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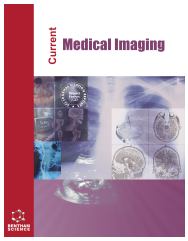

RESEARCH ARTICLE

Diagnostic Efficacy of High-frequency Ultrasound (HFU) in Early Diagnosis of Congenital Hip Dysplasia

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Abstract:

Background:

Hip dysplasia is one of the most prevalent disorders in children and one of the three primary congenital orthopedic deformities. Although there are numerous existing methods (*e.g.*, CT, MRI and arthrography) for early identification of hip dysplasia, their diagnostic criteria differ widely. It is critical to establish a safe, accurate, and reliable way for early diagnosis and treatment of hip dysplasia.

Objective:

This study aimed to analyze the diagnostic efficacy of high-frequency ultrasound (HFU) for congenital developmental hip dysplasia and hip dislocation and to provide a reference for the early diagnosis of congenital hip dysplasia in the future.

Methods:

A total of 104 infants and children suspected of having congenital hip dislocation or developmental hip dysplasia admitted to our hospital from April 2019 to August 2022 were enrolled as study subjects. All the infants and children were subjected to HFU and X-ray examination in our hospital. The diagnostic efficacy of HFU for congenital hip dysplasia was observed using X-ray as the gold standard.

Results:

HFU confirmed 79 cases of congenital hip dysplasia, while X-ray confirmed 71 cases. The sensitivity and specificity of HFU were 77.42% and 83.33%, respectively, in the diagnosis of congenital developmental hip dysplasia, 76.47% and 96.55% in the diagnosis of congenital hip dislocation, and 77.22% and 60% in the diagnosis of congenital hip abnormality, which is very close to the gold standard. According to statistics on infants and children, the majority of patients were girls, and the left joint was more likely to be affected.

Conclusion:

HFU has excellent diagnostic efficiency for congenital developmental hip dysplasia and hip dislocation, which can be considered an early assessment method for congenital hip dysplasia in the future.

Keyword: High-frequency ultrasound, Congenital hip dysplasia, Hip dislocation, Diagnosis, Infants, Children.

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1. INTRODUCTION

Hip dysplasia is a general term for developmental abnormalities of the shape and relationship between the acetabulum and the femoral head, which includes hip dislocation (complete dislocation/subluxation) and simple developmental hip dysplasia. It is one of the most common diseases in pediatrics and one of the three major congenital malformations in orthopedics [1]. The incidence of hip dysplasia is about 6–12.1‰ worldwide, with an obvious increasing trend year by year recently [2]. Hip dysplasia may evolve over time. For example, simple developmental hip dysplasia can progress into subluxation and complete dislocation of the hip due to delayed diagnosis and treatment,

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resulting in hip dysfunction and, eventually, disability [3]. Approximately over 20% of physical disabilities in infants and children with can be attributed to hip dysplasia [4]. Surgery is still the main treatment for hip dysplasia in clinics at present. However, it is suitable only for younger infants and children with lower acetabular index and symptoms of femoral head development [5]. Therefore, early diagnosis of hip dysplasia and effective treatment interventions are of great significance to prevent disease progression and promote normal hip development in infants and children.

Although multiple existing methods (*e.g.*, CT, MRI, arthrography) can be used for early diagnosis of hip dysplasia, their diagnostic criteria vary greatly. It is urgent to find a safe, accurate and reliable method for hip dysplasia [6, 7]. High-frequency ultrasound (HFU) is a widely used noninvasive diagnostic technique whose high application value has been proven in the clinical diagnosis of various bone and joint diseases [8, 9]. HFU is also suitable for the diagnosis of hip dysplasia in infants and children for its simple, non-invasive and repeatable operation. Considering rare relevant studies, whether HFU also has good diagnostic efficacy in hip dysplasia is not clear. Therefore, the diagnostic efficacy of HFU in congenital hip dislocation and developmental hip dysplasia was about to be investigated in this study to lay a reliable foundation for the future application of HFU and improve the early diagnosis rate of congenital hip dysplasia.

