Journal of Pioneering Medical Sciences
Received December 19, 2023 Accept January 16, 2024 Publish April 29, 2024.
Volume 13, Issue 2, Pages 54-59

DOI https://doi.org/10.61091/jpms202413208

Role of Dynamic Ultrasound Scan in Detection of Hip Instability and Changing Management Plan

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Abstract **Objectives:** To show the vital role of dynamic ultrasound in hip instability screening and review the management plans available for DDH associated with instability with a view to reduce the incidence of complication from delayed diagnosis in our region. **Place and Duration of the study:** Helena governmental rehabilitation center for children with special needs, Erbil-Iraq, between Nov'21 to Jan'23. **Material and Method:** This study included 942 infants' hips presenting with high risk indicators or a positive clinical examination ranging in age from 6 weeks to 6 months. We performed the ultrasonography using static Graf technique to determine the DDH Types and then apply the dynamic scan to find stability using Moren-Terjesen's and Harcke methods. The management approaches were conducted considering both techniques. We used SPSS version 28 along with Chi-square test for data analysis and comparison of proportions. **Results:** In this retrospective cross-sectional study of 942 hips, the mean age of the infants was 11.9± 4.8 weeks with male to female percentage of 46% to 54%. We found a correlation between family history and breech presentation to the dynamic scan stability. In the Graf technique 55% showed absence of dysplasia while the dynamic scan showed 66% of the hips as normal and 34% as unstable. Further the significant statistical association (P= 0.001) between results of dynamic scan stability to the effect on the management plan was also found to advise the change for the unstable hips. **Conclusion:** It is crucial to apply both static and dynamic scans in screening of DDH, so that we can reduce the possibility of late detection and elevate the level of diagnostic accuracy. We should follow a strict guideline for management of all DDH cases (stable and unstable) and change the plan accordingly.

Key Words DDH, stability, dynamic, subluxable, dislocatable, management

1. Introduction

DDH was first described by Hippocrates (460-370 B.C) who reported it to be caused by congenital and injury to the mother's womb, and Ambroise Pare found that it could be hereditary. Clinical screening is a common practice internationally for infant hips however its dependent on experience. There are numerous techniques used for the examination of infant hips using ultrasonography.

Developmental Hip dysplasia (DDH) is a group of disorders that ranges from unstable hip to total dislocation.

DDH is commonly found in infants with musculoskeletal birth defects with an occurrence in children of up to 11.5/1,000 live births estimated using meta-analysis procedures and numerous logistic regressions [1]. Some of the factors that increase the risks for DDH are positive family history, breech presentation and the oligohydramnios [2]. In infants DDH is asymptomatic and some of the early symptoms are abnormal walking, limping, waddling when the child is learning to walk however late detection can lead to pain and early osteoarthritis. Overall, the prevalence of 1% to 1.5% in infants is reported by Alfonso with 0.005% incidence in males and 0.013 in females [3]. The hip ultrasonography is performed both statically and dynamically and is acknowledged as an early diagnostic technique for DDH.

In order to assess the neonatal hips using the static ultrasound imaging, Graf's method is widely used in most places [4]. In this method, the infant's hip morphological assessment helps to assess the angle of the roof of the acetabulum (alpha angle) which is classified using the hips into being mature, immature, or dysplastic, however it is not considered as an effective tool for early neonatal diagnosis.

Ortolani method is the clinical test used to spot unstable hips whereby the dislocated femoral head is relocated by a sudden palpable clunk into the acetabulum by holding the infant's hip although the accuracy is dependent on skills and experience of the operators [2], [5].

In 1988, Harcke [6] first reported the dynamic ultrasound for hip examination. In previous literatures, lateral dynamic ultrasound (LDUS) & anterior dynamic ultrasound (ADUS) are the two techniques that are widely used for evaluating hip mobility [7]. Our objective is to study the role of dynamic ultrasound in screening while simultaneously reviewing the management plans for developmental dysplasia of the hip with a view to reduce the progression of true DDH in infants.

