Radiographic Outcomes and Evaluation of Developmental Dysplasia of the Hip in Children

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ABSTRACT

The Developmental Dysplasia of the Hip (DDH), also know as Congenital Dislocation of the Hip, is common in infants and children and may persist into adulthood. The radiographic interpretation is highly conditioned by appropriate patient positioning and image quality criteria. The main goal of this study is to demonstrate the value of radiographic evaluation of DDH. Through the retrospective analysis of 65 radiographs of the hips, only 2 (3.1%) female patients with 1-2 years of age presented radiographic findings of DDH. The inappropriate field size and the improper placement and size of the gonadal shields, were the most common errors observed.

Keywords: Developmental Dysplasia of the Hip, Radiographic Evaluation, Pediatric Hip Radiography, Radiographic Imaging Techniques, Radiographic Image Findings.

RESUMO

A Displasia de Desenvolvimento da Anca (DDA), também conhecida como Luxação Congénita da Anca, é comum em bebés e crianças, podendo persistir na idade adulta. A interpretação radiográfica é altamente condicionada pelo posicionamento do paciente e critérios de qualidade da imagem. O principal objectivo deste estudo é demonstrar o valor da avaliação radiográfica da DDH. Através da análise retrospectiva de 65 radiografias da bacia, apenas 2 (3,1%) pacientes do sexo feminino com idades entre 1-2 anos apresentaram achados radiográficos de DDH. O tamanho inadequado do chassi e a colocação e tamanho incorrecto das protecções gonadais, foram os erros mais comumente observados.

Palavras-chave: Displasia de Desenvolvimento da Anca, Avaliação Radiográfica, Radiografia da Anca Pediátrica, Técnicas Radiográficas, Achados Imagiológicos.

1. INTRODUCTION

The full spectrum of abnormalities that affects the immature hip are know by the term Developmental Dysplasia of the Hip (DDH), and can predispose a child to premature degenerative changes and painful arthritis (ACR, 2007; Storer & Skaggs, 2006). Any abnormality in size, shape (dysplasia), orientation or organization of the femoral head, acetabulum or both, can result in subluxation or dislocation (Storer & Skaggs, 2006).

Because no first-line method exists for diagnosis of DDH during the newborn period, the physical examination is the recommended screening tool, particularly for high-risk infants (female patients and positive family history for DDH). The hip stability must be assessed by means of provocative dynamic tests (the Ortolani and Barlow maneuvers) and be performed routinely since the birth of child. The gender, the family history, and uterus conditions (e.g. *breech* positioning and utero postural deformities) are the most frequent risk factors related with the DDH.

Diagnostic criteria are an important factor of influence in incidence rates in infants with DDH, possibly as a result of overdiagnosis. According (USPSTF, 2006) the incidence of DDH in infants is influenced by several factors, including the diagnostic criteria, female gender, genetics, race and age. This condition affects 1.5 per 1,000 of the American Caucasian population and it is less frequent in African Americans (ACR, 2007). Due to the normal left occiput anterior position in uterus, these abnormalities are three times more commons in the left hip than the right.

Therefore, the aims of our study are to demonstrate the value of radiographic imaging techniques to establish a correct diagnosis of DDH and give an overview of radiographic hips positioning issues in children and image quality criteria.

1.1 Radiographic evaluation overview

Given the limited value of radiography in newborn with suspected DDH, in children younger than six months the ultrasonography (US) is the best method (Storer & Skaggs, 2006). Until four to six months of age, the femoral heads don't are ossified, and only ultrasonography is capable of visualizing the cartilaginous anatomy of the femoral head and acetabulum. Plain radiographs are recommended after four to six months of age, allowing the evaluation of the hip by means of the visual assessment and measurements using several reference lines and angles (see Table 1).

Table 1. *Reference lines and angles used for radiographic evaluation of the hips of patients with DDH. Adapted from* (Greenspan, 2004).

