Is experience alone sufficient to diagnose developmental dysplasia of the hip without the bony roof (alpha angle) and the cartilage roof (beta angle) measurements?

A diagnostic accuracy study

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Abstract

In the Graf method of hip ultrasonography, the diagnosis of the infantile hip with developmental dysplasia of the hip (DDH) is strictly dependent on the bony roof (alpha angle) and the cartilage roof (beta angle) measurements. In this study, we investigated whether the infant hip could be diagnosed with DDH solely by evaluating ultrasound images obtained in the standard plane, without bony roof and cartilage roof measurements, in respect to different professional experience levels.

Two hundred ten hip ultrasounds were randomly selected from patients who presented to our hospital for DDH screening. A total of 6 ultrasound images were obtained for each hip. The hip morphology evaluations were made without the bony roof and the cartilage roof measurements by 2 orthopedic surgery residents; 2 orthopedic surgery specialists, trained in the diagnosis and the treatment of the DDH; and 2 pediatric orthopedic surgery professors, highly experienced in the diagnosis and treatment of DDH. After hip morphology evaluations, the bony roof and the cartilage roof measurements were obtained and hip type evaluations were made by the same raters, according to the Graf method of hip ultrasonography.

The highest intraclass correlation coefficients between the hip maturity evaluation before and the hip type evaluation after measurements were .676 \((P < .001)\) and .577 \((P < .001)\) in professors 2 and 1, respectively, and the lowest agreements were .185 \((P < .01)\) and .289 \((P < .001)\) in specialist 1 and resident 2, respectively.

The diagnosis of the infant hip as DDH could not be made solely by evaluation of the ultrasound images obtained in the standard plane without the bony roof and the cartilage roof measurements. The bony roof and the cartilage roof measurements were obligatory for the diagnosis of the infant hip as DDH, even in the very experienced pediatric orthopedic surgeons.

Level of evidence: 2.

Abbreviations: DDH = developmental dysplasia of the hip, fellow = Dursun AK, MD. The practitioner in the fellowship training program in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital, Istanbul, Turkey, ICC = intraclass correlation coefficient, prof1 = Professor 1. Hasan Hilmi Muratli, MD. Professor in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital, Istanbul, Turkey, prof2 = Professor 2. Mehmet Mufti Orak, MD. Professor in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital, Istanbul, Turkey, res1 = Resident 1. Ilyas Aslan, MD. Resident in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital, Istanbul, Turkey, res2 = Resident 2. Ozgun Karakus, MD. Resident in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital, Istanbul, Turkey. Chairmen of the Turkish Pediatric Orthopedic Surgery Association, prof1 = Professor 1. Hasan Hilmi Muratli, MD. Professor in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital, Istanbul, Turkey, res1 = Resident 1. Ilyas Aslan, MD. Resident in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital, Istanbul, Turkey, res2 = Resident 2. Ozgun Karakus, MD. Resident in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital, Istanbul, Turkey. Specialist in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital, Ankara, Turkey (e-mail: drasinansari@gmail.com).

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1. Introduction

Developmental dysplasia of the hip (DDH) is a common hip disease. It results from an abnormal relation between the head of the femur and the acetabulum and manifestations range from subtle dysplasia of the acetabulum to obvious dislocation of the femoral head. Treatment objectives include concentric reduction of the hip and good acetabular coverage of the femoral head.

Early diagnosis is the key for successful treatment. Most of the bony parts of the acetabulum and femoral head remain cartilaginous during the first few months of life, which limits the use of plain radiographs for the diagnosis of DDH in infants younger than 6 months of age. Due to this limitation of roentgenograms and the concern of ionizing radiation exposure in infants, hip ultrasonography is currently the most common method used in the diagnosis of DDH in the first 6 months of life. Graf, Harcke, Terjersen, and Suzuki have developed hip ultrasonography methods for the evaluation of the infantile hip. Of these, the Graf method is probably the most commonly used because of its high rate of sensitivity, specificity, and reproducibility.