2. Material and Methods

The detailed study was carried out during November 2021 to January 2023 including a total of 942 hips examination of infants with a suspicion of DDH aging 6 weeks to six months in Helena Governmental Specialized Rehabilitation Center of Children with Special Needs/ Iraq Government/Kurdistan Region/ Erbil City. The following infants were excluded in the study:

- infants with neuromuscular disorder
- myelodysplasia or arthrogryposis.

We also conducted a validation study by taking referrals from orthopedic specialists and outpatient pediatricians. After taking consent we logged patient data and assessed the presence of risk factors (family history as first degree relatives, breech presentation during third trimester or at birth, and first-born child). Both genders were examined. Once the validation study statistically proved the technique to be followed, we performed the ultrasound using a GE Versana Premier ultrasound system with a linear probe 12 L to check each patient bilaterally during static and dynamic scans.

The infant was positioned to lay on its side (15–20° flexion) or with the hip placed in 35 degrees of flexion to see the hip in a coronal view. Overall approach included coronal lateral neutral at rest (static morphological test for Graf Types and obtaining the ACI -acetabular coverage index). The coronal lateral flexion was obtained by adduction (stress) to calculate ACI and stability assessment for cases Graf Types I through IId, while Harcke [6] method (transverse abduction-adduction scan) is used for reducibility, which is only applicable to advanced cases of DDH [Type III and IV].

Modified Graf Method: the hip joint was classified by U/S; the coronal section at rest yielding the following Types:

1) Graf Type I (normal hip joint).
2) Graf Type IIa: age <3 m (representing physiological immaturity).
3) Graf Type IIb: age >3 months (regarded as delayed maturity).
4) Graf Type IIc: (dysplastic hip).
5) Graf Type IId: (dysplastic hip)
6) Graf Type III: (partially dislocated hip).
7) Graf Type IV: (frank total hip dislocation).

- (β) Alpha angle normal value >60
- (β) Beta angle normal value<55

A. Dynamic Scan included two Methods as given below:

1) **Moren-Terjesen's femoral head coverage method using 3 categories:** at rest, coronal lateral, neutral is used to obtain the percentage of acetabular coverage index [ACI] as d/D [normal value>50%]. In the same position, we applied adduction stress while the hip in 90-degree flexion, to drive the femoral head out of position with the least amount of force [without harming the baby], we then obtained acetabular coverage index[ACI] during stress (Figure 1 A and B). The terminology we used to classify stability are:
   A. Laxity if the ACI is >50% at rest but mildly reduced <50% on stress.
   B. Subluxable if ACI is <50% at rest and further reduced on stress but not dislocated.
   C. Dislocatable if ACI is <50% or normal at rest but the head is completely dislocated on stress.
2) **Harcke Method:** It is used to assess head reducibility, by positioning the infant in supine position and conducting the abduction-adduction movements and then probe in the transverse section (similar to Ortolani-Barlow Tests). In our analysis, this exam is only applicable to hips that are dislocated [Graf III and IV]. The terminology we used are:
   - Reducible head: if the head is already dislocated but reduced into the socket on abduction [Ortolani Test].
   - Complex or irreducible head: if the head is already out of place and not sufficiently reduced into the socket on the abduction test. This examination is subjective and not objective (Figure 2).

	Variable	Total Population
Demographics	Mean Age ± SD	11.9± 4.8
	Max	25 weeks
	Min	6 weeks
	Gender (%)	M (46%), F (54%)

Table 1: Demographics of Infants

The treatment plan is reviewed taking into account the different Graf Types as well as the stability and reducibility findings from the dynamic scan. Our orthopedic specialist put the treatment plan into practice and made the necessary adjustments and the ethical committee for the research protocol of the Kurdistan Board of Medical Specialties (KBMS) approved this study. The data proportions were compared using the Chi square test of associations. In several cases, Fisher's exact test and T-Test for two independent variables are also utilized to compare the means of two samples. We have considered the p-value of less than 0.05 to be statistically significant and analyzed the data using the SPSS, version.

