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ORIGINAL ARTICLE

Developmental dysplasia of the hip: Role of pelvic radiograph in patients with normal ultrasonography

Displasia del desarrollo de cadera: Rol de la radiografía de pelvis en pacientes con ecografía normal

Pedro Murati[a,b], Francesca Moller[a,b], Felipe Hodgson[a,b], María Jesús Figueroa[a,b], Ismael Cañete[a,b], Raúl Barraza[b], Gino Martínez[c], Angélica Ibáñez[a], Catalina Vidal[a]

[a]Ortopedia y Traumatología, Facultad de Medicina, Pontificia Universidad Católica de Chile. Santiago, Chile.
[b]Ortopedia y Traumatología, Complejo Asistencial Dr. Sotero del Rio. Santiago, Chile.
[c]Ortopedia y Traumatología, Clínica Universidad de los Andes. Santiago, Chile.

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What do we know about the subject matter of this study?

Developmental dysplasia of the hip (DDH) is an abnormality in the development of the hip joint. There are different screening programs that include physical examination, ultrasound, and X-ray, although there is no consensus in the literature.

What does this study contribute to what is already known?

In children with known risk factors for DDH and normal early ultrasound, 20% of X-rays were abnormal at 3 months. Risk factors included an α angle of less than 65° on the previous ultrasound and female sex. Follow-up with X-ray at 3 months is recommended for all children with risk factors, despite having a normal initial ultrasound.

Abstract

Developmental dysplasia of the hip (DDH) is an abnormal development of the components of the pediatric hip joint. Various screening programs are used, including physical examination, ultrasound, pelvic X-ray, or a combination of them. **Objective:** To evaluate the risk of abnormal findings on pelvic X-ray in infants with a normal early hip ultrasound. **Patients and Method**: Retrospective diagnostic test study. Infants born between 2018 and 2021 with at least one risk factor for DDH were included. All patients had a normal hip ultrasound performed between the 2nd and 12th week of life and a pelvic X-ray obtained at or after 3 months of age. Demographic data, risk factors, ultrasound results (alpha angle according to Graf classification), and radiographic findings (acetabular index at 3 months) were collected. Data were analyzed to identify factors associated

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Correspondence:
Catalina Vidal
cvvidal@uc.cl

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Luisa Schonhaut Berman

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with abnormal radiographic findings. **Results**: A total of 232 hips from 116 infants were included. Of these, 55.2% (n = 128) were male. At 3 months, 20.3% of the hips showed an abnormal pelvic X-ray. The main risk factors for this condition were a smaller alpha angle and female sex. An alpha angle < 65 degrees was associated with an odds ratio (OR) of 5.8 (95% CI: 2.0–11.6) for presenting an abnormal X-ray. **Conclusion**: Infants with a normal ultrasound before 3 months of age with an alpha angle < 65° are at high risk of an abnormal pelvic X-ray; therefore, follow-up is recommended.

Introduction

Developmental dysplasia of the hip (DDH) is an abnormality in the development of the components of the hip joint in children. The incidence of DDH has been reported to range from 1.5/1,000 to 20.7/1,000 depending on the country and screening method[1,2]. In the Chilean population, the incidence is approximately 3.9%[3], with an estimated incidence of 1 in every 500-600 live births presenting with subluxation or dislocation[4]. DDH has potential long-term complications, with hip osteoarthritis being the most feared and the leading cause of total hip replacement in young adults[5].

There are different screening programs that include physical examination, ultrasound (universal or targeted to risk groups), pelvic X-ray, or a combination of these methods[6]. A meta-analysis on this subject suggests that there is insufficient evidence to show that any of these methods reduce late diagnosis or the need for surgery[6]. In Chile, since 2008, DDH has been a condition included in the Explicit Health Guarantees (GES)[4]. This guarantees universal screening through an anteroposterior pelvic X-ray for all infants at 3 months of age. If there are major risk factors or suspicion of DDH on physical examination, an ultrasound should be performed from the second week of life[4]. This method has been reported to reduce the need for surgery, demonstrating the positive impact of this national screening strategy[7].

The GES Guideline does not explicitly specify the mandatory performance of an X-ray at 3 months in patients with normal early ultrasound[4]. Some studies have evaluated the need to repeat the ultrasound and have shown that an α angle < 55° in the initial ultrasound is a predictor of worsening ultrasound findings[8], while others have evaluated patients with X-rays at one year of age, finding residual dysplasia between 0-7%[9,10]. Therefore, the usefulness of X-rays at 3 months in these cases remains unclear, and there is still controversy in the literature. The objective of this study is to evaluate the risk posed by an abnormal pelvic X-ray in infants with risk factors and a normal early hip ultrasound.