2. MATERIALS AND METHODS

2.1. Study Subjects

A total of 104 infants and children suspected of congenital hip dislocation or developmental hip dysplasia admitted to our hospital from April 2019 to August 2022 were enrolled as study subjects. Inclusion criteria: Children/infants who cry continuously during palpation; children/infants whose gluteal sulcus is asymmetrical; children/infants with Click noise during manual examination of the hip joint, children/infants positive for Patrick test; children/infants undergoing HFU and X-ray examination in our hospital; children/infants whose family members have given informed consent to participate voluntarily in the study. Exclusion criteria: Children/infants with congenital malformations; children/infants with a history of trauma; children/infants diagnosed with hip dysplasia; children/infants whose family members are unwilling to cooperate with the study. Fifty-nine boys and forty-five girls were included, with a mean age of (4.79±2.06) months. This study is conducted in strict accordance with the Declaration of Helsinki, and all the subjects have signed the informed consent form.

2.2. HFU Examination

Logiq E9 (GE) was adopted, with a linear array probe and a frequency of 6–15 MHz. The child was in a neutral lateral position with the lower limbs slightly rotated and flexed inward. Graf method: The baseline, the top line of bone, and the top line of cartilage near the acetabulum were marked. The baseline was the straight acoustic shadowing of the ilium, the bony acetabular roof was the tangent line between the inferior margin of the ilium of the acetabular fossa and the bony acetabular fossa, and the cartilaginous acetabular roof was the line between the center line of the hip labrum and the turning point of the bony margin of the bony acetabular fossa. The angle between the bony acetabular roof and baseline was α, and the angle between cartilaginous acetabular roof and baseline was β. The two angles were measured. Diagnostic criteria were detailed below: an α angle ≥ 60° indicated normal hip (type I); an α angle of 43°(inclusive)–60°, with a β angle of 55°–77°, indicated developmental hip dysplasia (type II); an α angle < 43°, with a β angle ≥ 77°, indicated subluxation of hip (type III); an α angle < 43°, with dislocation of the femoral head to the posterior upper part, making unmeasurable β angle, indicated complete hip dislocation (type IV).

2.3. X-ray Examination

The Digitaldiagnost TH X-ray system (PHILIPS) was adopted for examination. In a quiet state, the child laid flat on the table. His/her pelvis was adjusted so that the pelvis was symmetrical bilaterally; the lower limbs were placed in a neutral position and extension position in line with the longitudinal axis; X-ray film of the pelvis was taken first, followed by separate axial radiographs taken by abducting the patient at 45° and internally rotating at 45°. Two radiologists read the film by double-blind method, and the results of X-ray were classified as type I–IV.

2.4. Diagnostic Efficacy Analysis

The diagnostic efficacy of HFU for congenital hip dysplasia was calculated using X-ray as the gold standard. Types II–IV hip were considered positive in both protocols. Detailed criteria were shown below: true positive: positive by both X-ray and HFU; false positive: positive by X-ray but negative by HFU; true negative: negative by both X-ray and HFU; false negative: negative by X-ray but positive by HFU. Sensitivity = Number of subjects with true positive result / (Number of subjects with true positive result + Number of subjects with false negative result) × 100%. Specificity = Number of subjects with true negative result / (Number of subjects with true negative result + Number of subjects with false positive result) × 100%. Diagnostic accordance rate = (Number of subjects with true positive result + Number of subjects with true negative result) / Total Number of subjects × 100%.

2.5. Statistical Analysis

SPSS25.0 was used for statistical analysis. All the results obtained were recorded in the form of [n (%)]. The Chi-square test was used for comparison, and the Kappa coefficient for consistency in diagnosis. Intervals of 0.41–0.60, 0.61–0.80, and 0.81–1.00, respectively indicate moderate, high, and almost complete consistency. $P < 0.05$ indicates a statistically significant difference.

3. RESULTS

3.1. Diagnosis

Among the 104 infants and children suspected of congenital hip dysplasia, 79 cases were confirmed as positive

by HFU, including 62 cases of type II, 15 cases of type III, and 2 cases of type IV; 71 cases were confirmed as positive by X-ray, including 55 cases of type II, 12 cases of type III, and 4 cases of type IV (Table **1**). Statistical analysis showed no significant difference between the two assays (P>0.05). In Fig. (**1**), we show certain typical cases of hip dysplasia. In Fig. (**2**), we show certain cases that were determined to be normal by HDF examination.

Table 1. Diagnostic results of HFU and X-ray.

