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Observation of the Application Value of Doppler Ultrasound in the Diagnosis of Pediatric Hip Dysplasia

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Abstract

Objective: To analyze the diagnostic value of Doppler ultrasound in pediatric hip dysplasia. **Methods:** A total of 70 cases of suspected developmental dysplasia of the hip (DDH) from March 2022 to March 2024 were selected. Three-dimensional CT was used as the diagnostic standard to evaluate the effectiveness of Doppler ultrasound. **Results:** Among the 70 subjects, 50 were confirmed to have DDH by three-dimensional CT. The sensitivity of ultrasound diagnosis was 94.00% (47/50), the specificity was 80.00% (16/20), and the accuracy was 90.00% (63/70). The anteroposterior, lateral, and vertical diameters in the DDH group were significantly lower than those in the normal group ($P < 0.05$). There was no significant difference in femoral head cartilage H/W ratio between the two groups, but the height and width of femoral head cartilage in the DDH group were significantly lower than in the normal group ($P < 0.05$). The detection rates of rounded or defective acetabular edges, shallow acetabular fossa, labrum located between the femoral head and acetabulum, blurred contours, and poor coverage of the femoral head by the acetabular roof were significantly higher in the DDH group than in the normal group ($P < 0.05$). **Conclusion:** Doppler ultrasound has high sensitivity and accuracy in diagnosing pediatric hip dysplasia, with key diagnostic indicators being the morphology of the femoral head cartilage and the ossification center of the femoral head.

Keywords

Doppler ultrasound; pediatric; hip dysplasia; diagnosis

Pediatric hip dysplasia is often caused by congenital developmental defects and may present with symptoms such as pain and restricted movement. Severe cases can impact the child's ability to walk or perform daily activities [1]. Developmental dysplasia of the hip (DDH), also known as developmental hip dysplasia, refers to the dislocation of the femoral head from the acetabulum, leading to misalignment of the joint. This is a primary type of pediatric hip dysplasia and is different from common hip dislocation, as it is caused by congenital malformations that prevent proper hip joint articulation [2]. The etiology and pathogenesis of this condition remain unclear, but the pathological basis is known to include hip joint capsule laxity and ligament laxity, and the disease can affect the acetabulum, femoral neck, femoral head, and joint capsule [3]. Early treatment is crucial for a good prognosis, and accurate diagnosis and disease differentiation play a vital role in guiding treatment. Therefore, diagnostic methods are a key focus in research on this condition [4]. Imaging techniques, especially ultrasound, are commonly used in disease diagnosis due to their broad applicability. However, limited research data exists in this area, making it difficult to provide sufficient evidence for clinical practice. Therefore, this study retrospectively analyzed the data of 70 pediatric patients suspected of having hip dysplasia to investigate the diagnostic value of Doppler ultrasound.

1. Materials and Methods

1.1 General Information

We selected 70 pediatric patients suspected of hip dysplasia from March 2022 to March 2024, including 20 males and 50 females. The age range was 1 to 6 months, with an average age of (3.18 ± 0.24) months. The height of the patients ranged from 51 to 79 cm, with an average height of (64.26 ± 3.58) cm. Inclusion criteria: (1) unequal limb lengths or unilateral hip abduction angle < 70 degrees; (2) underwent Doppler ultrasound examination; (3) obtained a three-dimensional CT diagnostic result. Exclusion criteria: (1) pathological hip dislocation; (2) congenital multiple joint contractures; (3) incomplete data.

