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Review Article

Advancements in screening techniques for hip developmental abnormalities in neonates

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Abstract

The most prevalent congenital condition affecting the musculoskeletal system in infants is called developmental dysplasia of the hip (DDH), which includes a range of conditions from a stable hip with a slightly dysplastic acetabulum to total hip dislocation. Over the past few decades, systematic screening for newborn DDH has been carried out globally, and it has made a significant contribution to the early diagnosis, treatment, and detection of DDH. Nonetheless, among the screened population, there are still some instances of delayed diagnosis or, on the other hand, overdiagnosis or overtreatment on occasion. Moreover, there is ongoing debate on DDH screening methods. Our study's objective was to examine the available research on DDH screening, with a focus on the efficacy of various DDH screening techniques. Using PubMed, we searched MEDLINE and other databases for the DDH screening literature from 1958 to 2022. In this study, we examined the development of screening tactics and the history of DDH screening. We also talked about the debates surrounding ultrasonography and clinical screening techniques, focusing especially on the views that are now held. Universal ultrasound screening appears to be the best choice for preventing late-detected cases and can be suggested as a beneficial preventive strategy in light of the current scientific evidence and modifications in neonatal DDH screening techniques.

Keywords: Developmental dysplasia of the hip, Hip screening, Ultrasound

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Introduction

The most prevalent congenital condition affecting the musculoskeletal system in infants is developmental dysplasia of the hip (DDH), formerly known as congenital dislocation of the hip (CDH). DDH is a spectrum disease that includes total hip dislocation as well as stable hips with moderately dysplastic acetabulums (1). The incidence varies by geography, ethnicity, etc., and ranges from 0.4% to 1%. The incidence of total hip dislocation is 1% (2). DDH can exacerbate or worsen if it is not provided the proper attention or treatment promptly, which further compromises children's ability to develop normally and grow healthily (3). For this reason, screening infant hips is crucial for prognosis prediction as well as for the early diagnosis, treatment, and detection of DDH.

For over 70 years, planned screening for newborn DDH has been carried out, having begun in Sweden in the 1950s (4). Different countries use different screening techniques and scales. Because of the substantial variations in economic status, screening programs differ significantly even among different regions of the same nation (5). When DDH screening was first being developed, physical examinations served as the primary basis for tests. Ultrasound technology became widely used for DDH screening in the early 1980s after it was developed for newborn hip evaluations. Whether a certain group of neonates or all neonates are screened determines whether ultrasound screening for DDH is universal or selective. Every one of the current screening approaches has pros and cons, fans and detractors, and some cases of delayed diagnosis or, on the other hand, overdiagnosis or overtreatment happen periodically even among the screened population. As a result, we have compiled the development of DDH screening methodologies and examined the available scientific data as well as modifications to newborn DDH screening procedures. We have also established effective programs and precise screening methodologies, compared the socioeconomic factors and efficacy of various screening programs, and hoped to assist medical practitioners in selecting the best course of action for early detection.

DDH screening's background

Several committed medical professionals, including Roser, Calot, Le Damany, Ortolani, Barlow, and others, developed tests that were similar or identical in the late 19th and early 20th centuries to diagnose DDH in infants who were dislocated and repositionable or repositioned and dislocatable hips (6). However, DDH is typically detected when a kid begins to stand and walk because formal screening is not available in the majority of countries. In certain nations and areas, systematic neonatal DDH screening was implemented in the 1960s, which significantly increased the accuracy of DDH diagnosis at an early age. Early in the 1960s, Von Rosen (4) of Sweden and Barlow (7) of Britain reported on the early diagnosis of DDH using the clinical examination of hip instability by Ortolani sign in approximately 24,000 and 9,289 newborns, respectively, and claimed very satisfactory effects to eliminate late cases. Their accomplishments sparked interest in early DDH diagnosis and treatment around the globe. The United Kingdom's Ministry of Health began conducting clinical screening for DDH in newborns nationwide in 1969, with encouraging outcomes. Subsequently, numerous other European and North American nations released papers outlining their unique screening procedures and accomplishments (8). During the 1960s, a physical examination was the only method used to screen neonates for DDH. The Barlow test was used to verify the hip's stability, and the Ortolani test was utilized to assess if the hip was dislocated. According to some academics, restricted abduction can become clinically significant after a month of age and is a useful predictor of DDH that can be used in addition to the Barlow and Ortolani tests.