-	Type II	Type III	Type IV	Total Positive Rate
HFU	62(59.62)	15(17.31)	2(1.92)	75.96
X-ray	55(52.88)	12(11.54)	4(3.85)	68.27
χ^2	0.957	0.383	0.687	1.530
P	0.328	0.536	0.407	0.216

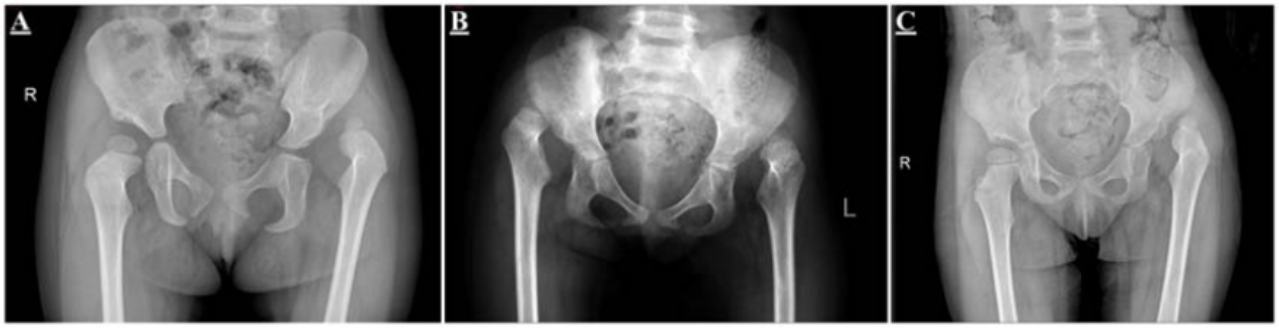

Fig. (1). Typical hip developmental anomalies (X-ray). (**A**) 3 years old, IV degree dislocation of the left hip and acetabular dysplasia of the right. (**B**) 2 years and 5 months old, bilateral developmental hip dislocations, IV degree dislocation of both the left and the right. (**C**) 2 years old, developmental hip dislocation of the left with IV degree dislocation.

