RESEARCH ARTICLE

Comparison Static and Dynamic Ultrasound Techniques of DDH: The Role of the Patient's Position

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Abstract

Objectives: The ultrasound examination of the hip joint is performed in the static (Graf) technique in the lateral recumbent position and in the dynamic technique in the supine position. This study compares the two static and dynamic techniques and assesses the role of the patient's position in the examination of DDH.

Methods: This cross-sectional study was conducted in 2020-2021 at Akbar Hospital, Mashhad University of Medical Sciences, Iran. 126 patients suspected of having DDH (199 hip) infants were enrolled in the study. All ultrasound examinations were performed with two static and dynamic techniques by a pediatric radiologist.

Results: In the static and dynamic ultrasound examinations, the average alpha angle was 51.57 ± 6.41 degrees, and 53.41 ± 6.94 degrees, respectively. These changes were not statistically significant (P = 0.312). The relationship and agreement between instability with dynamic technique and instability with static technique (IIC unstable, D, III, and IV) were investigated. Significant agreement (Kappa=0.77 (95% CI: 0.66-0.87) with excellent clinical significance was obtained between the two ultrasound examination method. Also, in terms of DDH types in the static method with instability types in the dynamic method, a substantial agreement was found between the two examination methods (Kappa =0.67; (95% CI: 0.59-0.75) with good clinical significance.

Conclusion: In the ultrasound examination of DDH with static and dynamic techniques, the change in the alpha angle was not statistically significant. Therefore, the hand of the radiologist is open in measuring alpha angles and there is no need to emphasize a specific position. The type of DDH in the static technique completely corresponded to the type of stability or instability in the dynamic technique.

Level of evidence: IV

Keywords: Developmental dysplasia of the hip (DDH), Dynamic technique, Hip ultrasound angles, Static (graf) technique

Introduction

Developmental dysplasia of the hip (DDH) is one of the most common developmental disorders of the musculoskeletal system in childhood, with an incidence of 0.1-2 cases per 1,000 live births and a prevalence of 0.15–4.0%.[1-3] DDH disorder encompasses a wide spectrum of conditions including hip immaturity, acetabular dysplasia, and hip dislocation.[4-7] Studies on the diagnosis, monitoring, and treatment of DDH have yielded controversial or conflicting results.[8] These discrepancies could be due to mis-interpretation of physiologic development of the hip as a pathologic process, use of different terminology by radiologists and clinicians, or different standards for physical examination and hip ultrasound.[1,8]

Although clinical examination is considered a safe and sensitive method to evaluate hip instability in this disorder,

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there is a possibility that some patients may not be treated or an incorrect treatment method may be chosen if only physical examination of the hip is relied upon. Ultrasound screening has been shown in several studies to be far more practical and specific than physical examination in diagnosing the patient and especially in determining the optimal treatment protocol.[9]

Today, in German-speaking countries and Italy, universal ultrasound screening is performed at a newborn age, and rates of 0.07 to 0.26 per 1,000 live births are reported for open reduction.[10,11]

The selective ultrasound screening at 3 months of age is performed in the Netherlands, Norway, and England when risk factors are present, and rates of open reduction in these countries range from 0.57 to 0.70 per 1,000 live births.[12-15] Studies from Germany and Austria showed a decrease in surgery rates and complications, as well as costs, since the introduction of universal ultrasound screening compared with no ultrasound screening.[16] several studies have been unsure whether ultrasound screening reduces overall health care costs.[11,12,15,17] However, the results of Austrian studies show a significant reduction in treatment costs with a modest increase in diagnostic costs.[10,18]

Several ultrasonography techniques have been developed to evaluate DDH. The Graf method has a static nature, established in the German-speaking countries, the Harcke and Suzuki methods have a dynamic nature, and the Terjesen method contains both dynamic and static nature, established in the English-speaking countries.[19,20] The static technique is mainly based on the analysis of the morphology of the acetabulum, whereas the dynamic technique is mainly based on the analysis of the stability of the joint. [21] In the static technique, the shape and development of the acetabulum are mainly studied by measuring of the alpha and beta angles.

