Original Research Article

HIP International

Early detection of developmental dysplasia of hip by ultrasound

HIP International
1–6

DOI: 10.1177/1120700019879687
journals.sagepub.com/home/hpi
SAGE

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Abstract

Objective: To assess the effectiveness of early universal ultrasound (US) screening of developmental dysplasia of the hip (DDH).

Study design: A prospective study of universal hip screening of all mature neonates was conducted from 2012 to 2013, at the Department of Obstetrics and Gynaecology, University of Szeged; 1636 newborns (3272 hips) had clinical examinations and hip ultrasound by the Graf method within the 1st 3 days of life. Prevalence of DDH, risk factors, sensitivity and specificity of clinical examinations were evaluated.

Results: At the 1st US, 70 of the examined 3272 hips (2.14%) were found to be positive. According to Graf categories, the following distribution was observed: type II C, 21 hips (30.0%); D, 24 hips (34.28%); III, 24 hips (34.28%); IV, 1 hip (1.44%). Regarding the risk factors, female gender, breech presentation and positive family history proved to be significant. Interestingly, 28 (50.90%) of the 55 newborns with DDH had neither positive physical signs nor any risk factors, except being female. The physical examination was calculated for sensitivity (20.0%) and specificity (98.34%).

Conclusions: In our 1-year period study, 50.9% of the newborns with DDH had neither any positive physical signs nor any risk factors, except being a female. In contrast, early universal US screening of the hip facilitated to diagnose all cases with hip dysplasia. Hip sonography is an effective mode of prevention in orthopaedics, however further studies are needed to compare the rates of operative procedures in selective versus universal screening models.

Keywords

Developmental dysplasia of the hip, neonatal screening, ultrasonography

Date received: 23 July 2018; accepted: 11 September 2019

Introduction

Developmental dysplasia of the hip (DDH), if untreated, is of the main causes of disability in childhood. It can lead to higher than normal load and shearing forces of the hip with the potential risk of hip replacement in adult life.[1–3] Introduction of early detection and management of DDH has given the chance for faster improvement with mainly non-invasive treatments. However, the number of late cases requiring surgery has still not decreased substantially.[4] Still no general agreement exists neither on the type of screening (how and when), nor on treatment, and a widely accepted definition of pathological dysplasia is still not established. Surprisingly, as Graf first stated in 1980, the diagnosis by ultrasound (US) has changed the clinical view of the disease;[5] it has been shown that morphological abnormalities may not be associated with Ortolani and Barlow signs.[6] Ultrasound screening can be universal for all newborns or selective for risk groups only. In Hungary, newborns are screened by clinical examinations within 72 hours of birth and at 3 weeks of age by paediatricians and at 6–8 weeks of age by orthopaedic or paediatric surgeon specialists. Selective ultrasound screening is performed only for infants

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Table 1. Sonographic hip types.

Type	Maturity	Bony roof	Bony angel	Bony rim	Cartilage roof	Beta-angel	Age	Therapy
Type I	Mature	Good	$\alpha \geq 60°$	Sharp	Good coverage femoral head	Ia = $\beta < 55°$ Ib = $\beta > 55°$	All	No
Type II a+	Immature but appropriate for age	Adequate	50–59°	Blunt	Coverage femoral head		<12 weeks	No
Type II a–	Immature and inappropriate for age	Deficient	50–59°	Rounded	Coverage femoral head		<12 weeks	Needed with controls
Type II b	Delay in ossification	Deficient	50–59°	Rounded	Coverage femoral head		>12 weeks	Needed with controls
Type II c	Stable or unstable	Severely deficient	43–49°	Rounde/flat	Still coverage femoral head	$\beta < 77°$	All	Needed with controls
Type D	Decentring hip	Severely deficient	43–49°	Rounde/flat	Displaced	$\beta > 77°$	All	Needed with controls
Type III	Eccentric hip	Poor	≤43°	Flat	Labrum pressed upwards		All	Needed with controls
Type IV	Eccentric hip	Poor	≤43°	Flat	Labrum pressed downwards		All	Needed with controls

with positive clinical findings and for the ones who were considered to belong to the following risk groups: positive family history for DDH; breech presentation; macrosomia; or other persisting foot deformities.