Screeners in different nations and areas had different backgrounds and approaches to screening in the 1960s. In 1972, MacKenzie (9) wrote a summary of the experience of DDH screening for all infants born in Scotland's northeast between 1960 and 1969. First, the physical hip assessment techniques were demonstrated to all physicians and midwives. Pediatric registrars examined hospitalized newborns, whereas family physicians and midwives assessed newborns born at home or in outlying hospitals. In the third week following birth, all newborns with aberrant findings were referred to the clinic for treatment. At that time, the Swedish National Health and

Welfare Board advised routine DDH screening for all infants, and several other nations and regions, including Northern Ireland, Finland, Sweden, and Norway, adopted a similar approach. In 1,983, Hansson (10) wrote a paper outlining the Swedish screening approach that obstetrics departments employed between 1973 and 1978. It was suggested that a pediatrician check each newborn baby's hip joints twice a day while they are in the ward. Because hip instability may regress spontaneously during the first few days of life and there is no guarantee that a newborn child whose hip instability recovers spontaneously will not later develop DDH, Hansson emphasized the importance of performing the first clinical examination during the first 24 hours of life. In Vancouver, formal screening for congenital hip problems began in 1964 for babies. Lehmann et al. (11) assessed the results of initial screenings conducted in Vancouver in 1981 and noted that systematic screening can successfully lower the rate of delayed diagnosis. They also demonstrated that the highest success rate was achieved when screening was conducted in the community by a single, skilled orthopedic surgeon and specially trained nurses.

Because of the varying false positive and false negative rates shown in the literature, the usefulness of physical screening for all newborn hips has remained debatable since the 1970s (12). The screening results from the Norwich region of England for the five years from 1968 to 1972 were examined by Jones et al. (12). Even though skilled orthopedic surgeons conducted the screens, the findings imply that their efforts were only successful in 50% of the infants screened, and it is more likely that a significant portion of malformed hips remain undetectable at birth when using the standard clinical instability tests. A study by Engesaeter et al. (13) found that no hip instability was found in 92% of patients who had clinical screening after delivery and received hip replacement due to hip deterioration from possible dysplasia. Robertson (14) conducted a 30-year analysis of DDH screening papers and concluded that all screening attempts had failed and that there had been no change in the requirement for DDH-related procedures. Numerous clinical studies have demonstrated that in cases where hip dislocation is irreducible, hip instability goes away soon after delivery, or the instability is too slight to be identified, hip dislocation may go undetected. Additionally, the prevalence of hip dislocation varied widely during the period, ranging from 0.041% to 16.8% according to several screening organizations (15). Naturally, the occurrence is influenced not only by the physical screening method's limits but also by ethnic and genetic characteristics, the diagnostic criteria employed, the expertise and training of the examiners, and the child's age at the time of the examination. Numerous studies that yielded fresh perspectives on screening practices were spurred by these unfavorable outcomes concerning the physical screening approach.

Using ultrasound to examine the hips

Many of the above-mentioned issues with physical screening of the hip existed before the 1980s, and standard X-rays were unable to resolve them. The majority of a baby's cartilaginous hip joint cannot be seen via an X-ray, which exposes the patient to radiation (16). To accurately identify hip dislocation, Von Rosen examined x-rays with each hip rotated medially and abducted 45° or more; yet, this position is challenging to achieve, and positioning and interpretation should be left to qualified professionals. The results are easily skewed when the position does not adhere to the guidelines (9). An intrusive diagnostic technique that exposes patients to X-rays is provided by the clinical usage of arthrography. Magnetic resonance imaging (MRI) is expensive, and it can take up to 20 minutes to complete an inquiry, necessitating anesthesia. Austrian orthopedic surgeon Reinhard Graf (17) produced the first report on ultrasonography tests of the baby's hip in 1980. Graf demonstrated that because the femoral head is primarily cartilaginous, ultrasonography could easily detect the anatomy of the baby's hip joint. Graf (18) presented the Graf diagnostic criteria and examined the use of ultrasonography in DDH screening in a 1984 paper that marked a turning point in the early diagnosis of DDH. Since then, ultrasonography examination has steadily risen to the top of the list of crucial and often-used methods for DDH early diagnosis. According to Roposch (19) in 2003, the advent of hip ultrasonography for DDH was a noteworthy development, and there aren't many instances of this kind of care in juvenile orthopedics.