Method

Design

Retrospective study of diagnostic tests, which was approved by the institutional scientific ethics committee.

Patients

Infants with risk factors for DDH were evaluated at a high-complexity hospital between 2018 and 2021. The inclusion criteria were 1) Having at least one major risk factor: first-degree family history, breech presentation, or abnormal physical examination; 2) Normal ultrasound (Grade I or IIa) performed between the second and twelfth week of life in full-term newborns, and 3) Pelvic X-ray from the third month of life. Patients treated for DDH diagnosed with early ultrasound or incomplete study were excluded.

Data collection

The birth date and examinations, sex, and risk factors for hip dysplasia were recorded, such as family history, breech presentation, and abnormal physical examination. The following physical examination abnormalities were considered indications for pelvic ultrasound: a positive Ortolani-Barlow maneuver, limited abduction, and the presence of other congenital deformities, such as talipes calcaneus, clubfoot, or torticollis.

The α angle value was measured on ultrasound (Figure 1) using the Graf method[11]. Measurements had been performed by pediatric orthopedic surgeons with more than 5 years of experience. Hips were considered normal and, therefore, not requiring treatment, according to the GES guidelines and Graf's classification:

- Type I hips: good bony roof, good cartilage roof coverage, α angle ≥ 60º, sharp bony rim.
- Type IIa hips: adequate bony roof, good cartilage roof coverage, α angle between 50º and 59º, blunt bony rim, in children younger than 12 weeks of age.

An orthopedic surgeon measured the acetabular index on the 3-month X-ray of all patients (Figure 2).

A pelvic X-ray was considered abnormal when both criteria for normality established by the GES guideline were not met, i.e., if: (1) the acetabular angle < 30° and (2) the Perkin's line located in the middle or outer third of the metaphysis [4].

Statistical analysis

Data distribution was assessed with the Shapiro-Wilk test. Numerical variables were expressed as mean and standard deviation (SD). Categorical variables were expressed as absolute frequencies (n) and relative frequencies (%). The association between an abnormal X-ray and α angle, sex, family history, breech presentation, abnormal physical examination, and age at ultrasound was evaluated using Student's t-tests for independent variables and the Chi-square (X^2) tests. A post hoc power calculation was performed for the analyses comparing the α angle and the association with sex. The observed difference between groups, the standard deviation, and a significance level of 0.05 were used since no study with the data required for sample size calculation was found.

A multivariate logistic regression was performed with the variables that were statistically significant ($p < 0.05$) in the univariate analysis, reporting the odds ratio (OR) with a 95% confidence interval. The Youden index with ROC (Receiver Operating Characteristic) curve was used to identify the cut-off point of the α angle at which sensitivity and specificity are maximum for predicting an abnormal X-ray. In addition, the area under the curve (AUC) was measured. STATA v.16 software was used for the analysis.

Results

232 hips were included, corresponding to 116 children. 55.2% of the hips (n = 128) were from male patients. Regarding the risk factors, 51.7% (n = 120) of patients had a family history, 36.2% (n = 84) had a breech presentation, and 16.4% (n = 38) had an abnormal physical examination. 12 hips (5.2%) had two risk factors for DDH.

Ultrasound was performed at a mean age of 6.7 weeks (SD 2.7) and X-ray at a mean age of 14.8 weeks (SD 2.9). The mean α angle was 67.2° (SD 5.2°; 50 min – 80 max) and the acetabular index was 26.5° (SD 3.9°, 17 min – 40 max).

47 (20.3%) hips had abnormal X-rays, i.e., an acetabular index greater than 30° (Figure 3). Patients with abnormal X-rays had a mean α angle of 63.3° (SD 0.7), significantly lower than that of the group with normal X-rays (68.2°, SD 0.4; $p < 0.01$). The statistical power for this comparison was 100%. In addition, a significant association was observed between female sex and