In the Graf method, the diagnosis, classification, and follow-up treatment of infantile DDH strictly depends on the bony roof angle (alpha angle) and cartilage roof angle (beta angle) measurements. Many radiological modalities used in orthopedic surgery do not necessitate precise measurements for the diagnosis of a suspected pathological condition; instead, diagnosis is made by detailed physical examination of the patient, with careful evaluation of radiological images. However, classification of the pathological condition and treatment decisions are reliant on measurements obtained on radiological images after the diagnosis. Likewise, careful evaluation of high-quality roentgenograms of a patient who suffers from forearm pain after a fall are generally sufficient for diagnosing fracture of the forearm bones. However, surgical versus conservative treatment decisions are usually based on the precise measurement of the angulation and/or displacement on roentgenograms after closed reduction of the fracture.

In the present study, we investigated whether this kind of relationship exists with ultrasonography of the infantile hip. We evaluated the diagnostic accuracy of the infant hip as DDH made by careful evaluation of ultrasound images obtained in the standard plane, without bony roof, and cartilage roof measurements, in respect to different professional experience levels.

2. Methods

This study was approved by the Kayseri Erciyes University Hospital ethics committee and signed consent was obtained from the parents/guardians of all the study participants. Two hundred ten hip ultrasounds were randomly selected from patients (mean age of 11 weeks, range 3–21 weeks) who presented to our hospital for DDH screening. All clinical examinations and ultrasound screenings were performed by the same pediatric orthopedic surgery fellow. All ultrasound examinations were performed via a Sonoline G60S ultrasound system (SIEMENS, Erlangen, Germany) using a 7.5 MHz linear probe, according to the Graf method of hip ultrasonography. Infants were placed on the hip ultrasound table in a lateral decubitus position. During ultrasound screening, images on the monitor were frozen to determine if they were in the standard plane; when the standard plane was confirmed, 6 copies of the image were printed. The 6 images were evaluated by 2 orthopedic surgery residents (res1 and res2), 2 orthopedic surgery specialists (spe1 and spe2), 2 pediatric orthopedic surgery professors (prof1 and prof2), highly experienced in the diagnosis and treatment of DDH. One of the raters had completed a Graf method training program. Each rater evaluated the ultrasound images in the same order. First, the rater evaluated whether the ultrasound image was in the standard plane. If the rater decided that the ultrasound image was

| Table 1 | The age, sex, and the experience in orthopedic surgery of the raters. |
|---------|---------------------------------------------------------------|
| Age (yr) | Sex | Experience in orthopedic surgery (yr) |
|---------|-----|-------------------------------------|
| res1    | 29  | Male 4                              |
| res2    | 28  | Male 3                              |
| spe1    | 38  | Male 13                             |
| spe2    | 35  | Male 10                             |
| prof1   | 56  | Male 24                             |
| prof2   | 53  | Male 28                             |

| *res1, res2, spe1, spe2, prof1, and prof2 correspond to resident 1, resident 2, specialist 1, specialist 2, professor 1, and professor 2, respectively. |
| *Includes the residency program of the practitioner. |

| Table 2 | The alpha and beta angle measurements according to the raters. |
|---------|---------------------------------------------------------------|
| Alpha angle (°) | Beta angle (°) |
| mean ± std deviation | mean ± std deviation |
| median (minimum – maximum) | median (minimum – maximum) |
| res1 | 67.106 ± 7.190 | 56.462 ± 5.594 |
| 70.0 (42.0 – 82.0) | 55.0 (45.0 – 75.0) |
| res2 | 67.0 ± 7.130 | 56.462 ± 5.589 |
| 70.0 (42.0 – 82.0) | 55.0 (45.0 – 75.0) |
| spe1 | 67.096 ± 7.207 | 56.548 ± 5.614 |
| 70.0 (42.0 – 82.0) | 55.0 (45.0 – 75.0) |
| spe2 | 66.196 ± 6.134 | 45.362 ± 8.716 |
| 67.0 (44.0 – 78.0) | 44.0 (30.0 – 71.0) |
| prof1 | 63.814 ± 6.845 | 61.050 ± 6.220 |
| 65.0 (36.0 – 80.0) | 60.0 (45.0 – 85.0) |
| prof2 | 66.091 ± 7.051 | 60.146 ± 7.872 |
| 67.0 (38.0 – 77.0) | 60.0 (40.0 – 90.0) |

| *res1, res2, spe1, spe2, prof1, and prof2 correspond to resident 1, resident 2, specialist 1, specialist 2, professor 1, and professor 2, respectively. |
in the standard plane, the rater classified the hip as mature or immature solely by examining the image. According to the Graf method, the mature hip corresponds to type 1 hip and the immature hip corresponds to types 2, D, 3, and 4 hips. Thereafter, measurements of the bony roof (alpha angle) and the cartilage roof (beta angle), and determination of the hip type were performed. All measurements were made with a goniometer, according to the Graf method.\[7\] All raters were blinded to the evaluation results of the others. The intra and interobserver agreements of the classifications and measurements were evaluated statistically.

