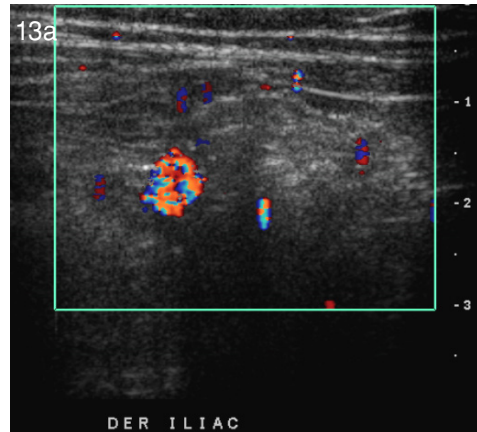


Figure 13. Doppler ultrasound of lower extremities (same patient as in Figure 12). No display of the common femoral veins and right external iliacs (a) with development of multiple collateral veins in relation to the rod of the internal saphenous vein (b).

Genu valgum

Genu valgum is a dynamic and even physiological concept in gait maturation in children. Older studies indicated its appearance as normal in children of between 2 and 12 years⁽¹⁸⁾, but now this condition is accepted until 6-7 years, emphasizing that it may increase in early adolescence due to lack of bone remodeling. The exact cause is unknown, but the defective development of the lateral femoral condyle, the medial collateral ligament laxity of the knee, obesity and flat feet have been implicated in its appearance.

Genu valgum is usually an aesthetic and functional problem, with an awkward-looking painless gait. The clinical assessment of this condition is rather subjective and radiology provides vital information, aiming at increasing the medial femorotibial vertex angle to above 8-9° in girls and above 6° in boys (Figure 15).

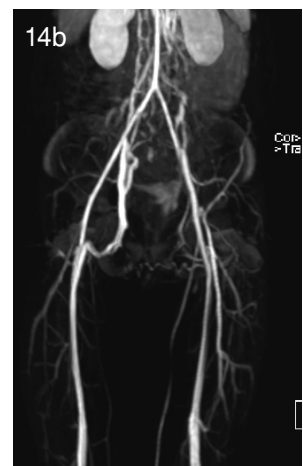
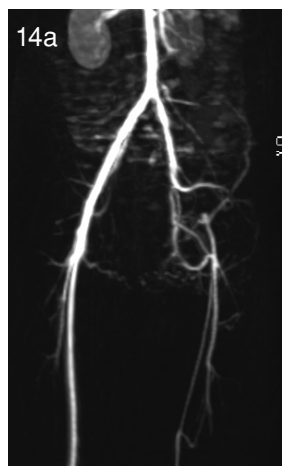


Figure 14. Arterial angiography and venous MRI sequences (same patient Figure 12 and 13). In arterial phase (a), no display of the left external iliac artery with prominent collaterals towards common and superficial left femoral arteries. In venous phase (b) no display of right common femoral and iliac veins and the inferior vena cava, with marked presence of collaterals draining into ascending lumbar veins.



Figure 15. 8 year old patient with suspected scoliosis and genu valgum. Full spine radiograph without evidence of scoliosis. TLR of lower extremities shows a pelvic slope with right femoral head, shortening of the right leg in 14 mm with genu valgum estimated at 14°.

Treatment and control

It is a fact that in nature inequality is the norm and lower extremities are no exception. This is how it has been estimated that differences of up to 10 mm in adults are frequent and asymptomatic. Regarding major differences, although it is possible to find some agreement in literature in the category of asymmetry in terms of the magnitude and treatment recommendations (Table II), these concepts should be considered as a reference in choosing therapeutic options for each particular patient.

The timing and nature of the treatment of children with anisomelia will depend then on both the objective asymmetry and the underlying cause. These factors, in turn, are influenced by the functional repercussions at the time of diagnosis and the great possibility for remodeling that the child’s skeleton offers. The prediction of the magnitude of the discrepancy at the end of growth has been associated both with chronological age and bone age according to the Greulich and Pyle atlas without agreement among specialists about the best predictor element.

Table II. Lower extremities Asymmetry. Magnitude and its relationship with treatment.		
Asymmetries	Difference in length	Treatment
Mild	5 mm - 20 mm	Orthopedic
Moderate	20-50 mm	Surgical
Severe	Greater than 50 mm	Surgical

Differences of up to 20 mm in symptomatic children are usually treated orthopedically with “lifts” installed inside the shoe (Figure 16). However, minor asymmetries might require surgery. Angular deformities with asymmetries that remain stable despite orthopedic treatment benefit from procedures such as epiphysiodesis, which allows correction of angular deformity, with a consequent reduction of the asymmetry (Figure 17). Moreover, certain structural changes prognosticate progressive deformities if they are not corrected (Figure 18). Surgery in these cases repairs the structural deformity and stops the progression of the asymmetry as well as eventual angular deviations (Figure 19).



Figure 16. Hemipertrophy, treatment with lifts in footwear, without gait alterations (same patient as in Figure 4). TLR control at 2 years of treatment shows stabilization of the asymmetry in 20mm.



Figure 17. Genu valgum, control six months after medial epiphysiodesis of the right distal femur (same patient as in Figure 15). TLR shows rapid correction of valgus deformity.