This method mainly uses the mid-acetabular-coronal view, which seems to provide a simple and fast way to check the status of hip dislocation.[22,23] The dynamic technique is much more complex but allows a more accurate assessment of hip joint stability by Ortolani, Barlow, Pull, and Push maneuvers.[24] However, which method provides a more accurate assessment of DDH status remains in doubt, and the choice of the best method requires further investigation.

The ultrasound examination of the hip joint is performed in the static technique in the lateral recumbent position and in the dynamic technique in the supine position. This study compares the static and dynamic methods of hip ultrasound examination with variations in the patient's position between lateral recumbent and supine positions.

This study assesses the role of the patient's position in the examination of DDH in two static and dynamic techniques. For this purpose, we compare measurements, the final conclusion, and the agreement of these two techniques.

Materials and Methods

Study Design and Participants

This cross-sectional study was conducted in 2020-2021 at Akbar Hospital, Mashhad University of Medical Sciences, Iran. 126 infants suspected of having DDH (199 hip) were enrolled in the study after parents provided written informed consent. The indications for ultrasonography were abnormal or suspicious findings in the hip or suspected neuromuscular disorders in the hip based on physical examination, bridging presentation at birth, evidence of oligohydramnios. Exclusion criteria were age older than one year and a definitive diagnosis of DDH.

Data Gathering

Ultrasonography was performed by a pediatric radiologist. All examinations were performed using a sonographic machine by 7.5 to 12 MHz linear probes. The hips were examined using two techniques, which were:

Static (Graf) technique: In lateral recumbent position with semi-flexion joint hip in coronal view, the evaluation was made based on the following indicators: 1) the position of the femoral head (normal, decentering, eccentric) 2) the relative shape of the acetabular roof (sharp, rounded, flat) 3) the degree of coverage of the femoral head (coverage, displaced) 4) and labrum shape. In addition, the morphology of the acetabulum is evaluated using the alpha (α) and beta (β) angles. The classification in static (Graf) technique included Type I until Type IV [Table 1].

Dynamic technique: In supine or semi-recumbent position, the measurements were performed in coronal view with semi-flexion joint hip. The classification in dynamic ultrasound technique included stable joint (stable, laxity), and unstable joint (subluxable, subluxated/Dislocatable, reversible dislocated, and irreversible dislocated (luxated)). In the reversible dislocated (Type III), the labrum pressed upward, and in the irreversible dislocated, (Type IV) labrum pressed downward.

Finally, we recorded the angles, final conclusions, and the agreement between the two methods for assessing DDH and Recordings of angle changes were made by altering the patient's position using two different techniques [Figure 1].