3. Results

In this retrospective cross-sectional study 942 hips of infants were included, and the mean age of the infants of 11.9± 4.8 weeks with male to female percentage of 46% to 54% with age of minimum 6 to maximum 25 weeks (Table 1).

Figure 1: A: Coronal lateral neutral plan, B: ACI at rest and on stress

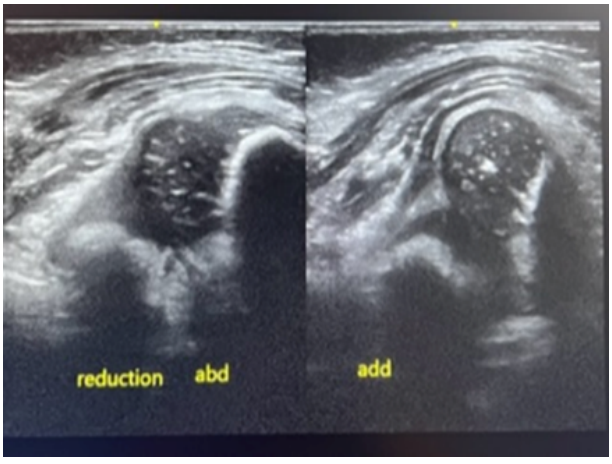

Figure 2: Reducibility test-transverse plan[ortolani-barlow]

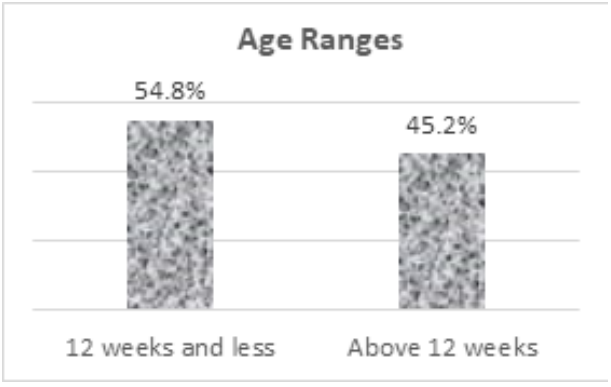

Figure 3: Age-Range of Infants

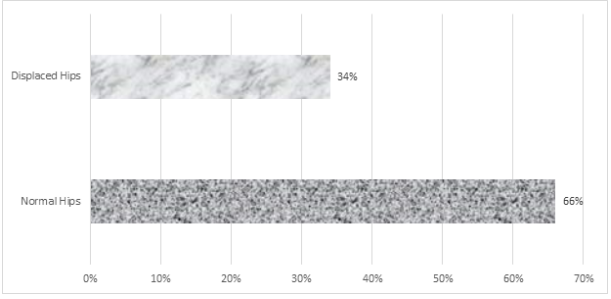

Figure 4: Dynamic scan stability

Amongst the total infant, around 54.8% of them were aged 12 weeks and less, and 45.2% were aged more than 12 weeks (Figure 3). Regarding the Graf Types of the hips, we noted 55% of them were Type 1, 22.4% were Type 2a and 15.1% were Type 2b. Furthermore 55% showed absence of dysplasia, 22.9% had right-side dysplasia, and 22.1% had left-side one while the dynamic scan was negative showing 66% of the hips as normal and 34% as displaced (Figure 4) with 55.3% left side being affected and 44.7% with right side being affected. About 17.2% showed laxity, 14.1% were sublaxable, and only 2.7% were dislocatable.

*Among the unstable hips (Out of 320 unstable hips), 50.6% of the infants had laxity , 41.6% were subluxable and only 7.8% had disclocatable hip (Figure 5).