	Reference lines	**Angles**
Anteroposterior projection	Hilgenreiner line (Y-Line)	Acetabular index
	Perkins-Ombredanne line	Wiberg angle*
	Shenton-Ménard line	
	Localization of the ossification center of femoral head	
Von Rosen view	von Rosen line	None

**only used after femoral head ossification.*

The visual assessment of pelvic radiographs is predominantly used; however the measurement of the acetabular index (AI) is an objective parameter for diagnosis and follow-up of patients with DDH. According the American College of Radiology the 95 percent tolerance interval for intraobserver variability is 8.35 degrees, with interobserver variability exceeding the intraobserver variability (ACR, 2007). The radiographic interpretation is highly conditioned by an appropriate patient positioning (symmetry and rotation evaluation) and by the image quality criteria of intraobserver. The Figure 1 shows the reference lines and AI used for radiographic evaluation of the hips of patients with DDH.

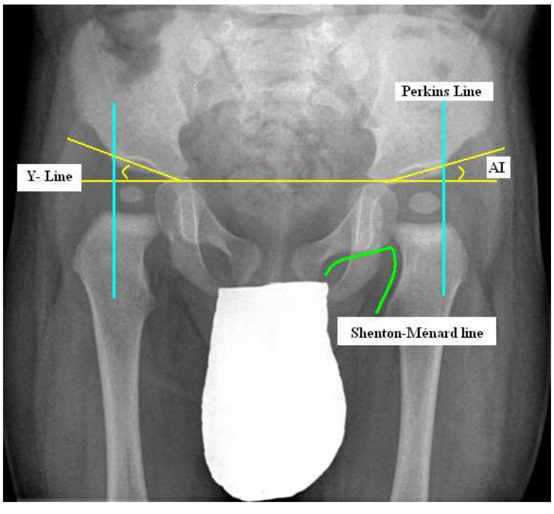

Figure 1. *Example of the measurement of the acetabular index used in hip radiography of normal children.*

However, the U.S. Preventive Services Task Force (USPSTF) have concluded that 60 to 80 percent of the newborn hips identified by physical examination and more than 90 percent identified by Ultrasonography, as abnormal or suspicious for DDH resolve spontaneously and require no intervention (USPSTF, 2006).

The preliminary pelvic radiographic examination performed on children includes an anteroposterior (AP) projection of both hips and the Lauenstein ("frog leg" position) projection (Ballinger & Frank, 1999). The AP projection must be obtained with the hips in neutral position (ACR, 2007). To demonstrate in accentuating a dislocated hip, complementary radiographic projections can be useful, namely the von Rosen view with legs at 45 degree angle, abduction and internally rotated. The "frog leg" position is used to assess reduction when neutral view is abnormal.

For the AP projection, the patient must be placed in supine position on the examination table with the midsagittal plane of the body centered with the mildline of the table (Ballinger & Frank, 1999). The elbows must be flexed with hands resting on the upper chest. Ensure patient body isn't rotate and center the cassette midway between the anterior superior iliac spine (ASIS) and the pubic symphysis. The resulting image should clearly demonstrate the entire pelvis along with the proximal femora, both ilia equidistant to the edge of the radiograph, symmetry of bone structures (as iliac alae, obturator foramina) and sacrum and coccyx aligned with the pubic symphysis.

Figure 2 depicts two radiographic positioning performed in children and the resulting images. As observed in Figure 2b, the patient body rotation causes an asymmetry of the bony structures of pelvis, and difficult the correct placement of the gonadal shield. A correct pelvic radiographic positioning is demonstrated in Figure 2a; all efforts must be perform to obtain a correct bony symmetry in order to improve radiographic interpretation and consequently the diagnosis.