The purpose of this study was to evaluate *a* universal newborn screening hip US model, performed on the 3rd day, followed on the 3rd and 6th weeks of life, combined with clinical tests. Incidence of DDH, risk factors, sensitivity, specificity of clinical examination, effectiveness of different kind of treatments, number of late-diagnosed cases and complications of the universal US screening model were evaluated.

Methods

A prospective study of a universal hip screening and treatment of all mature newborns (gestational age ≥37 weeks), born between 0 January 2012 and 31 December 2012 at the Department of Obstetrics and Gynaecology, University of Szeged was performed. During this period, 2529 newborns were born, out of which 1636 (64.68%) administered to the Neonatology Ward were checked (3272 hips). The other 35.5% were excluded from the study due to various reasons, e.g. low birth weight, signs of congenital malformations, intrauterine infection or transfer to Neonatal Intensive Care Unit. These newborns were examined later when their general condition had improved. Graf method ultrasound examination was performed usually on the 3rd day (range day 1–4) by the same trained professional orthopaedic specialist on the Neonatology Ward. The precise standard technique introduced by Graf was used. The Graf method of ultrasound classification for developmental dysplasia of the hip is a standardised examination technique with appropriate equipment. During the ultrasound examination, the infant is is placed in lateral position with the hips slightly flexed, adducted and medially rotated. The coronal sonogram is obtained with a high-resolution (5–10 MHz) linear transducer on a standard section through the mid-portion of the acetabulum. After the anatomical identification, the bony roof angle (alfa-angle) and the cartilage roof angle (beta-angle) are determined. Measurements are done in the standard plane, and the classification of the basic types and subtypes are made by objective parameters. Separation of pathological movements (instability) from harmless movements (elastic whipping) is important. In certain cases, stress test is carried out to decide whether the joint is stable or unstable.[7]

The hips were assessed in a coronal plane by morphology and angular measurements according to Graf (Table 1).[8]

In our study, DDH includes all the types worse than IIa hips, which are considered physiologically immature. Ultrasound positivity was declared if α angel was $<50°$ and β angel $>55°$. Newborns having hip type IIc, D, III, IV were controlled at age of 3 and 6 weeks by physical examination and US. Afterwards, follow-up was continued until 1 year of age. All newborns with abnormal US and clinical findings received treatment according to the national protocol followed in our university: physiotherapy, and broad diapering were applied from diagnosis and depending on the grade of DDH, Pavlik harness or fixed abduction brace treatments were added on, after the 2nd examination at 3 weeks of age.

All neonates with hips worse than IIa on 1st measurement were started on treatment. Mothers were trained to conduct physiotherapy, apart from the single newborn with type IV hip, and to use broad diapering until 1st control on

Table 2. The results of physical examination, including false positive and false negative cases.

Physical examination ($n=3272$)	Ultrasound positive ($n=70$)	Ultrasound negative ($n=3202$)
Positive ($n=67$) (2.05%)	14 (0.43%)	53 (1.62%)
Negative ($n=3205$) (97.95%)	56 (1.71%)	3149 (96.24%)

Table 3. The distribution of ultrasound positive hip types, the percentage of physically negative hips and the gender ratio.

Sonographic hip types	Number of hips ($n=70$)	Physically negative	Male/female ratio
II c	21 (30.0%)	14 (66.6%)	4/17
D	24 (34.28%)	16 (66.6%)	6/18
III	24 (34.28%)	15 (62.5%)	3/21
IV	1 (1.44%)	1 (100.0%)	0/1

week 3 of life. The 4 newborns having hip dislocation type III and D were treated with Pavlik harness or fixed abduction brace started on week 3 until complete normalisation.

Parallel with the US screening, the usual physical examinations, Ortolani manoeuvre and Barlow tests were performed on every neonate.

Results were collected and recorded; sensitivity and specificity of clinical examination were calculated. Statistical analysis was performed using the chi-square test; $p < 0.05$ was considered to be statistically significant. Macrosomia was declared when birthweight was >4000 g. Study protocol was approved by Ethical Committee at University of Szeged, Hungary (140/2017-SZTE).

Results

The overall presence of DDH was 21.4 per 1000. Out of 55 newborns, 45 were female (81.8%) and 10 were male (18.2%); the difference is significant ($p < 0.01$).