The first method disclosed was the Graf hip ultrasonography skill, which is arguably the most popular way. It

is based on morphological assessment of the hip in the coronal plane at rest, with the main objective being the standardization of the assessment of acetabular morphology. Clearly stated quality requirements, such as anatomical identification (checklist I) and usability check (checklist II), are required in addition to the standard approach, which is crucial. The chondro-osseous border, the femoral head (the ossification nucleus), the synovial fold, the joint capsule, the labrum, the hyaline cartilage of the acetabulum's roof, the bony portion of the acetabulum's roof, and the bony rim are all included in Checklist I. Checklist II consists of the following: (a) the os ilium lower limb's presence, indicating that the beam passes through the acetabular fossa, the deepest portion of the iliac bone; (b) the iliac bone's straight silhouette; and (c) the labrum, indicating that the scan was carried out in a standard plane (26, 27, 28). Infant hip joints are classified into four types and ten subtypes based on the Graf ultrasonographic hip classification system. The α and β angles are quantitative indications of the bony and cartilage acetabular roofs, respectively (**Table 1**).

Table 1: Hip categories based on sonography according to Graf

Type	Cartilage roof α angle	Cartilage roof β angle	Bony rim	Subtype
Type I Mature hip	Good α ≥ 60°	Covers the femoral head β < 77°	Angular/blunt	Ia: β ≤ 55° Ib: β > 55°
Type IIa Physiologically immature (age ≤ 3 months)	Deficient α = 50°–59°	Covers the femoral head β > 55°	Rounded	IIa+: α = 55°–59° (0–6 weeks) IIa−: α = 50°–54° (6–12 weeks)
Type IIb Delay of ossification (age > 3 months)	Deficient α = 50°–59°	Covers the femoral head β > 55°	Rounded	
Type IIc Critical hip	Severely deficient α = 43°–49°	Still covers the femoral head β < 77°	Rounded to flattened	
Type D Decentring hip	Severely deficient α = 43°–49°	Displaced β > 77°	Rounded to flattened	
Type III Dislocated hip	Poor α < 43°	Pressed upwards, perichondrium slopes cranially	Flattened	IIIa: hypoechoic cartilage acetabular roof IIIb:hyperechoic cartilage acetabular roof
Type IV Dislocated hip	Poor α < 43°	Pressed downwards, perichondrium is horizontal or dips caudally	Flattened	

Features of the graf technique in comparison to alternative DDH ultrasonography techniques

Between 1980 and 2000, some researchers developed novel ultrasonography techniques to evaluate baby hips. The views acquired and the imaging planes employed in these techniques varied noticeably from one another. The techniques include the femoral head coverage-focused Morin's method (20) and Terjesen's method (21), the dynamic hip stability-detecting Novick method (22) and Hacke method (2), Suzuki's method (23), which assesses the relative positions of the femoral head and acetabulum, and Rosendahl's method (24), which thoroughly assesses morphology and stability. A hip ultrasound technique combining static and dynamic imaging was published by Harcke and colleagues. The femoral head's position at rest and during stress testing was the primary focus of the supine imaging of the infant, both with and without the application of tension (the Barlow maneuver). Examiners' subjective considerations can readily alter the results of the dynamic phase of the examination, which determines if the hip is stable, lax, subluxable/subluxed, or dislocatable/dislocated. Using a unique long probe, the Suzuki method simultaneously scans both sides of the hip joint and uses the auxiliary line to determine how the femoral head and acetabulum relate to one another. The technique can be used to show how to maintain reduction of a dislocated hip in an infant wearing a harness or a plaster cast, according to the author's description. On the other hand, according to the work's original illustration, this makes sense for a Pavlik harness but appears hard to imagine for a plaster cast that usually reaches the navel. Furthermore, the shape of the acetabulum and dynamic stability are not taken into account by this technique (25).

The measurements made using the Terjesen method are (a) from the acetabular floor to the lateral bony rim of the acetabular roof and (b) from the same place on the acetabular fossa to the lateral joint capsule. The method focuses on the bony rim percentage (BRP). The formula for the BRP is a/b × 100. This approach can only indicate whether a hip is aberrant in basic terms and cannot provide a more detailed classification of hips. Instead, it assesses the development of the acetabulum indirectly based on the coverage of the femoral head. However, using objective standards, the Graf approach can identify hip joints that require therapy by directly evaluating the growth of the acetabular crest. Peterlein et al. (26) and Diaz et al. (27). When infant's hips were evaluated using the Graf, Harcke, Suzuki, and Terjesen procedures, it was discovered that the α angle had greater dependability than the β angle and that the Graf methodology was the most dependable. The primary benefit of the Graf technique, according to certain clinical research, is that it is a straightforward, precise, quantitative, and standardized assessment linked to an understandable, standardized hip categorization system that may directly lead treatment.

Universal versus selective ultrasonography screening

Since the 1980s, when ultrasound was first used for hip exams in numerous nations, the DDH screening approach has continuously evolved. Ultrasound screening can be "universal" for all newborns or "selective" for high-risk populations. The data in the literature varies greatly when it decides between universal and selective ultrasonography screening. The literature does, to some extent, represent changes in practice between various nations or areas as well as changes in understanding over time.