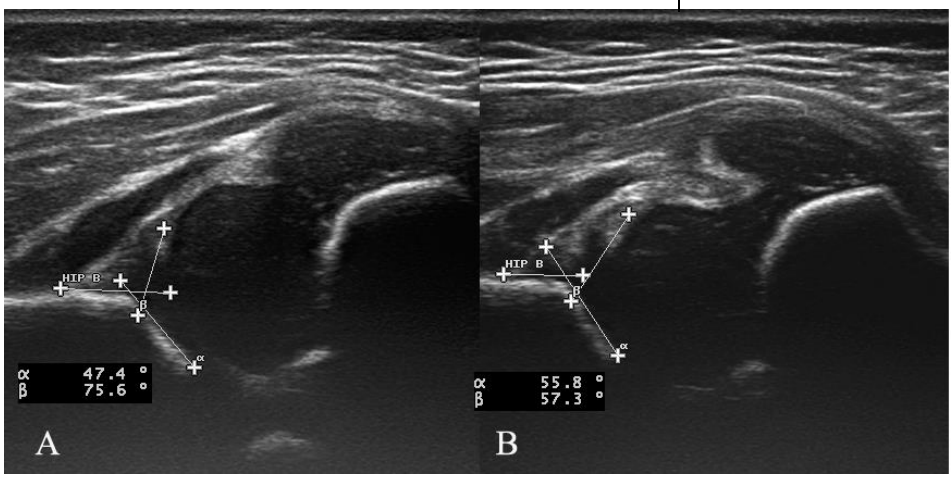

Figure 1.Changes in α and β angles of the hip with position changes. A) Coronal neutral view in the lateral recumbency of the static method. B) Coronal neutral view in supine position

Table 1. The frequency of Static and Dynamic classification and related angles

Graf classification Number (%)		Dynamic classification Number (%)		α (Lateral)	β (Lateral)	α (supine)	β (supine)	α (P-Value)	β (P-Value)
Type I	20 (10.1)	**Stable**	95 (47.7)	55.7±4.1	63.7±6.3	57.3±4.8	60.3±7.3	0.310	0.147
Type IIa+	54 (27.1)								
Type IIa-	21 (10.6)								
Type IIb	27 (13.6)	**Stable, Laxity**	18 (9.0)	46.8±1.5	69.1±6	49.3±3.5	63.3±10.5	0.292	0.151
Type IIc stable	39 (19.6)	**Laxity/ Stable**	39 (19.6)	54.8±3.6	64.9±6.6	54.1±3.3	66.3±7.8	0.480	0.221
Type IIc unstable	14 (7.0)	**Subluxable**	22 (11.1)	49±3.7	72.1±10	49.7±4.7	79.1±17.5	0.471	0.091
Type D	5 (2.5)	**Subluxated/ Dislocatable**	7 (3.5)	47.7±3.4	75.7±7.9	46.3±2.3	69.7±11	0.356	0.106
Type III	8 (4.0)	**Reversible dislocated**	9 (4.5)	39.2±2	72±1	40.2±3.8	69±4.6	0.367	0.149
Type IV	11 (5.5)	**Irreversible dislocated**	9 (4.5)	41.3±11	73.1±4.5	36.7±9.2	70.1±4.3	0.192	0.154
Total				51.6±6.4	66.5±7.7	53.4±6.9	63.7±10.9	0.312	0.146

Statistical Analysis

Data were analyzed using SPSS software (version 18). Qualitative variables were described using frequency and percentage, and quantitative variables were described using mean and standard deviation. The paired t-test and One-way Analysis of Variance (ANOVA) were used to compare means. The Kappa statistic was also used to calculate the agreement between the two techniques. For all statistical tests, $P < 0.001$ was considered statistically significant.

Ethical Considerations

This study was registered in the Research Ethics Committee of Mashhad University of Medical Sciences and was approved (the approval code: IR.MUMS.MEDICAL.REC.1401.105). Informed consent was obtained from the parents of patients before participating in this study.

Results

In the present study, 126 patients suspected of having DDH (199 hip) were examined by ultrasound. The mean age of the patients was 1.76 ± 1.41 months, ranging from 1 to 9 months. 78.2% (154) of patients were girls. In 103 hips (51.8%), the involvement was on the left side. The static types and their equivalent Dynamic classification of patients are presented in Table 1.

In the static ultrasound examination, the average alpha angle was 52 ± 6 degrees and the average beta angle was 67 ± 8 degrees. Also, in the semi-recumbent position, the average alpha angle was 53.41 ± 6.94 degrees and the average beta angle was 64 ± 11 degrees. There was no statistically significant difference in alpha and beta between lateral (static method) and supine positions (P=0.312 & P=0.146). Table 1 shows the static types and their equivalent Dynamic classification and the ultrasound measurements of patients.