Independent of US screening, all newborns had physical examination: 67 of 3272 hips (2.05%) were Barlow or Ortolani positive, but among these 67 hips only 14 (20.8%) were US positive, the remaining 53 hips (79.2%) were declared negative according to Graf method by US.

Important to emphasise that with physical examination, 14 hips of 70 US positive cases (20.0%) were positive, while 56 US positive hips (80.0%) had no physical alteration at all. Sensitivity and specificity of clinical examinations were calculated: 20.0% (95% confidence interval [CI], 11.39–31.27%) and 98.34% (95% CI, 97.84–98.76%) respectively.

Accuracy, namely overall probability that a patient will be correctly classified with physical examination was 96.67% (95% CI, 96.00–97.26%). Positive predictive value of physical examination was 20.90% (95% CI, 13.35–31.17%), negative predictive value 98.25% (95% CI, 98.04–98.44%) (Table 2).

Different types of positive hips on US according to Graf classification, results of physical examinations and the male/female ratio are shown on Table 3.

Regarding the risk factors, 79 among 1636 infants (4.82%) were born in breech presentation and 7 of them (12.72%) were in the DDH group, breech presentation proved to be a significant risk factor ($p < 0.05$). Regarding macrosomia, 119 neonates of 1636 (7.27%) were affected, among them 5 (9.09%) were in *the* DDH group, difference was not significant ($p=0.61$). Family history was positive in 49 cases (2.99%), and 6 of them (10.90%) were infants with DDH, which also showed significant difference ($p < 0.05$). No newborns had serious foot defects. All twin newborns (46) and triplet neonates (3), were physical and US negative (Table 4).

Taking into consideration only the proven significant risk factors, 13 of 55 involved newborns (23.64%) had either positive family history or *were* born in breech presentation. In addition, 28 of 55 newborns with DDH (50.90%) had neither any positive physical signs nor any risk factors except being female.

On the 3rd week of life, 50 of 55 US positive newborns were controlled; the remaining 5 did not appear for follow-up examination. At this 1st control, 58 of 65 hips (89.2%) had already negative US (Table 5) and all of them (50 newborns) attending the nd control, on the 6th week of life, were both on US and physical examination negative (Figure 1). In our study, patients were followed up for 1 year, during this time, we encountered no complications related to treatment and no cases of late diagnosis.

The single patient with type IV dislocated hip was referred straight to an orthopaedic surgeon specialist but the family left the country and returned when the child was 10 months of age. Surgical treatment was offered and performed. In her case, only female gender but neither risk factors nor any physical examination signs were positive.

Discussion

The prevalence of DDH in our universal US screening study was 2.14% which is consistent with the earlier reported data, 0.5–4% according to ethnicity, method of ascertainment and age.[4,9]

Table 4. Risk factors of developmental dysplasia of the hip (DDH).

Risk factors	DDH positive	DDH negative	*p*-value
Female gender $n=820$	45 (5.48%)	775 (94.52%)	$<0.05^*$
Macrosomia $n=119$	5 (9.09%)	114 (90.91%)	0.61
Breech presentation $n=79$	7 (12.72%)	72 (87.28)	$<0.05^*$
Positive family history $n=49$	6 (10.9%)	43 (83.1%)	$<0.05^*$
Multiple gestations $n=49$	0	49 (100%)	–

Significance at $p<0.05$ is indicated by*

Table 5. Ultrasound (US) positive hips and control examinations.

Sonographic hip types	US positive on 1st examination (hip) $n=70$	Attended on 1st control (hip) $n=65$	Negative on 1st control (hip) $n=58$	Negative on 2nd control (hip) $n=65$
II c	21 (30.0%)	21	19 (90.4%)	21 (100%)
D	24 (34.28%)	22	20 (90.9%)	22 (100%)
III	24 (34.28%)	22	19 (85.7%)	22 (100%)
IV	1 (1.44%)	0	–	–
Total	70	65	58 (89.2%)	65 (100%)

