The whole leg radiograph and radiation exposure in pediatrics

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Learning objectives

- To explain the whole leg radiograph (WLR) as a radiographical procedure, illustrating that with digital fluoroscopic imaging the WLR is quick and easy to perform.
- To present the related Dose Area Product (DAP) received by 34 paediatric patients aged 3-10 years undergoing the WLR procedure.

Background

Trauma, congenital or developmental skeletal disorders may cause an angular and/or positional deformity consequently resulting in some form of malalignment and/or limb length discrepancy (LLD). This has been shown to have important biomechanical consequences in paediatrics and early adolescence as it can influence development of other abnormalities. LLD causes a pelvic obliquity in the coronal plane which may subsequently result in discopathy, coxarthrosis, knee osteoarthritis (OA), low back pain or posture deformation, e.g. lumbar scoliosis with convexity towards the short extremity.

Frontal plane malalignment may either be a varus, valgus angulation and/or a translation deformity. In knee OA, a malalignment in both knees of $> 5^\circ$ in either valgus or varus deviation is associated with significantly greater functional decline over time compared to less malaligned knees. Varus deviation appears to be the most common deformity. However, it should be noted that healthy individuals generally demonstrate a slight varus angulation of 1-2°. (Fig.1)

Precise and accurate measurements of lower extremity alignment are a prerequisite for both research and clinical handling of the cause of misalignment. To determine axial alignment of the lower extremities the whole leg radiograph (WLR) is considered the gold standard. However, despite its popularity, this technique is argued to be costly, time consuming and unfeasible for many local hospitals, in addition to expose the patient to a high radiation dose.

The International Commission on Radiological Protection (ICRP) regards three basic principles concerning radiation protection as fundamental for radiation protection in all planned, emergency and existing exposure situations. First and foremost, the examination should be justified. One should reduce existing exposure and maximise the margin of benefit over harm to avoid severely inequitable outcomes. The principle of optimisation of protection states that the individual dose received should be kept as low as reasonable achievable.
Fig. 1: Figure showing the difference in a valgus and varus deviation of the lower extremeties compared to normal alignment.
Imaging findings OR Procedure details

This part of the exhibit will describe the whole leg radiograph (WLR) procedure to measure the Hip-Knee-Ankle (HKA) angle and present the related Dose Area Product (DAP) received by 34 patients aged 3-10 years.

A WLR examination includes a frontal anteroposterior (AP) image and a lateral image of each leg separately. The majority of WLR examinations are confined to an AP image only; in addition to reduce radiation exposure, the patient may not have a malalignment in the sagittal plane. If further imaging is required to determine limb deformity, the limb in question will be imaged separately in the lateral position, and only occasionally with the opposite limb for comparison. The images must cover the hip, knee and ankle joints in order to accurately measure the HKA angle.

The patient

The frontal WLR is achieved with the patient standing in the AP position. The patient is barefoot with maximum knee extension and equal weight on both feet. The patient is positioned in a correct weight bearing axis which runs as a vertical line from the centre of the femoral head to the centre of the talus. When a lateral WLR image is required a true lateral projection is ensured by outlining the patient’s footprint in the AP position and turning it 90 degrees.

If limb length discrepancy is present, the pelvis is levelled by placing blocks of known height under the shortest limb. This is important to ensure maximum knee extension and subsequently a correct weight bearing axis. The precise discrepancy is obtained by using low dose fluoroscopy at the hip area, only imaging the acetabular roofs. The pelvis is levelled when the acetabular roofs are equal in height.

A lead marker is placed at the anterior centre of the patella. The patella with the marker is then positioned right above the femoral intercondylar notch, using low dose fluoroscopy. A transparent metric ruler with millimetre markings is placed behind the patient at the centre ray. With the use of calibration tools in the Picture Archive and Communication System (PACS), correctly calibrated measurements of the axis alignment and HKA angle's are calculated. (Fig. 2)

Equipment
The WLR is acquired using digital fluoroscopy equipment. The Source-Image-Distance is 125 cm from the over-couch tube to the 48 cm flat-field detector. The exposure parameters are defined by patient size. However, 82 kVp and 160-320 mA are routinely used in correlation with software designed to rapidly regulate the parameters to acquire optimal exposure.

Time

The images are obtained using a vertical dynamic exposure run. The speed of acquisition is adjusted to a frame speed of 3.8 images per second. An average of 20-30 images is recorded during the dynamic exposure run, depending on the child's height. The exposure run is therefore completed after 7-10 seconds and the whole examination is concluded within 3-5 minutes, depending on how cooperative the child is. The images are post-processed and reconstructed to one complete leg overview.

Dose

Having acquired approval from the institutional review board, the PACS was searched for all WLR examinations performed in the Department of Radiology between March 2012 and November 2012. Patients younger than ten years of age when undergoing the WLR examination were identified. Children below the age of three years are typically unable to stand independently thus requiring modification of the WLR procedure. These patients were therefore excluded from the study. Children with only a frontal image were included in our data. A total of 34 paediatric patients aged 3-10 years were identified. The Dose Area Product (DAP) denoted in µGy*m² was then collected for all 34 patients.

The data shows that the mean dose for WLR is 11.6 µGy*m² with a median of 8 µGy*m² (Tab. 1). There is a tendency towards increasing DAP with increasing age, although the DAP values varies more greatly from seven years of age which may be due to greater variation in patient size (Fig. 3).

The study has limitations: patient weight and height were not documented. Investigation into a potential correlation between patient dose and patient size is therefore not possible, and discrepancies in radiation dose may also be attributed to operator or machine malfunction. A further limitation is the relatively small sample size. A larger sample size could provide more reliable data.

Images for this section:
**Fig. 1:** Figure showing the difference in a valgus and varus deviation of the lower extremities compared to normal alignment.
Fig. 2: A frontal whole leg radiograph showing measurements of the axis alignment.

<table>
<thead>
<tr>
<th>Age / Year</th>
<th>Patients / n</th>
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<th>Median / μGy·m²</th>
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</table>

Table 1: Table showing the mean and median Dose Area Product related to age (years) and the number of patients in each age group.
Fig. 3: The data shows a tendency towards increasing Dose Area Product with increasing age.
Conclusion

Employing digital radiography the whole leg radiograph procedure is carried out in 3-5 minutes in our institution. The Dose Area Product for 34 patients aged 3-10 years shows a mean radiation dose of 11.6 µGy*m² and a median of 8 µGy*m².

References


Personal Information