In the dynamic approach, the mean alpha angle was significantly different between stable conditions (53 ± 5 degrees) and unstable conditions (46 ± 7 degrees) (P<0.001). There was a significant agreement between the two ultrasound examination methods, with a Kappa value of 0.77 (95% CI: 0.66-0.87), and excellent clinical significance.

In a number of patients with subluxation or dislocation, by changing the position of the patient, a better view of the acetabular morphology was obtained and the possibility of better morphological evaluation and also the angle measurements were improved. The reversibility of the femoral head in patients with dislocation could only be examined with the dynamic method.

Similarly, in the supine position's mean alpha angle was significantly different between the stable (56 ± 5 degrees) and unstable (46 ± 7 degrees) groups ($P < 0.001$), according to the static approach.

As for the relationship between the beta angle values and the dynamic indices, the mean beta angle in dynamic stable and dynamic unstable conditions was 65 ± 7 and 71 ± 10 degrees, respectively, which was significantly higher in the dynamic unstable group ($P < 0.001$). Also, the mean beta angle in supine position under dynamic stable and dynamic unstable conditions was 62 and 8 ±75 degrees, respectively, which was significantly higher in the dynamic unstable group ($P < 0.001$).

The study investigates the correlation between instability in dynamic and static techniques (IIC unstable, D, III, and IV).

Discussion

Hip ultrasonography is currently the most accurate diagnostic tool for the development of DDH in early infancy

and both universal and selective neonatal hip screening (hip ultrasonography) can significantly reduce the rate of DDH cases detected late and treated surgically.[25] Two sonographic techniques are used to assess the presence of DDH and the severity of its involvement, namely, static evaluation (analysis of acetabular morphology based on alpha and beta angles) and dynamic evaluation (analysis of joint stability). The first technique mainly examines the alpha and beta angles determined by Graf, whereas the second type of exanimation mainly examines the degree of stability and the intensity of joint dislocation and its reversibility or irreversibility. The compatibility of the two techniques in patients with DDH isn't complete. However, it is controversial which technique can provide a more accurate overview of the condition and severity of DDH.[16,26]

Results of this study show that there is no perfect agreement between joint stability and joint type in a number of types II, but in other types this match is substantially established. These results are consistent with Diaz et al study.[27] In addition, the average alpha angle in the supine position, (53.4±7) is greater than the lateral position (51.6±6.4) and beta angle in the supine position (63.6±10.9) is less than the lateral position (66.5±7.7) without statistically significant. These values are reversed in the beta angle. Therefore, in a number of patients, a change in position may change the type of DDH.

By changing the position or using a maneuver, it is possible for some patients with a decentering or eccentric hip to return to a normal position [Figure 2]. Therefore, re-measurement in these patients reduces the estimation of the severity of dysplasia. Since the greater trochanter is the axis of rotation of the probe for measuring the acetabulum, so by changing its location during a change of position or maneuver, the cross-sectional area of the measurement also changes, and different results are obtained.