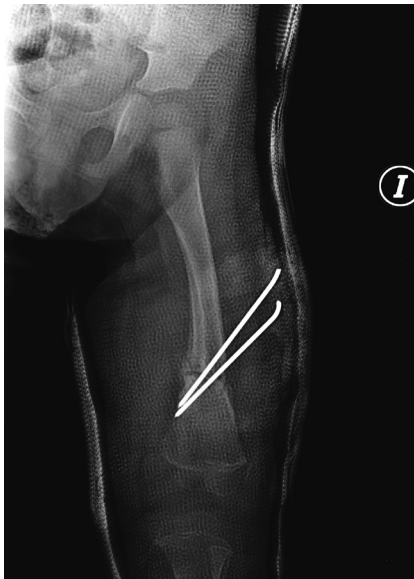


Figure 18. Distal femoral focal deficiency, corrective osteotomy (same patient as in Figure 2). Localized radiograph, with transverse metaphyseal osteotomy and osteosynthesis needles.



Figure 19. Distal femoral deficiency, control two years after corrective osteotomy (same patient as in Figures 2 and 17). TLR shows correction of the distal femoral structural deformities and varus angle of the extremity, with asymmetry of 7 mm.

Moderate anisomelias are typically candidates for surgical treatment with epiphysiodesis, focally slowing the growth of one or more bone segments (Figure 20). Severe asymmetries, greater than 60 mm and involving substantial functional impairment, require bony enlargements that may or may not be combined with other procedures⁽⁸⁾ (Figure 21). The devices used allow not only distraction in the elongation locations but also the management of rotation forces, such as the Ilizarov-type devices⁽¹⁹⁾.

Expectant management or with minimal intervention is also an alternative to unusual underlying causes

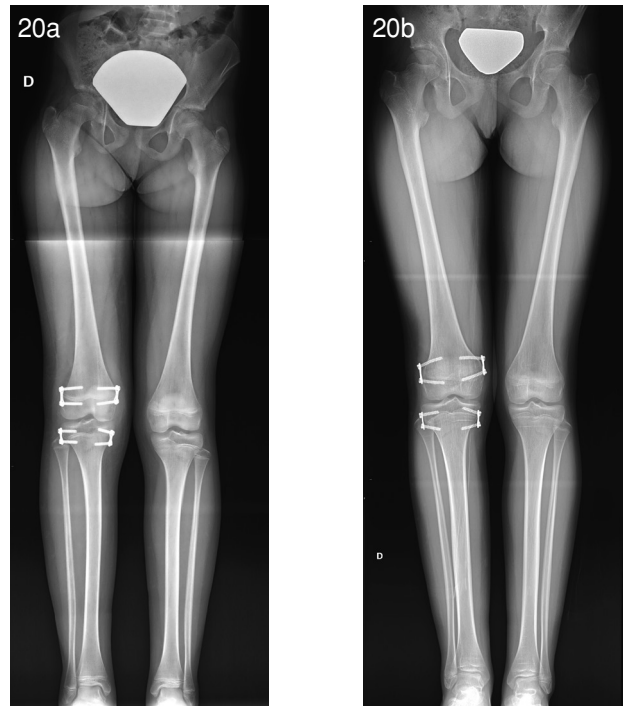


Figure 20. Klippel-Trenaunay-Weber Syndrome (same patient as in Figure 5). Control after 3 months (a) and 1 year and 6 months (b) after epiphysiodesis of distal femur and proximal tibia. TLR shows asymmetry decreased to 20 mm in the initial control and then to 4 mm in the most recent.

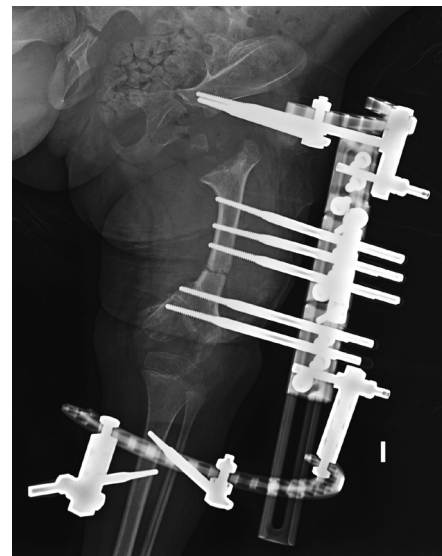


Figure 21. Septic arthritis sequelae of the right hip (same patient as in Figure 9). Control of surgery for femoral lengthening with distal diaphyseal osteotomy and distraction with hybrid external fixator, with principal monoplanar components and a secondary rotational one (Ilizarov type) with iliac, femoral and tibial fixations.

where the progression of the disease or deformity is uncertain. This is the case for patients in our series, with asymmetry secondary to tumors and vascular abnormalities. In these cases, radiological control should collaborate to establish the time and need for further interventions.

In patients being treated, monitoring changes due to the treatment and the detection of possible complications of the procedures or of the support devices are the main indications for serialized radiographic evaluation of these patients. Thus, the focus of the radiographic evaluation must be engaged to contribute to the early detection of malunions, poor alignment, angulation, joint deformity, neurovascular problems, infections and mechanical failure of the devices⁽¹⁹⁾.

The repercussions of anisomelia in adulthood may be a direct consequence of alterations in the extremities, such as osteoarthritis and lameness or may extend beyond those, with the presence of chronic low back pain, difficulty in walking and increased secondary energy expenditure to the development of compensatory muscles on a skeleton facing dwindling laxity and plasticity.

Conclusion

The causes of asymmetry of the lower limbs cover a wide spectrum of disorders. Knowledge of these alterations and their clinical behavior allows us a better assessment of the imaging findings.

The radiological report is an important tool for both the diagnosis and clinical management of these patients, having as a joint goal for clinicians and radiologists the functional and aesthetic limb prognosis in adult life.

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