Program for selective ultrasound screening

Selective ultrasound screening, which is used for newborns with hip abnormalities identified through physical examination and infants with risk factors for DDH, combines clinical and sonographic neonatal hip screening. According to some research, having a favorable family history and presenting breech are the primary risk factors for DDH (28). Torticollis, oligohydramnios, female sex, and swaddling of the infant are additional risk factors (29).

Many nations, including Australia, the United Kingdom (UK), and North America, use selective ultrasound screening (29). Using a selective screening program based on risk factors and clinical examination, the majority of medical centers screen newborns for ultrasound within the first six weeks of life if the examination is positive, and those who are at risk but do not show any clinical abnormalities are screened within the first two weeks of life (16).

Certain neonates with temporarily underdeveloped and physiologically unstable hip joints may receive a positive diagnosis if ultrasonography is done too soon. To avoid needless repeat ultrasonography exams and treatments, it is crucial to ascertain the ideal time for DDH screening and assessment. According to the American Academy of Pediatrics (AAP), hip ultrasound tests should be avoided within two weeks following delivery. The American Institute of Ultrasound in Medicine (AIUM) advises that if necessary, these procedures be carried out 3-5 weeks apart. It is advised by the American Academy of Orthopedic Surgeons (AAOS) to have an ultrasound done 2-4 weeks after delivery (30). Nearly 90% of cases of moderate hip instability at birth resolve spontaneously within the first eight weeks of life, because most hip joints that appear immature at birth will grow later (31) Additionally, Gokharman et al. (32) demonstrated that an ultrasound scan done eight weeks postpartum can reliably and securely identify any pathology and avert needless follow-up exams and concern among parents.

The question of whether specific US screening techniques can lower the frequency of DDH that is discovered too late is up for debate. When targeted ultrasound screening was used, Lewis and colleagues (33) found that the number of late-diagnosed DDH patients decreased significantly, from 2.2 ‰ to 0.34 ‰ of neonates, with 15% of the population having risk indicators. Studies by other researchers provided more evidence in favor of this position (34). Nevertheless, several investigations said that the majority of DDH diagnoses occur in newborns who have no discernible risk factors and that selective ultrasonography cannot reduce the frequency of late-detected DDH (5). According to others, the ability of examiners to do selective ultrasound screening determines the accuracy of the results; in 14% of cases, even highly skilled professionals have been known to misdiagnose DDH (35). A study by Sink et al. (36) demonstrated that children are not included in the group that is advised to have selective ultrasound examination, which results in false negatives when they do not have any significant risk factors for DDH and no positive physical examination results. Its rate of incorrect diagnoses might reach 85.3%. A delayed diagnosis of DDH increases the risk of additional damage, higher surgical treatment expenses, and lasting abnormalities. When selective ultrasound screening is unable to lower the rate of DDH that is discovered too late, it is advised that universal ultrasound screening be employed (36).

Program for universal ultrasound screening

A common procedure in many nations, particularly in European nations like Germany, Austria, and Norway, is universal ultrasound screening, which entails doing hip ultrasound exams on all babies. Although it varies by country, most ultrasound examinations are done 4–8 weeks after birth or within a few days of the baby's birth (5). Referred to a specialist for additional diagnosis are infants whose ultrasound examination results indicate a positive or probable condition. The outcomes of numerous research on universal ultrasonography screening have been positive. Early detection of DDH considerably reduced both open surgeries and closed reduction procedures (37). In 1992, Austria implemented a statewide universal ultrasound screening program for DDH utilizing the Graf approach. Von Kries R et al. (38) demonstrated that in the five years following the implementation of universal ultrasound screening, the rate of surgical treatment for DDH decreased by approximately 52%. In January 1996, Germany launched a screening program for DDH that included universal static ultrasound imaging for all children. In nations with a greater incidence of DDH, Treiber M et al. (39) stated that widespread ultrasound screening has lowered the number of cases that are discovered later, shortened treatment times, and reduced the need for hip surgery. They also suggested universal screening for newborns.