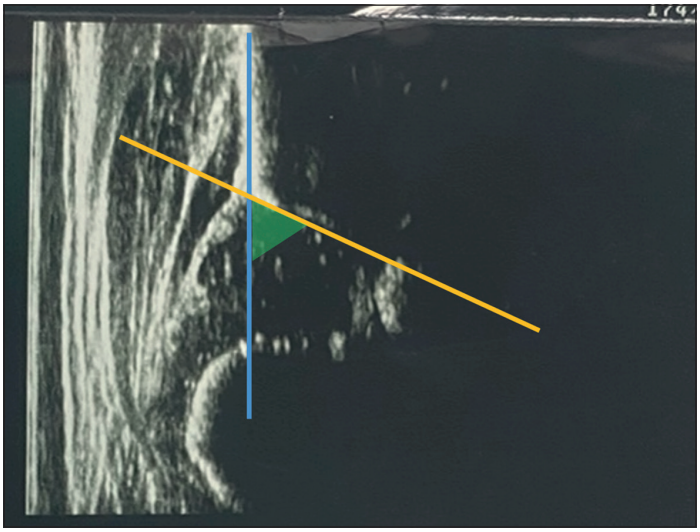

Figure 1. Measurement of the α angle on hip ultrasound according to the Graf method. The image shows a static coronal view of the hip in the neutral position. The baseline (blue) is drawn along the osseous margin of the ilium. The acetabular roof line (yellow) extends from the lateral edge of the acetabulum to the transition point with the ilium. The α angle (green area) is formed between both lines and represents the inclination of the osseous acetabular roof.

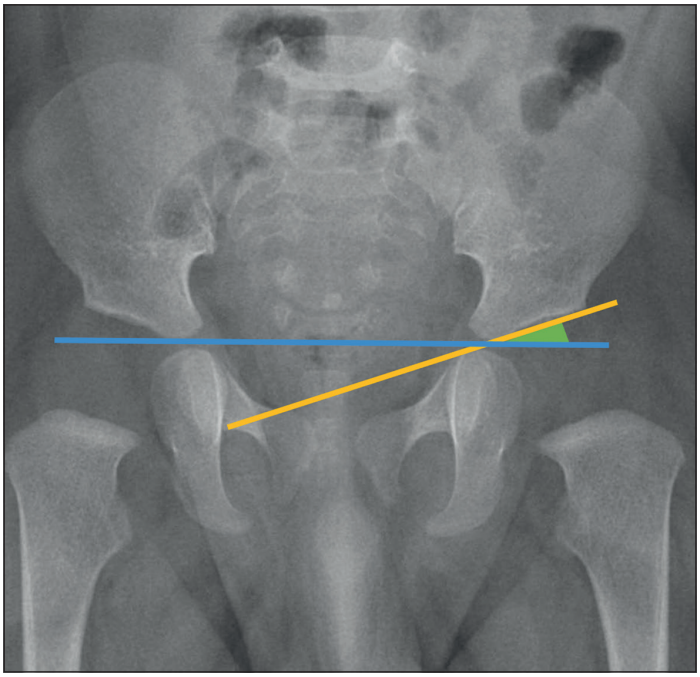

Figure 2. Measurement of the acetabular index on an anteroposterior pelvic radiograph. Hilgenreiner's line (blue) is a horizontal line connecting the triradiate cartilages. The acetabular roof line (yellow) extends from the lateral edge of the acetabular roof to the most medial point where it intersects Hilgenreiner's line. The acetabular index (green area) corresponds to the angle formed between both lines and reflects the slope of the acetabular roof.

the presence of abnormal X-rays (Table 1), with a statistical power of 97%.

No association was observed between the age (weeks) at which the ultrasound was performed and abnormal X-rays [6.8 (SD 2.3) vs. 6.7 (SD 3.8); p = 0.9], nor with family history, breech presentation, or abnormal physical examination (Table 1).

The ROC curve yielded an AUC of 0.77. The cut-off point for the α angle at which sensitivity and specificity are highest is 65° (sensitivity 64%, specificity 67%; Youden = 0.4) (Figure 4). This means that when considering 65° as the cut-off point for ultrasound, of the total number of patients with a normal value but below it (α angle < 65°), 10% still have an abnormal X-ray (acetabular index > 30).

Logistic regression showed an association between an acetabular index > 30 with the α angle and sex. Females are 5.1 times more likely to have an abnormal index compared to males; a larger α angle is a protective factor for abnormal X-ray. In addition, an α angle < 65° has an OR of 5.8 (95% CI 2.0-11.6) of presenting an abnormal X-ray (Table 2).

Discussion

The objective of this study was to evaluate the use of pelvic X-ray at 3 months in patients with normal early ultrasound. We observed that 20.3% of hips had an abnormal X-ray at 3 months, with a smaller α angle and female sex being the main risk factors for this condition.

An α angle within the normal range but < 65° has an OR of 5.8 times for presenting an abnormal X-ray in patients with known risk factors. Graf described that a hip with an α angle between 50° and 59° (Graf IIa) is considered immature and requires a repeat study at 3 months[11]. One study analyzed the natural history of this type of hip and concluded that an α angle < 55° is an independent predictor of dysplasia at 3 months[8]. However, other studies that have evaluated the late presentation of dysplasia with normal ultrasound have evaluated it at one year of age and have not considered the α angle as a predictor[9,10]. Based on our results, it would be advisable to consider performing an X-ray in all patients with known risk factors, regardless of the α angle, given that 10% present normal ultrasound and abnormal X-ray with the new cut-off points.