*There was a significant statistical association (P= 0.001) between the Graf Types of the hips to the results of dynamic scan stability, (Table 2). *: Fischer exact test We found a correlation between family history and breech presentation in utero to the dynamic scan stability (P= 0.001 and 0.001, respectively), while it was less significant compare to the P value for the firstborn child (P= 0.452) (Table 3). *There was significant statistical association (P= 0.001) between results of dynamic scan stability to the effect on the management plan, where unstable hips changed the management plan,

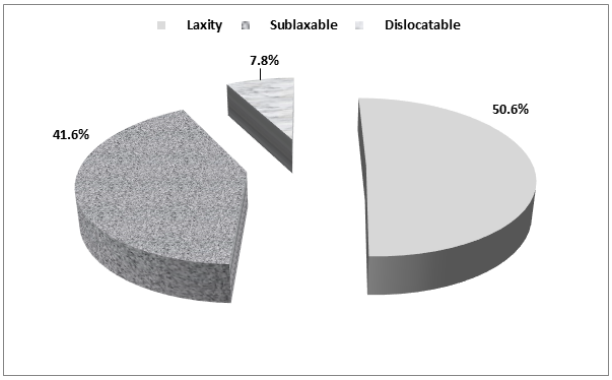

Figure 5: Types of instability among infant hips

Variables	Dynamic scan stability (No. & %)			P value*
	Stable	Unstable	Total	
Graf type				
Type 1	412(65.4)	106 (34)	518 (55)	0.001
Type 2 a	105(16.7)	106 (34)	211 (22.4)	
Type 2 b	103(16.3)	39(12.5)	142 (15.1)	
Type 2 c	2 (0.3)	50(15.6)	52 (5.5)	
Type 2 d	0 (0.0)	3 (1)	3 (0.3)	
Type 3	0 (0.0)	7 (5)	7 (0.7)	
Type 4	0 (0.0)	9 (2.9)	9 (1.0)	
Total	622 (66)	320 (34)	942 (100)	

Table 2: Association of Graf type to the hip stability

(Table 4).

4. Discussion

DDH can cause hip join laxity and acetabular dysplasia both and some of the common risk factors have been hormonal factors, ligament laxity, breech birth, presence of oligohydramnios, swaddling, family history and even environmental factors play a role too.

About 1 in 60 infants have hip instability and more than 60% of them get recovered within 2 months and only 12% need therapy to stabilize DDH [8].

Some of the most used approaches of screening for DDH in infants are sequential physical examinations of the hip with the Ortolani and Barlow maneuvers and using ultrasonography. Despite all the studies and techniques, DDH detection is challenging in infants and selection of the best sonographic method is yet a matter of controversy however Graf's Method or a modification using Harcke's and Morin's technique are widely advisable.

Variables	Dynamic Scan Stability n: (%)			
	Stable	Unstable	Total	P Value
Family History				
Yes	310 (49)	213 (66.6)	523 (55.5)	0.001
No	312 (50.2)	107 (33.4)	419 (44.5)	
Breech Presentation				
Yes	191 (30.7)	140 (43.8)	331 (35.1)	0.001
No	431 (69.3)	180 (56.2)	611 (64.9)	
Firstborn				
Yes	174 (28)	95 (29.7)	269 (28.6)	0.452
No	448 (72)	225 (70.3)	673 (71.4)	
Total	622 (66)	320 (34)	942 (100)	

Table 3: Associated Risk Factors to the Dynamic Scan Stability

Dynamic Scan Stability			
Effect on Management Plan	(No. and %)		P value*
	Stable	Unstable	
No change	622 (100)	0 (0)	0.001
Change the plan	0 (0)	320 (100)	
Total	622 (66)	320 (34)	942 (100)

Table 4: Association of dynamic scan to the effect on management plan

Although for the Graf method, it's vital to analyze the eight anatomical markers namely acetabular bony rim, hyaline cartilage, labrum, bony roof, chondro-osseous junctions, femoral head, synovial fold and hip joint capsule and the use of coronal lateral flexion view obtained by adduction helps reveal anatomic landmarks and in improving the accuracy of the angles.