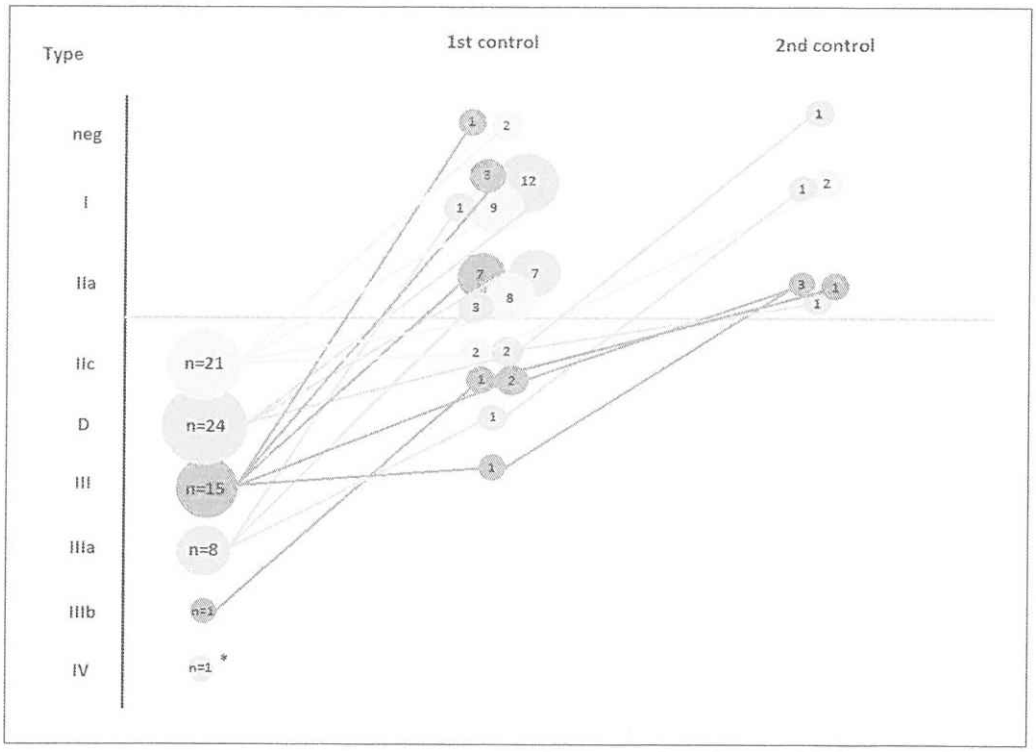

Figure 1. Grades of ultrasound positive hips on the 1st and 2nd control examinations.

Prior to this study, selective US screening model had been used in our university, namely newborns in risk groups and with positive physical signs had US examination. In our study, we showed that more than half of the neonates (50.90%) diagnosed with DDH had neither positive physical signs nor any risk factors except being female. According to our previous selective screening protocol, all these neonates would have been missed and diagnosed late.

The effectiveness of the standard physical examination method, consisting of Ortolani manoeuvre and Barlow tests, was carefully analysed. We also demonstrated that physical

examination has a poor sensitivity (20.0%) compared to the Graf US method; using physical examination only is an inaccurate and ineffective way of screening DDH. Several previous studies have also reported that selective screening protocol would have missed large percentage of DDH cases, and the sensitivity of the Ortolani and Barlow manoeuvres was similarly low.[10] Discrepancies between clinical and ultrasound examinations were present even if both examinations had been performed by the same orthopaedic specialist.[11]

"Graf technique" of hip sonography no longer uses the original clinical and x-ray classification of normal, dysplastic, subluxated and dislocated hip, but classifies according to the exact anatomical pathology that must be identified and treated appropriately. Not only the bony structures but also the hyaline cartilaginous preformed parts can be identified in a sonogram: the bony angle alpha quantifies the bony socket, and the cartilage angle beta quantifies the cartilaginous acetabular roof. In order to be reproducible, the same sonographic section through the hip joint must be always used, the standard plane. The accurate diagnosis can be achieved only after the proper anatomical identifications and objective measurements of hip joint with considering the age of the patient as well. Potential risk factors of DDH are under continuous investigations.[12] Some of them like female gender and positive family history, have genetic predisposition and others are related to intrauterine circumstances, like breech presentation and macrosomia. Macrosomia and twin pregnancy, generally considered as risk factors, did not show significant correlation with DDH in our study.[13]