1.2 Methods

Ultrasound examination: Ultrasound examinations were performed using a GE Logic9 color Doppler ultrasound machine, with a linear array probe at 5-7 MHz and 9-14 MHz. Graf method measurements: On standard coronal images of the hip joint, a baseline, cartilage acetabular cover line, and bony acetabular roof line were drawn. The β angle is formed by the intersection of the baseline and the cartilage acetabular cover line, and the α angle is formed by the intersection of the baseline and the bony acetabular roof line. Both angles were measured twice, and the average value was taken. Graf classification: Type I: Mature development with a sharp bony acetabular edge; Type II: Developmental dysplasia with a defective acetabular roof and a rounded bony acetabular edge; Type III: Subluxation with a poor acetabular roof and a rounded or flattened bony acetabular edge; Type IV: Complete dislocation with a poor acetabular roof and a rounded or flattened bony acetabular edge. Types II + IV were categorized as hip dislocation. Terjesen method measurements: On standard coronal hip images, line b was drawn parallel to the long axis of the probe along the bony acetabular roof, and lines a and c were drawn parallel to line b, tangent to the outer and inner edges of the femoral head. The ratio of the distances between lines bc and ac was defined as the bone rim percentage (BRP). For patients with femoral head ossification center lesions, the lateral head distance (LHD) was measured from the outer edge of the ossification center to line b. Ultrasound assessment of femoral head cartilage: Ultrasound beams passing through the greater trochanter and femoral head were used to obtain the largest section of the femoral head and neck. In this section, the maximum width (W) of the femoral head parallel to the apex of the femoral shaft was measured, as well as the distance (H) from the apex of the femoral head to W. The H/W ratio was calculated to assess for flattening of the femoral head. Three-dimensional CT examination: An experienced radiologist performed and analyzed the three-dimensional CT scans. The diagnostic results were classified as normal hip joint, hip dysplasia, hip subluxation, and complete hip dislocation, with the latter three classified as DDH.

1.3 Observation Indicators

(1) Using the three-dimensional CT results as the standard, the diagnostic efficacy of ultrasound was assessed;
(2) The morphological indicators of the femoral head ossification center were observed, including anteroposterior diameter, lateral diameter, and vertical diameter;
(3) The morphological indicators of the femoral head cartilage and ossification center were measured, including height (H), width (W), and femoral head cartilage H/W ratio;
(4) Ultrasound imaging findings were recorded.

1.4 Statistical Analysis

Statistical analysis was performed using SPSS 26.0 software. Measurement data were expressed as mean ± standard deviation ($\overline{x} \pm s$), and comparisons between the two groups were made using the t-test. Categorical data were expressed as percentages, and comparisons between groups were made using the χ^2 test. A P-value < 0.05 was considered statistically significant.

2. Results

2.1 Diagnostic Efficacy of Ultrasound

Among the 70 subjects, 50 cases were confirmed as DDH by three-dimensional CT. The sensitivity of ultrasound diagnosis was 94.00% (47/50), the specificity was 80.00% (16/20), and the accuracy was 90.00% (63/70) (Table 1).

Table 1. Ultrasound Diagnostic Results

Diagnostic Method	Diagnostic Result	3D CT Results	
		Positive	Negative
Ultrasound	Positive	47	4
	Negative	3	16

2.2 Morphological Indices of the Femoral Head Ossification Center

In the DDH group, the superior-inferior diameter, medial-lateral diameter, and anterior-posterior diameter were all significantly lower than those in the normal group ($P < 0.05$) (see Table 2).

Table 2. Comparison of Femoral Head Ossification Center Indices Between Two Groups [($\bar{x} \pm s$), cm]

Group	N	Superior-Inferior Diameter	Medial-Lateral Diameter	Anterior-Posterior Diameter
DDH Group	50	0.71 ± 0.10	0.85 ± 0.12	0.95 ± 0.10
Normal Group	20	1.04 ± 0.14	1.13 ± 0.10	1.10 ± 0.15
t	-	11.076	9.222	4.881
P	-	< 0.001	< 0.001	< 0.001

2.3 Morphological Indices of the Femoral Head Cartilage and Ossification Nucleus

There was no significant difference in the H/W ratio of the femoral head cartilage between the two groups. However, the height and width of the femoral head cartilage in the DDH group were both significantly lower than those in the normal group ($P < 0.05$) (see Table 3).

Table 3. Comparison of Femoral Head Cartilage and Ossification Nucleus Indices Between Two Groups [($\bar{x} \pm s$), cm]

Group	N	Height (H)	Width (W)	Femoral Head Cartilage H/W
DDH Group	50	0.81 ± 0.10	1.65 ± 0.20	0.49 ± 0.10
Normal Group	20	0.94 ± 0.13	1.89 ± 0.21	0.50 ± 0.11
t	-	4.499	4.472	0.367
P	-	< 0.001	< 0.001	0.715

2.4 Ultrasound Imaging Findings

In children with DDH, the incidence of rounded or deficient acetabular margins, shallow acetabular fossa, labrum positioned between the femoral head and acetabulum, blurred contours, and poor coverage of the femoral head by the acetabular dome was significantly higher than in the normal group ($P < 0.05$) (Table 4).