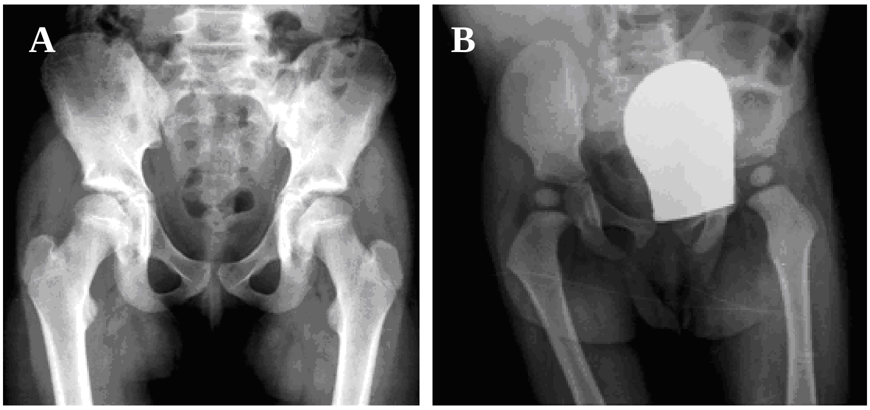

Figure 2. *Examples of a correct (a) and an incorrect (b) radiographic positioning of pelvis.*

Radiation protection is an important factor to be taken into account when selecting radiographic evaluation. When directly pelvic exposure is necessary, gonads must be protected and without impairing necessary diagnostic information, however for the Lauenstein projection, gonad shields are unsuitable (Ballinger & Frank, 1999; European Commission, 1996).

Concerning the use and relevance of gonadal protection shields in Children during pelvic radiography, the following guidelines (Ballinger & Frank, 1999) should be followed by the radiology technologist:

- *Use always gonadal shielding on males.* The top of the shield can be placed at level with the trochanters covering the scrotum and without obscuring the pubic symphysis. Avoid touching the pubic symphysis.
- *In females, the gonadal protection cannot be used on the first AP pelvic radiography.* The top of the gonadal shield must be placed at level with the ASIS centered with the mid-pelvis.
- *Choose appropriate gonadal protection size according child body composition and age.*
- *Remove diapers and check that both ASIS are equidistant from the examination table before gonad shield placement.*

- *Use explanation and reassurance as part of the immobilization method.* For the active or the potentially active child, use a Velcro strip around the knees and place large sandbags over the arms.

The relative radiation level (RRL) is based on effective dose used to estimate population total radiation risk associated with an imaging procedure. The following table describes the RRL for the radiologic procedures approved by (ACR, 2007) for the evaluation of DDH and their rating according the DDH variants.

Table 2. *Relative radiation levels and rating of the radiologic procedures used for the evaluation of DDH .*

DDH child variants	Radiologic procedure	Rating	RRL
Variant 1 (patient younger 4 months of age and positive Physical findings)	US hips X-Ray hips	7 2	None Medium
Variant 2 (patient younger 4 months of age and equivocal physical findings)	US hips X-Ray hips	8 2	None Medium
Variant 3 (patient younger 4 months of age, breech presentation or positive family history) without physical findings	US hips X-Ray hips	6 2	None Medium
Variant 4 (patient 4 months of age or older, clinically suspicious for DDH	US hips X-Ray hips	3 8	None Medium
Variant 5 (clinical suspicious for teratogenic dysplasia	US hips X-Ray hips	5 8	None Medium

Rating scale:1=least appropriate, 9=most appropriate

In late DDH, the imaging goals consist firstly in making the diagnosis, then to quantify the abnormality and finally to assist in surgical planning (Grissom, Harcke, & Thacker, 2008). According (Clohisy et al., 2009) the process of obtaining quality in radiographic views and subsequently interpreting those radiographs accurately is extremely important for establishing a correct diagnosis. The reliability of radiographic parameters in evaluating the skeletal immature hips remains unclear. Several authors have examined the interobserver and intraobserver reliability of selected measurements (Boniforti, Fujii, Angliss, & Benson, 1997; Clohisy et al., 2009; Hartofilakidis, Yiannakopoulos, & Babis, 2008; Pedersen et al., 2004; Tan, Aktas, Copuroglu, Ozcan, & Ture, 2001). In Clohisy et al., 2009, the authors have concluded that many of the standard radiographic parameters used to diagnose DDH are not reproducible; therefore patient suspicious and physical examination contribute considerably to the interpretation of the radiographs.