Immediately after the 1st positive US result, physiotherapy and wide diapering for spreading were started following our treatment protocol. We observed that 89.2% of positive US cases, mainly those with minimal anatomic abnormalities, showed significant improvement on the 3rd week. Benefit of early-age spreading has been known, however the effect of physiotherapy and broad diapering versus spontaneous improvement cannot be judged owning to the lack of randomisation.[7]

Adjusted rate of 1st operative procedure that we calculated, 0.61 per 1000 live births, showed similarity to many other studies with general US screening.[14] Furthermore, the only 1 operative intervention in our study could have been avoided if after the correct diagnosis of DDH, recommendations had been followed by the parents. These observations are in accordance with the earlier published research findings. Marks et al.[15] found no late detected cases in a group of 14,050 neonates screened by US. Even the randomised controlled trial of Holen et al.[16] showed that US screening could have the potential to eradicate the late presenting cases. Reduction of operative procedures was observed in a nationwide survey in Germany as well; data collected over 5 years showed that incidence of 1st operative procedures was 0.26 per 1000.[14] Previous reports from the period of selective screening had shown higher, relatively stable incidence of late presenting DDH of approximately 2–3 per 1000, including frank dislocation, subluxation, and acetabular dysplasia.[17]

Limitations of our study are its nature of being non-randomised, the relatively small sample size and the lack of long-term follow-up.

The role of DDH screening is known to be essential; however, the exact methodology and mode, whether universal or selective, has not been fully established yet.[18] Taking into consideration that DDH can potentially lead to lifelong disability, beneficial effect of universal US has been recognised and its application was recommended more than half a century ago.[19] General US screening was introduced in some European countries, like Austria (1991), Switzerland (1995) and Germany (1996) resulting in a dramatic fall in the rate of open reduction and osteotomies and with Graf technique there was no overtreatment.[20,21] On the other hand, there are opinions that the general screening can lead to overdiagnosis and overtreatment, therefore, according to these opinions, considering cost-benefit-equation, selective screening is more favourable.[22] In many of these earlier studies, however, the different sonographic techniques were not properly distinct. There are few randomised controlled trials and meta-analysis comparing effectiveness of general versus selective US screening, where absence of conclusive evidence for improved outcomes were shown.[23]

Rosendahl et al.[24,25] stated that the effect of US screening in reducing prevalence of late DDH was at best marginal despite a considerable increase in diagnostic and therapeutic efforts. Woolacott et al.[18] in their systematic review based on 23 medical databases, concluded that general US compared with clinical screening in newborns may increase overall treatment rates, but US screening seemed to be associated with shorter and less intrusive treatment. Similarly, in our study, an increased treatment rate was observed compared to previous selective US era, but we concluded that all diagnostic and therapeutic works used in our study were noninvasive, cheap and tolerable without any long-term consequences, in contrast to surgical procedures.

Diagnosis and the treatment were both conducted by specially trained orthopaedical and physiotherapeutic specialists. Exact diagnosis is crucial, to make sonograms reproducible and comparable only the standard plane is allowed with standardised examination technique, to avoid typical mistakes like tilting effect.[26] In experienced hands with correct technique, the anatomical structures can be visualised and classified according to Graf in seconds without any harmful radiation, leading to proper diagnosis.

In our study no operative procedure was needed, except on the patient who did not appear in time for control examinations. Clinical screening combined with universal US examination was effective and early detection of DDH was useful to reduce the need of surgical interventions. Patients without any clinical signs but proven US abnormalities were given the chance for better long-term outcome.

We found the universal screening model with Graf technique a valuable tool for identifying infants with DDH. With careful follow-up and treatment, including physiotherapy, broad diapering, Pavlik harness or fixed abduction brace, it proves to be a simple, non-invasive way to restore a centered hip within the 1st year of life.

These results should be taken into consideration when new screening models and clinical guidelines are discussed. Early diagnosis is extremely important; every newborn, not only the risk group, should have technically correctly performed US examination. Follow-up studies over more decades would be useful to assess benefits of US screening in preventing impaired hip function and degenerative joint diseases in adulthood which could be a subject of further investigation.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship and/or publication of this article.

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