Table 4. Ultrasound Imaging Characteristics of Two Groups (n, %)

Group	N	Rounded or Defective	Shallow Acetabular Fossa	Labrum Positioned Between	Blurred Contour	Poor Acetabular Coverage of Fem-
DDH Group	50	50(100.00)	50(100.00)	48(96.00)	47(94.00)	48(96.00)
Normal Group	20	1(5.00)	1(5.00)	0(0.00)	1(5.00)	0(0.00)
χ^2	-	65.196	65.196	61.091	52.507	61.091
P	-	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

3. Discussion

Developmental dysplasia of the hip (DDH) is the most common form of pediatric hip deformity, with a significant incidence in infants, often associated with congenital developmental anomalies [5]. Early diagnosis is critical, as untreated cases may lead to worsened conditions, affecting hip joint function in the long term [6]. While X-ray imaging has been traditionally used, it cannot visualize the cartilaginous femoral head, limiting its diagnostic value in early-stage DDH [7].

In this study, out of 70 subjects, 50 were confirmed with DDH via 3D CT. Ultrasound demonstrated a sensitivity of 94.00%, specificity of 80.00%, and overall accuracy of 90.00%, indicating that ultrasound is a highly effective tool for diagnosing DDH. Accurate diagnosis of DDH using the Graf method is heavily reliant on capturing standard coronal plane images of the hip joint. Postnatal hip joint ossification begins around six months, and abnormalities such as a shallow acetabulum or defective acetabular edge may suggest DDH at this stage. However, visual assessment of acetabular morphology is subjective, which may impact diagnostic accuracy [8]. Continuous coronal plane scanning is crucial for evaluating acetabular morphology holistically.

The morphological changes in the femoral head ossification center play a key role in diagnosing DDH. In this study, the superior-inferior, medial-lateral, and anterior-posterior diameters of the femoral head ossification center were significantly smaller in the DDH group compared to the normal group. Additionally, although the femoral head cartilage H/W ratio showed no significant differences between the two groups, the height and width of the femoral head cartilage were both lower in the DDH group. This suggests that DDH is often accompanied by morphological changes in the femoral head, which can assist in diagnosis [9]. Ultrasound has excellent resolution for soft tissues, allowing clear visualization of the femoral head cartilage and labral cartilaginous structures. By measuring the width and height of the femoral head cartilage, it can assist in assessing DDH. Ultrasound imaging of children with DDH primarily reveals rounded or deficient acetabular margins, shallow acetabular fossa, labrum located between the femoral head and acetabulum, blurred contours, and poor coverage of the femoral head by the acetabular dome. Ultrasound examinations can clearly display certain intra-acetabular soft tissues, including degenerative changes in the joint capsule, soft tissue proliferation in the acetabulum, and abnormalities of the round ligament of the femoral head. These structural and morphological changes can manifest as blurred contours and shallow acetabular fossa in the ultrasound images [10].

The results highlight several advantages of ultrasound in the diagnosis of developmental dysplasia of the hip (DDH) in children. Ultrasound provides valuable information about the cartilage and soft tissue structures surrounding the hip joint and allows direct observation of the relationship between the cartilaginous femoral head and the acetabulum, thus offering ample and reliable data for diagnosis. Additionally, ultrasound technology is advantageous in pediatric examinations due to its radiation-free, non-invasive nature and strong reproducibility, making it highly feasible and safe. However, there are certain limitations, such as the inability to simultaneously image both hips. Although elongated probes can display both hip joints, further improvements and widespread adoption are needed.

In conclusion, Doppler ultrasound demonstrates high sensitivity and accuracy in diagnosing hip deformities in children, with the morphological indices of the femoral head cartilage and ossification center serving as the primary diagnostic evidence.

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