The remaining of this paper is organized as follows. In the next section, the paediatric patients and methods used for the image quality assessment are described, in particular the data analysis process. Then, in section three, the image quality criteria and principal radiographic outcomes are presented and discussed, considering the radiographic positioning issues and radiographic orthopaedic measurements of pelvic radiographs. Finally, the conclusions are pointed out in the last section.

2. METHODS

2.1 Paediatric patients

We selected randomly 65 paediatric patients, with a range of ages between 3 months to 13 years, who performed pelvic radiographs at the Radiology Department of the Hospital S. João E.P.E. of Porto, during January to May 2010. All the paediatric patients had realized at least one pelvic radiography, 19 patients realized the AP projection of both hips and the Lauenstein (“frog leg” position) projection; the resultant radiographic projections mean was of 1.29. Since it was not possible to obtain the clinical information for the radiographic examination, a different number of cases were evaluated from normal children to children with DDH.

2.2 Image quality assessment and measurements

Through the retrospective analysis of 65 radiographs performed in children, the image quality was assessed by a single person for consistency. Only the AP projection of the pelvis was selected and evaluated for each patient with regard to the appropriateness of most relevant image quality criteria and to the radiologic outcomes and measurements.

The image quality criteria of radiographs were assessed taking into consideration the presence or absence of the following parameters:

- *No rotation or symmetry of the pelvis.*
- *No tilting.* Iliac alae at the same horizontal line.
- *Proper central ray.*
- *Appropriate field size*. Cassette size of 18 x 24 cm (8 x 10 inch) in neonatal, 24 x 30 cm (10 x 12 inch) in infants and 35 x 35 cm (14 x 14 inch) in children older than 10 years
- *Appropriate x-ray beam limitation*. It was considered adequate only when x-rays beam collimation was superior to 1-2cm
- *Gonadal shield placement and its adequacy.*

Regardless of the appropriateness or otherwise of the image quality criteria, all the radiographic outcomes were used. Using DICOMWorks® (version 1.3.5b, developed by Philippe Puech and Loïc Boussel), a free DICOM viewer, we performed the visual assessment and measurements of the following parameters:

- *Femoral head or ossification center visualization.*
- *Shenton-Ménard line.* This line must be continuous and cross the medial border of femoral neck and the superior border of the obturator foramina.
- Perkins-Ombredanne *line crossing femora and localization of the ossification center or femoral head in the inferior medial quadrant.*
- *Distance between the highest point of the femoral metaphysic and the Y-Line.* This measure was performed only when the bilateral comparison seems considerably different.
- *Acetabular index.* Angle formed by the acetabular roof line and the Y-Line. This angle was measured only when Shenton-Ménard line was broken.

3. RESULTS

Of the 65 pelvic radiographs studied, 34 were performed in female and 32 in male patients. Of these children 53.8 percent have between 1-2 years of age, and 26 (40%) are older children (over then 3 years of age). The results of the assessment of the image quality criteria of radiographs are summarized in Table 3.

Table 3. A*ssessment results of image quality criteria.*

	No (%) present (n=65)
1. No rotation or symmetry	51 (78.5)
2. No tilting	31 (47.7)
3. Proper central ray	42 (64.6)
4. Appropriate field size	24 (36.9)
5. Appropriate x-rays beam limitation	22 (33.8)
6. Gonadal shield placement	38 (58.5)

As observed in Table 3, the absence of body rotation or symmetry was achieved in 51 (78.5%) of the paediatric patients. The gonadal protection was used in 38 patients; however it only was placed correctly in 15 of these children. Unprotected gonadal shielding was encountered almost in the same proportion for both genders, namely 51.9 percent of the female and 48.1 percent of the male children.

The incorrect placement or an inadequate size of the gonadal shields observed in 23 (60.5%) hips radiographs, besides the ineffective purpose of its use, makes difficult the diagnosis obscuring pelvic bony structures. Furthermore, additionally to the unprotected radiographs, the excessive radiation exposure of gonads is significant (76.9%) in this study.