In our study of 942 hips of infants the mean age was 11.9± 4.8 weeks which is equivalent to 2 to 4 months while Alamdaran,S.A and colleagues conducted a study on 300 high-risk infants and their mean age was 1 to 2 months [8].

Similar results were found in the study of 50 infants conducted by AMER et al [9]. [9]. and colleagues with mean age of 11.21±4.81 weeks and minimum and the maximum age of 3 weeks to 18 weeks.

We found a correlation between family history and breech presentation in utero to the dynamic scan stability (P= 0.001 and 0.001, respectively), and DDH was less significant according to the P value for the firstborn child (P= 0.452) and similar findings were reported by Bohac ˇek, I [10] where he mentions that the risk factors of a child to advance into DDH is 6% if one of the siblings has DDH history and 12% if his parents has DDH and 36% if both parent and siblings have DDH. Similar findings were reported by AMER, et al [9] showed the most prevalence in C-section delivered infants and family history.

Regarding the Graf types in our study, we noted Type 1(55%), Type2a (22.4%) and Type 2b (15.1%) with 55% showing no dysplasia and 22.9% with right-side dysplasia, and 22.1% with left-side dysplasia. This was supported by similar close findings of dynamic scan showing 34% as displaced. However, the detection of left and right side was relatively different resulting in 55.3% with left side dysplasia and 44.7% with right side being affected. Its significant to note that according to Irha et al. [11] study which evaluated 100 hips, the detection rate of 19% was reported using the Graf technique.

According to the Moren-Terjesen's method in our study which is recommended as the second most suitable technique further seconded by Gunay et al [12] study which evaluated 100 hips and reported a detection rate of 30% and sensitivity of 89.47% and an overall precision of 82.59% using this

method. In our study 66% of the hips were stable and 34% were reported to be unstable/displaced hips, with 50.6% showing laxity, 41.6% sublaxable, and only 7.8% showing dislocatable hips. Concerning the relationship between risk factors and dynamic scan stability, there was a significant statistical association between family history and breech presentation to dynamic scan stability (P= 0.001 and 0.001, respectively), but not to the firstborn child (P= 0.452). A female infant through a frank breech position at birth and a family history of DDH are two of the most significant risk factors for the disease.

In one study, they performed the dynamic stress maneuver by flexing the hip and knee with the thigh adducted and assessing hip stability (Barlow maneuver) and the hip morphology was assessed at rest [13]. The same strategy was used in our study by using coronal neutral (static morphological test for Graf types), coronal flexion for acetabular coverage index at rest and on stress for the purpose of stability assessment in Graf Types I through IId while transverse abduction-adduction scan-Harcke method [in supine position with transverse view] for reducibility, which is limited to advanced cases of DDH [Type III and IV].

LDUS (lateral dynamic ultrasound) allows for a visual assessment of the change in the femoral head's percentage cover with pressure. Early studies discovered that eDUS scans, particularly when performed by skilled professionals, results in a relatively better diagnostic value of static morphology in the ultrasound [14].

Kosar's study [15] discovered that Graf technique showed a 20% of hips as immature while only 10% showed unstable status using the dynamic screening. The immature results were observed lesser in cases and could be due to the reduced rates of DDH in that area. The term "subluxation" includes laxity and displacement while the "degree of subluxation" is an unclear state and needs further validating results. According to Harcke in Marco et al. [16] study, the infant must be relaxed in order for the stress exercises to be precise and consistent. Sonography can sense subluxation even if it is not visible on a clinical examination.

The occurrence of DDH in late cases can be reduced by early ultrasound using the dynamic technique as supported by Clarke et al. [17].

In our study, the results of dynamic scan stability and the effect on the management plan are statistically significant (P= 0.001), where unstable hips result in a changed management plan. According to Barbuto, L et al. [18], reported that in 50% of subjects, most of the information gathered through ultrasound assessment showed changes in diagnosis and consequently the treatment methods in 32% of subjects.