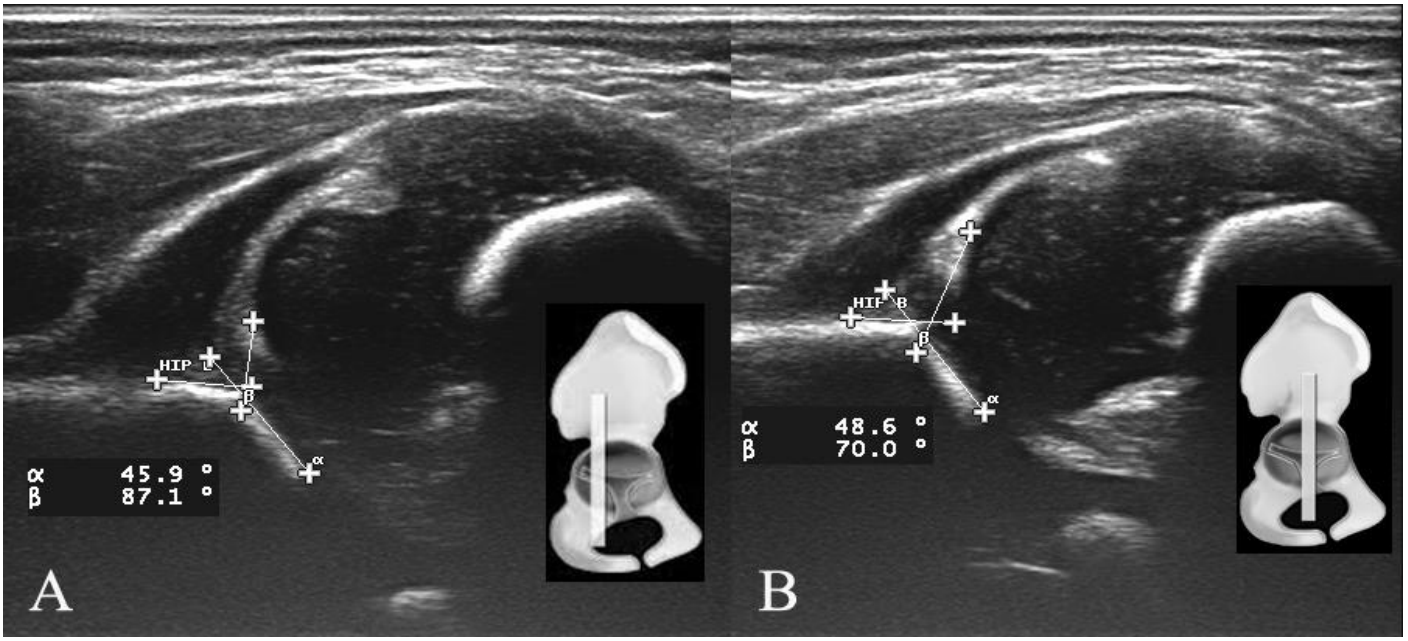

Figure 2. Changes in α and β angles after reduction, possibly by repositioning the probe. A) The coronal view in the lateral recumbency of the static method shows a decentered hip. B) Coronal neutral view in supine position after reduction. Re-measurement indicates a decrease in the severity of dysplasia

There are few studies comparing the usefulness of both static and dynamic ultrasound techniques in the diagnosis of DDH. In the study by Alamdaran *et al.* (2016), of all the hip samples examined, 5% had an immature hip on static ultrasound, while almost all of them were diagnosed using the unstable dynamic technique. Also, 0.3% of normal hips diagnosed by the static technique were diagnosed as unstable by the dynamic technique, and 9% of cases diagnosed as unstable by the dynamic technique also had normal morphology by the static technique. In general, there was the correlation of both techniques in the diagnosis of DDH in 99% of suspected cases. Changes in β angle during pull and push maneuver as an objective hip unstability index was 14.43 ± 5.47 degree in unstable hips.[28]

In the study by Tosun *et al.* (2013), 99.38% patients were in Type 1 at Graf's classification and stable on Harcke's classification. In other patients, in initial evaluation 14 hips were followed according to the result of Harcke's, whereas 18 hips were directed to follow up for their suspicious Graf's result. After 3 months hips were reevaluated and 4 hips were diagnosed to be DDH according to both methods. One hip was diagnosed as DDH by only Graf's method, it was stable in Hercke's. Eleven hips were normal for both methods. They concluded Static and dynamic methods lead to diagnose DDH easily without repetitions and combination of both methods may provide better selection of groups for follow

up and Graf's method performed after normal Harcke diagnosed one more abnormal hip.[29] Finnbogason *et al.* (2008) showed that in the Graf technique, 77% of the hip cases were normal, 20% were borderline/premature, and 3% were diagnosed as pathologic, whereas in the dynamic technique, 88% of the hips were stable, 10% were unstable, and 2% were diagnosed as dislocations, so the correlation between the two techniques in the diagnosis of instability was considered high. Their results show fair to moderate agreement between infant hip instability assessed by dynamic ultrasound and acetabular morphology determined by the Graf method (kappa=0.381).[30] Also, in Rosendal's study (1992), 91% of newborns' hips were unstable with dysplastic morphology and 49% of unstable hips had normal morphology.[31]