Comparing the image quality criteria results, we observed the considerable lower percentages concerning the field size (36.9%) and x-rays beam collimation (33.8%). These parameters are chosen by the radiology technologists and besides its relevance for the patient radiation protection, have an important impact in image detail.

The most frequent errors found in this image data analysis were the inappropriate field size according child body composition and age (in general larger cassettes) and the improper size of gonadal shields (covering and obscuring bony structures).

The radiographic outcomes and measurements are demonstrated in Table 4. From the results of radiographic evaluation, normal findings were found in 52 (80%) children. Only two female children (3.1%) with 1-2 years of age have presented radiographic findings of DDH, on the left hip. Besides the absence of the ossification center, we observed for both cases: (1) the Shenton-Ménard line broken; (2) Perkins-Ombredanne line don't crossing femora; (3) differences existing when comparing the distances measured between the highest point of the femoral metaphysic and the Y-Line for both hips; and (4) an AI above 30 degree.

Table 4. Radiographic outcomes and measurements.

	Number (%) present (n=65)
1. Normal radiographic findings	52 (80)
2. DDH radiographic findings	2 (3.1)
3. Hardly enlightening to diagnosis	11 (16.9)
	Number present
4. Distance range	9 and 15 mm
5. Acetabular index range	33 and 38 degrees

Nevertheless, on 11 (16.9%) pelvic radiographs it wasn't possible to realize an adequate and accurate radiographic analysis mainly because we observed an inappropriate patient body symmetry and an incorrect use of the gonadal protection shields.

4. CONCLUSIONS

In this study we demonstrate the value of radiographic evaluation of the pelvis to establish a correct diagnosis of DDH and we give an overview of radiographic positioning issues of the hips in children and image quality criteria. The most important radiographic outcomes of 65 pelvic radiographs were presented and the image data was analyzed. Regarding to the image quality criteria assessment, the results are very satisfactory, mainly the symmetry of the patient body (78.5%).

The radiographic outcomes and measurements demonstrated that only 2 (3.1%) female patients with 1-2 years of age presented radiographic findings of DDH, on the left hip. However, on 11 (16.9%) pelvic radiographs, it wasn't possible an accurate assessment, due to inappropriate field size and the improper placement and size of gonadal shields (covering and obscuring bony structures).

In our study some difficulties have been encountered concerning the evaluation of the radiographic appearance of the pelvis, namely of the acetabulum; appropriate care must be taken in the visual assessment of radiographs due to the normal anatomical variation of bone structures during infancy and also because the radiographic interpretation is highly conditioned by patient positioning issues (e.g. symmetry, placement of gonadal shields). These problems can be partially solved by means of a software program, as developed by Pedersen et al., 2004, to automate the measurement of 12 standard radiographic parameters used in DDH.

However, regarding the parameters related with the field size and x-rays beam limitation, the results are very disappointing; in 41 (63.1%) patients the cassette size selected by the radiology technologist was generally to larger considering age and body composition, and the x-rays beam limitation was performed only in 22 (33.8%) patients. Considering the relevance of these parameters, either to improve image quality and reduce radiation exposure to patients, more care and efforts should be made to improve the accuracy of the diagnosis, namely in paediatric population.

Despite our attempt to demonstrate the value of radiographic evaluation to establish a correct diagnosis of DDH, our results emphasize the importance of a correct radiographic positioning pointing the most common errors affecting the reliability in radiographic diagnosis. This also highlights the need of understand the many functional differences of paediatric patients comparing with adults, in order to adopt the best practices during the pelvis radiographic examination, improving the image quality and consequently the diagnosis and accuracy of measurements.

The application of the current guidelines concerning the radiation protection must be assessed and followed as far as possible, and more care should be taken in the correct positioning of gonad shields. Their use must be more emphasized in clinical departments, but without compromising the diagnosis of hip abnormalities.

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