Hips with normal or immature morphologically assessed sonographically doesn't required treatment as per the study cited by Husum et al. [19] the series demonstrated was all recovered spontaneously.

As cited by Aarvold, et al. [20], it is agreed widely that the greater number of clinically unstable hips at birth spontaneously heal. However, in order to assess which hips might develop dysplasia, or dislocate, there are no recognized tools. To be fair, Infants with such signs and findings usually go treatment starting from birth. In our institution we treat DDH as in Table 5 and 6:

Kotlarsky et al. [21] studies suggested full time harness treatment with weekly repeat dynamic ultrasounds for infants of acetabular dysplasia along with repeat dynamic ultrasounds. Although the Pavlik harness is the standard treatment, however Craig splint and the von Rosen splint have been revealed to be effective as cited by Jacek [22]. Once the hip is stable on ultrasound, the patient can be seen at 3 to 4 months of age, and then every 2 to 3 months after that for radiographic evaluation

However, it's an argument that if patients with modest acetabular dysplasia and no hip instability in the Barlow or Ortolani maneuvers of the hip require treatment. We didn't do this in our study because we discovered that some of the unstable ones become completely dislocated in the future and we can't tell which ones are likely to develop DDH. A study by Kelley et al. [23] evaluated that the success rate of treating 96 infants with Ortolani-positive hips in a Pavlik harness and found 44 hips were treated by utilizing data from dynamic ultrasound. After an average of 17.6 weeks in the Pavlik harness, 39 of the 44 hips were successfully reduced, with 0% cases of Pavlik harness-induced femoral head osteonecrosis.

5. Conclusion

Therefore, for accurate diagnosis of DDH, conducting static and dynamic ultrasound examinations in the first 6 weeks to screen morphology and stability of infant hips is the best method because in young age, milder dysplasia is most common which could be cured on its own and it does not involve treatment however all risky infants should go through an ultrasound for detection of dysplasia. Our study concluded that the two significant risk factors are the family history and breech presentation and the skills of the operator are extremely necessary for accuracy .We envision a future goal of having a reliable authorized guideline for DDH management in terms of both static and dynamic scan, as the rate is identified in late stages often leads to surgical treatments for DDH however it is being reduced due to the universal or selective neonatal hip screening programs that have been adopted widely.

Conflict of interest

The authors declare no conflict of interests. All authors read and approved final version of the paper.

Authors Contribution

All authors contributed equally in this paper.

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Graf Type	Stable hip management plan	Unstable hip management plan
Type 1	Reassure	Reassure and follow-up
Type 2a	Reassure and follow-up	Full time Static splint, follow-up at 45 days.
Type 2b	Full time Dynamic splint, follow-up every 45days then part time splint 45days	Full time Static splint, follow up every 45days then part time splint 45days
Type 2c	Full time Closed reduction and splint, follow-up every 45days then part time splint 45days	Full time Closed reduction and splint, weekly ultrasound, if reducible, splint will be there for 45days then weaning gradually
Type 2d	Full time Closed reduction and splint, follow-up every 45days then part time splint 45days	Full time Closed reduction and splint, weekly ultrasound if reducible splint will be there for 45days then weaning gradually.

Table 5: Management of DDH hips according to stability on dynamic scan [coronal lateral plane at rest and stress]

Graf Type	Reducible on dynamic scan	Complex
Type III	Closed reduction and cast, weekly ultrasound for the first 3weeks, if reducible cast will be there for 3months then weaning gradually in splint	Surgery
Type IV	Closed reduction and cast, weekly ultrasound for the first 3weeks, if reducible cast will be there for 3months then weaning gradually in splint	Surgery

Table 6: Management plan of dislocated hips [Type III and IV] according to reducibility on transverse dynamic scan [Ortolani and Barlow]

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