The cost-effectiveness and efficacy of universal screening programs have also been questioned by some researchers, who also doubt their involvement in overdiagnosis and therapy. Olsen and colleagues (40) reported that the inclusion of universal ultrasound in clinical screening for DDH doubled the treatment rate without affecting the already low numbers of late-diagnosed cases. The study was conducted in Norway and involved 4,245 newborns who underwent both clinical and ultrasound screening for DDH within the first one to three days of life. Additionally, Roovers and Rosendah noted that their retrospective study indicated that widespread

ultrasound screening results in overtreatment rather than eradicating late occurrences of DDH (41). To accurately identify individuals with DDH who resolved on their own and those who need therapy, several additional writers proposed methods. This is crucial since it helps avoid treating patients needlessly. By delaying the start of DDH treatment, Bialik and colleagues (15) were able to distinguish between babies who need treatment and those who resolve on their own. They also found that 90.4% of babies with DDH-related hip joint conditions were spared needless medical intervention. Following the hip joint's maturation curve, an ultrasound should be performed between the start of the sixth week (16). Graf type II hips can be classified as IIa (those under three months) or IIb (those over three months) to help avoid missing the ideal treatment window and avoid unnecessary treatment. Further research also suggests that ultrasounds be performed no later than six weeks following delivery (5).

Whether the advantages of routine ultrasonography screening outweigh the expenses is a further worry. In a retrospective analysis, Thaler et al. (42) compared the number and cost of interventions related to hip dysplasia in three patient age groups. They found that ultrasound screening was associated with higher initial costs, but that there was also a significant decrease in the overall number of interventions and costs associated with treating newborns with dysplastic hips, both surgical and nonoperative. The overall cost for DDH management is comparable for the various screening policies, according to Clegg et al. (43), who compared the cost of treating the condition and operating the screening program using three screening methods: universal ultrasound screening alone, universal clinical examination with selective ultrasound examination for newborn babies with risk factors, and universal clinical examination alone. Using the Graf technique, an international consensus ultrasound meeting on the evaluation of DDH (5) in 2018 concluded that a system of universal ultrasound screening is both cost-effective and will reduce dysplasia-related problems in the future when all short- and long-term costs are considered.

Treatment

Different screening programs aim to prevent undiscovered instances and enable earlier, less harsh interventions to achieve hip reduction, even if the best way to screen for DDH is debatable. Worldwide, there are significant differences in hip dislocation treatment methods. In the end, it is important to reduce all dislocated hips as soon as feasible using manual closed reduction, varied reduction bandaging, or extension therapy, all of which can be made easier with arthroscopic control (44). The Pavlik harness is still the most widely used brace for dynamic splinting, but Tubingen splints have been shown to have better results with greater tolerance and compliance. Dynamic splinting, including the Frejka splint, Pavlik harness, or Tubingen splint, has a low contraindication for hip retention and is very well tolerated, according to a recent meta-analysis of 29 observational studies. Static braces, such as rhino-style braces, Ilfeld braces, or generic abduction braces, can be used to treat patients with acetabular dysplasia who are older than six months and have stable hip joints. However, the femoral head must be positioned correctly in the acetabular base (45) A change in method is advised after two to three weeks if reduction is insufficient due to the danger of femoral head necrosis associated with conservative banding treatment (46). If a hip cannot be reduced closed, it can be decreased openly starting at around 6 months of age, either with or without bone correction on the femur side and/or the acetabular side (47).

Efficiency and quality of screening are ensured by a well-organized, systematic DDH screening process. A certification for operators devoted to doing DDH screening would also be helpful, as the value of hip screening depends on adherence to the proper technique and a consistent system of teaching and training correct hip physical examination and ultrasound abilities. Another issue is the necessity for health services to encourage interdisciplinary cooperation to identify appropriate screening sites and come to an agreement on several DDH screening-related concerns. Plans for early detection, diagnosis, and treatment should be developed, as well as an efficient screening system with a stringent screening procedure and quality control.

Conclusions

There are significant differences in infant hip screening protocols between various nations and areas. Both universal and selective ultrasonography screening procedures have been adopted by the majority of them, and they are employed in conjunction with physical examinations. Graf states that hip ultrasonography, when used in conjunction with comprehensive screening regimens and standardized hip ultrasound teaching and training programs, is now the most accurate diagnostic tool for DDH in the early stages of infancy. Quality control and adhering to a rigorous screening procedure are equally crucial. While universal ultrasound screening reduces late-detected cases more effectively than other screening programs, it may also tend to overtreatment and high beginning expenditures. Overtreatment could be decreased by scheduling the ultrasound exam as best as possible and appropriately postponing treatment. Over time, the cost savings from avoiding surgery and nonsurgical care make a universal ultrasound screening technique more economical. Furthermore, it might lessen the likelihood of DDH residual abnormalities. Any of these could be the focus of upcoming research.

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Contributions

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Data analysis and interpretation: **MB**

Collection and/or assembly of data: **MB**

Writing the article: **MB**

Critical revision of the article: **MB**

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