In our study, females were 5.1 times more likely than males to have abnormal X-ray results, even when they had known risk factors and normal ultrasound results. The literature has described that females are at higher risk of presenting DDH[13,14], and suggests that they are at higher risk of late diagnosis (> 3 months of age)[13-15] and that females with immature hips or Graf IIa are at higher risk of persisting with dysplasia at 3 months[16]. Female susceptibility to the relaxin hormone has been suggested as the underlying reason[17]. The importance of sex is reflected in the need for more comprehensive follow-up in female patients, regardless of other risk factors.

We did not observe an association between breech presentation and abnormal X-ray at 3 months. The literature on this subject is controversial: some studies have failed to find a significant relationship[10,18], while others, such as that by Imrie et al.[19], report that 29% of patients with breech presentation had

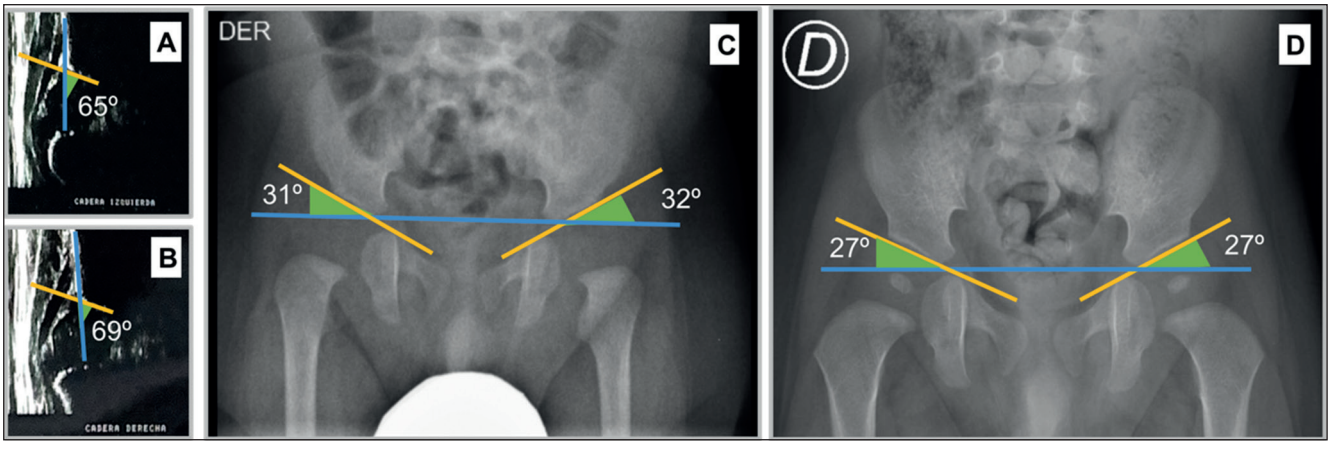

Figure 3. Clinical case. Male infant aged 1 month and 15 days referred for breech presentation. Ultrasound shows an α angle of 69° on the right and 65° on the left (A and B). At 3 months, an anteroposterior pelvic radiograph demonstrates bilateral hip dysplasia with acetabular indices of 31° and 32° (C). Pavlik harness straps were discontinued at 12 weeks, achieving normalization of the radiograph by 11 months (D). Angles are annotated as described in Figures 1 and 2.

Table 1. Characteristics of patients with normal or abnormal pelvic radiograph according to sex and risk factors. SD: Standard deviation

	Radiografía normal n = 185	Radiografía alterada n = 47	Valor-p
Sex			
Female	69 (66.4%)	35 (33.6%)	p < 0.01*
Male	116 (90.6%)	12 (9.4%)	
Family history			
No	90 (80.4%)	22 (19.6%)	p = 0.82
Yes	95 (79.2%)	25 (20.8%)	
Breech presentation			
No	117 (79.1%)	31 (20.9%)	p = 0.73
Yes	68 (80.9%)	16 (19.1%)	
Abnormal physical examination			
No	156 (80.4%)	38 (19.6%)	p = 0.56
Yes	29 (76.3%)	9 (23.7%)	
Age at ultrasound (weeks), mean (SD)	6.8 (2.3)	6.7 (3.8)	p = 0.9
α angle, mean (SD)	63.3 (0.7)	68.2 (0.4)	**p < 0.01**

DS: Desviación estándar.