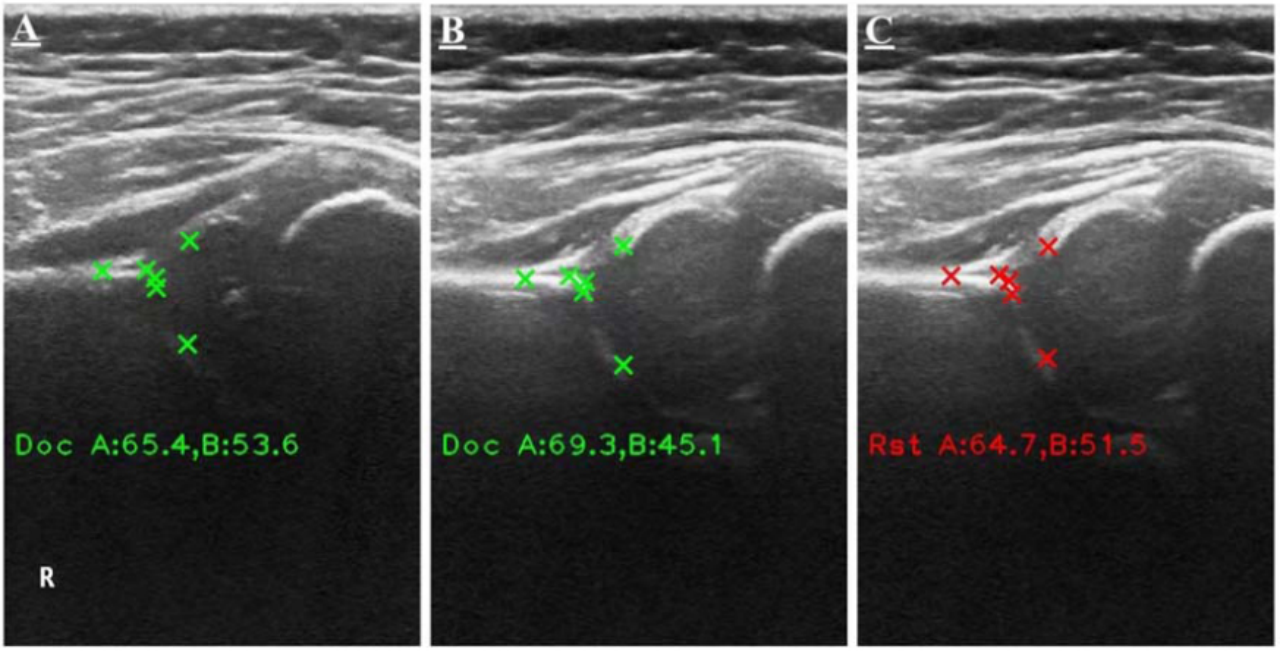

Fig. (2). Children diagnosed as normal after HDF examination.(**A**) 2 months, normal hip α angle = 65.4° (>60°), β angle = 53.6° (<55°). (**B**) 3 months, hip α angle = 69.3° (>60°), β angle = 45.1° (<55°), normal. (**C**) 5 months, hip α-angle = 64.7° (>60°), β-angle = 51.5° (<55°), normal.

Table 2. Diagnostic efficacy of HFU for congenital developmental hip dysplasia.

-	-	HFU		Total	Kappa
-	-	(+)	(-)		
X-ray	(+)	48	7	55	0.694
	(-)	14	35	49	
Total	-	62	42	-	

Table 3. Diagnostic efficacy of HFU for congenital hip dislocation.

-	-	HFU		Total	Kappa
-	-	(+)	(-)		
X-ray	(+)	13	3	16	0.816
	(-)	4	84	88	
Total	-	17	87	-	

3.2. Diagnostic Efficacy of HFU for Congenital Developmental Hip Dysplasia

The diagnostic efficacy of HFU for type II hip was analyzed (Table **2**). After calculation, the diagnostic sensitivity, specificity, and accordance rate of HFU for type II hip were respectively 77.42%, 83.33%, and 79.81%. Using Kappa = 0.694, the results obtained by HFU for the diagnosis of type II hip showed high consistency with the gold standard.

3.3. Diagnostic Efficacy of HFU for Congenital Hip Dislocation

The diagnostic efficacy of HFU for types III and IV hip was analyzed (Table **3**). After calculation, the diagnostic sensitivity, specificity, and accordance rate of HFU for types III and IV hip were respectively 76.47%, 96.55%, and 93.27%. Using Kappa = 0.816, the results obtained showed high consistency with the gold standard.

3.4. Diagnostic Efficacy of HFU for Congenital Hip Dysplasia

The diagnostic efficacy of HFU for types III and IV hip was analyzed (Table **4**). After calculation, the diagnostic sensitivity, specificity, and accordance rate of HFU for types III and IV hip were respectively 77.22%, 60.00%, and 73.08%, showing high consistency with the gold standard (Kappa = 0.658).

3.5. Clinical Characteristics of Infants and Children with Congenital Hip Dysplasia

According to the clinical data of patients with congenital hip dysplasia, the majority of patients were girls, and the left joint was more likely to be affected; the age distribution was relatively even, without any prominent features (see Table **5** for details).

Table 4. Diagnostic efficacy of HFU for congenital hip dysplasia.

-	-	HFU		Total	Kappa
	-	(+)	(-)		
X-ray	(+)	61	10	71	0.658
	(-)	18	15	33	
Total	-	79	25	-	

Table 5. Clinical characteristics of infants and children with congenital hip dysplasia.

-	Age (months)	Gender Boy / Girl	Affected Joint Left / Right	Family History of the Disease Yes/No	Only Child Yes/No	Delivery Method Vaginal Delivery / Cesarean Section
Normal (n=33)	4.71±2.55	26(78.79)/7(21.21)	-	1(3.03)/32(96.97)	18(54.55)/15(45.45)	22(66.67)/11(33.33)
Abnormal (n=71)	4.83±1.82	33(46.48)/38(53.52)	54(76.06)/17(23.94)	5(7.04)/66(92.93)	43(60.56)/28(39.44)	41(57.75)/30(42.25)
t(χ^2)	0.273	9.581	-	0.667	0.336	0.751
P	0.786	0.002	-	0.414	0.562	0.386

4. DISCUSSION

His dysplasia is one of the most common skeletal system diseases in infants and children, mainly caused by congenital dysplasia of the femoral head and acetabulum and shallow

acetabulum [10]. Severe hip dislocation directly affects children's walking ability and is closely related to advanced degenerative hip diseases [11].