Although Falliner *et al.*'s (2006) study showed that 1.3% of hips were pathological according to the Graf method, compared to 4.1% according to Terjesen, with the fair agreement between the two methods,[32] the Czubak *et al.* (1998) show the rate of DDH was 3.9%, according to Graf and 2.9%, according to Terjesen with good accordance between the two methods was shown.[33]

Today's focus is on quantifying static and dynamic ultrasound techniques in the early detection of DDH and the severity of the resulting instability.

Our results showed that the average alpha Graf angle was 51.57 ± 6.41 degrees in the lateral position and 53.41 ± 6.94 degrees in the supine or semi- recumbent position without statistically significant change (P= 0.312). In the supine position compared to the lateral position, the alpha angle increased by 2 degrees in stable cases and 1 degree in reversible dislocation cases and decreased by 4 degrees in irreversible hip dislocation cases. However, these alterations of angles are probably due to changing the cross-sectional area of the measurement during a change of patient position and probe location.

In our study, the results also showed strong diagnostic agreement between the static and dynamic assessment techniques (kappa=0.77). In this regard, it was shown that the value of alpha and beta angles obtained by static technique had a high correlation with joint stability and the severity of dislocation, and that the measurement of these two angles in the static state could be a good representative of the intensity of instability in the dynamic examination of the joint. On the other hand, the instability assessment based on the static assessment substantially agreement with the state of instability and its intensity in the dynamic assessment. In other words, the application of both the static technique and the dynamic technique and their joint alignment can provide a correct and accurate picture of the condition and severity of DDH. Depending on which technique can be used based on the experience of the physician, both techniques can provide an accurate view of the condition and severity of joint instability in DDH, and therefore ultrasonography using both approaches is very useful in diagnosing DDH and its severity. Although significant intra-observer and inter-observer errors have been reported, the classification of DDH into subtypes according to the method of static and Dynamic is standardized.[34] Table 1 shows the approximate equivalent of each of the subgroups in two types of classification.

Overall, both the static technique based on acetabular morphology analysis and the dynamic technique based on joint stability analysis is valuable in diagnosing DDH. The static method provides a simple and quick way to assess hip dislocation status. However, the main advantages of the dynamic technique include free- hand method without the need for a positioning device (Graf candle), better visibility of the acetabular cavity for measurement in some patients, and evaluation of reversibility of the femoral head in patients with dislocation. However, unlike the static technique, the types of DDH in the dynamic technique are not standardized and their guidelines and diagnostic approach are not clear.

Simplified dynamic techniques such as the single-view (coronal/flexion view) method[28] are quick and easy methods, and their standardization can contribute to practicality. The reversibility of the femoral head in patients with dislocation may be prognostic value and even of therapeutic planning, that need to more research. Comparison of measurements of hip angles in different positions has been done in a few studies and this is one of the strengths of our study. Considering the small size of the sample in this research and its single centric, it is suggested that the large multicenter studies be designed and conducted to increase the generalizability and certainty of the results.

Conclusion

In the ultrasound examination of DDH with static and dynamic techniques, the alpha angle may change by one or two degrees depending on the patient's position, but this change is not statistically significant. Repositioning the patient using dynamic techniques may provide a clearer view of the acetabulum morphology, allowing for better morphological assessment and improved measurements. In addition, the size of the alpha angle in the static technique corresponds to the type of stability or instability seen in the dynamic technique. Then, it can be said that both static and dynamic ultrasound methods can detect DDH and determine the severity of dysplasia with a high degree of agreement.

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