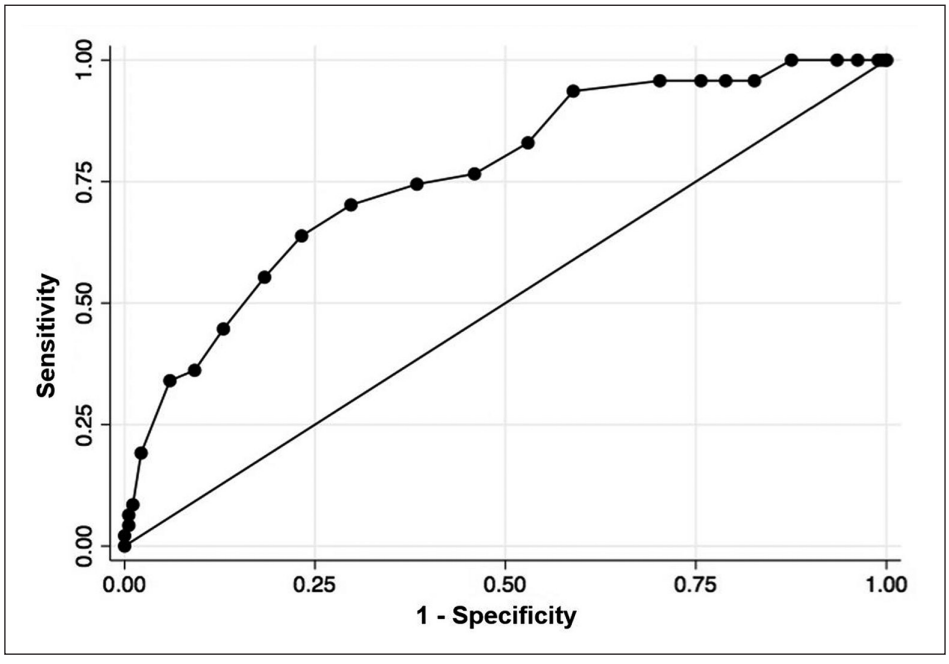

Figure 4. ROC curve showing the discriminative ability of the α angle on ultrasound to predict radiographic abnormalities at 3 months. The area under the curve (AUC) was 0.77.

Table 2. Logistic regression analysis of factors associated with an abnormal pelvic radiograph

	Odds Ratio	p value	95% Confidence interval
α angle < 65°	5.8	< 0.001	2.9-11.6
Female sex	5.1	< 0.001	2.3 – 11.3

hip dysplasia requiring treatment at 4-6 months of follow-up. Brusalis et al.[20] also found 10% dysplasia on 6-month X-rays. Despite discrepancies in the findings, all studies agree that this group of patients requires close follow-up to detect possible complications as they grow up.

It is important to consider that DDH is a condition with a multifactorial etiology, whose pathophysiology is not fully understood. Although classic risk factors have been identified, there are multiple other variables that could influence its onset and progression. Among other factors not evaluated in this study are postnatal positional factors, such as the use of ergonomic carrying systems. These have been shown to promote proper hip development compared to other devices. Recent studies, such as that by Siddicky et al. (2023)[21], have shown differences in hip morphology assessed by ultrasound in infants using ergonomic carrier backpacks versus those in Pavlik harnesses, suggesting that certain care practices may influence the maturation of the hip joint. These findings reinforce the need to consider a comprehensive approach when assessing the risk of DDH, integrating both clinical and environmental factors.

Our study has some limitations, as its retrospective design poses possible selection biases and depends on the quality of medical records. In addition, the ultrasound measurements were performed by five different specialists, which, according to the literature, could imply high interobserver variability[22]. However, it should be noted that one of the specialists had formal training in the Graf method and was responsible for training the other evaluators. Furthermore, a study has shown that even a two-hour training session can significantly improve interobserver variability and ultrasound technique[23].

Conclusion

20% of infants' hips with known risk factors and normal early ultrasound show X-ray abnormalities at three months, which is particularly relevant in female patients and those with an α angle < 65°. Follow-up with X-ray at 3 months is recommended for all children with risk factors, despite having a normal initial ultrasound.

Ethical Responsibilities

Human Beings and animals protection: Disclosure the authors state that the procedures were followed according to the Declaration of Helsinki and the World Medical Association regarding human experimentation developed for the medical community.

Data confidentiality: The authors state that they have followed the protocols of their Center and Local regulations on the publication of patient data.

Rights to privacy and informed consent: This study was approved by the respective Research Ethics Committee, which, according to the study's characteristics, has accepted the non-use of Informed Consent.

Conflicts of Interest

Authors declare no conflict of interest regarding the present study.

Financial Disclosure

Authors state that no economic support has been associated with the present study.

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