According to the results of the study, HFU has an excellent diagnostic efficacy for congenital developmental hip dysplasia and hip dislocation and has a high consistency with X-ray, suggesting that HFU can be used as an early diagnostic scheme for congenital hip dysplasia in the future, thus to guarantee the diagnosis of congenital hip dysplasia. It is clearly indicated in clinical practice that screening for hip disorders in infants and children is important for early detection and prevention of congenital hip dislocation and developmental hip dysplasia, as they may lead to hip dysfunction and a high rate of disability if not detected and treated timely [12]. Early diagnosis by X-ray is difficult as the femoral head ossification center of infants develops at 6 months after birth [13]. Hip examination by HFU is achieved by the HFU, which penetrates the cartilaginous hip tissues and generates angles α and β, and the two angles are measured for the determination of status of the hip; whether the position and shape of the hip are normal is judged by the intensity of echo [14]. The Graf method is a quantitative method to assess the hip by measuring angles α and β; its fixed assessment standard, low operational difficulty and non-invasive property make it a routine screening method for hip dysplasia in infants. The α angle in the Graf method reflects the depth of the bony acetabular roof and the coverage rate of the femoral head, which is closely related to the maturity of the hip; the α angle of a normal mature hip should not be less than 60°, and the size of the angle is inversely proportional to the degree of developmental hip dysplasia [15]. The β angle reflects the degree of femoral head upward movement, and the β angle of normal infants should be less than 55°; the size of the angle is inversely proportional to the area of femoral head covered by the cartilaginous acetabular roof and directly proportional to the degree of developmental hip dysplasia [13, 16]. The Graf method offers a relatively detailed classification of hip development and an adequate response to the developmental characteristics of the hip, providing a more accurate basis for clinical determination of hip dysplasia. HFU, which is non-radiological and non-invasive and has no contraindications, is also convenient and allows for repeated application; it effectively prevents infants and children from being exposed to ionizing radiation [17, 18]. The excellent diagnostic efficacy of HFU for congenital hip dysplasia in this study also fully confirmed the feasibility of HFU application. Moreover, Huang YP *et al*. proposed in their study that HFU has excellent diagnostic efficacy for hip and knee osteoarthritis [19], which also supports our view. However, a more detailed classification of hip dysplasia is required to achieve ideal diagnostic efficiency in HFU examination using the Graf method for the diagnosis of congenital hip dysplasia, so as to fully reflect the developmental characteristics of the hip. The measurements of angles tend to be influenced by the subjective operation of the measurer (especially the β angle), so the measurer is strictly required in terms of professional operation skills. Strict HFU operation training is also needed in clinical practice to reduce the possibility of misdiagnosis. According to the data of patients with congenital hip dysplasia, the majority of patients are girls, and the left joint is more likely to be affected, which is also consistent with the current epidemiological findings of hip dysplasia [20, 21]. Since the pathogenesis of hip dysplasia is not yet completely clear, the specific causes of the above characteristics remain indeterminate, which is also one of the key points worthy of further analysis.

The combination of the Harcke method with HFU for the diagnosis of hip dysplasia was not analyzed in this study, which will be addressed in subsequent studies. In addition, the small number of cases included in this study does not rule out the possibility of statistical calculation contingency, which also requires a larger sample size for a more comprehensive analysis.

CONCLUSION

HFU has excellent diagnostic efficacy for congenital hip dysplasia. It can effectively distinguish congenital developmental hip dysplasia and hip dislocation, and can be used as an early diagnosis scheme for congenital hip dysplasia, so as to improve the early diagnosis rate of the disease and guarantee the healthy growth of infants and children.

ABBREVIATION

HFU = high-frequency ultrasound

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Ethics Committee of the Anhui Provincial Children's Hospital, Children's Hospital of Anhui Medical University, Anhui, Hefei 230000, China. Approval no. 20190021).

HUMAN AND ANIMAL RIGHTS

No animals were used for studies that are the basis of this research. The current study abided by the 1964 Helsinki Declaration.

CONSENT FOR PUBLICATION

Written informed consent was obtained from the Parents/guidance for the publication of this report.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

The dataset used and/or analyzed during the present study are available from the corresponding authors [J.S].

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or

otherwise.

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Declared none.

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