### 2.1. Statistical analysis

Shapiro–Wilk’s test was used to assess the normality of distributions of the continuous variables. As distributions were not normal, agreements between measurements were analyzed by Spearman rho correlation coefficients. Interrater reliabilities and agreements were evaluated by Cohen Kappa statistics for discrete variables. Data analyses were performed using the Statistical Package for the Social Sciences, version 19.0 (IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp). A P value <.05 was considered statistically significant. The results of statistical analysis were expressed as number and ratio of observations (n, %), mean ± standard deviation (mean ± SD), median and minimum – maximum values [M (min – max)].

### 3. Results

Res1, res2, spe1, spe2, prof1, and prof2 evaluated 2, 2, 5, 6, 6, and 2 images as not in the standard plane, respectively; thus, these were excluded from their classifications. The mean alpha and beta angle measurements according to the raters are expressed in Table 2. The hip maturity evaluations prior to the measurements and the hip type evaluations after the measurements are shown in Tables 3 and 4, respectively.

The intraobserver agreements between the hip maturity evaluation prior to the measurements and the hip type evaluation after the measurements are expressed in Table 5. The highest agreements were .676 (P < .001) and .577 (P < .001) in prof2 and prof1, respectively and the lowest agreements were .185 (P < .01) and .486 (P < .001) in spe1 and res2, respectively.

The interobserver agreements of hip morphology evaluations before and hip type evaluation after measurement are expressed in Table 6. The highest agreements were .808 (P < .001) in between res1 and res2 in the evaluation of the hip maturity and .892 (P < .001) in between res1 and res2 in the evaluation of the hip type. The lowest agreements were .177 (P < .01) in between spe1 and spe2 in the evaluation of the hip maturity and .486 (P < .001) in between prof1 and prof2 in the evaluation of the hip type.

### 4. Discussion

Graf used hip ultrasonography to develop a protocol for the early diagnosis of DDH, which has become widely accepted in many
The intraobserver agreements between the hip maturity evaluation prior to the measurements and hip type evaluation after the measurements in respect to the different experience levels.

| Experience Level | ICC | Comment | Rater |
|------------------|-----|---------|-------|
| Hip maturity     | .808 | Poor    | res1, res2, and spe1 |
|                  | .577 | Fair    | prof1 and spe2 |
|                  | .486 | Good    | prof2 |
| .80 to .74       | .545 | Poor    | res1, res2, and spe1 |
|                  | .305 | Fair    | prof1 and spe2 |
|                  | .289 | Good    | prof2 |
| .75 to 1.00      | .185 | Poor    | res1, res2, and spe1 |

Table 7

Intraobserver agreements between the hip maturity evaluation prior to the measurements and the hip type evaluation after the measurements according to the raters.

| ICC   | Comment | Rater |
|-------|---------|-------|
| <.40  | Poor    | res1, res2, and spe1 |
| .40 to .59 | Fair    | prof1 and spe2 |
| .60 to .74 | Good    | prof2 |
| .75 to 1.00 | Excellent | |

The intraobserver agreements between the hip maturity evaluation prior to the measurements and the hip type evaluation after the measurements aligned as prof2 (.676; P < .001), prof1 (.577; P < .001), spe2 (.545; P < .001), res1 (.305; P < .001), res2 (.289; P < .001), and spe1 (.185; P < .01) (Table 5). The Graf method of infantile hip ultrasonography is usually standardized; therefore, the experience and skill of the examiner are of little importance after a comprehensive education program. However, the accuracy of hip maturation evaluations without bony roof and cartilage roof measurements may depend on the experience and skill of the examiner. In our study, prof1 and prof2, who had the highest professional experience levels in diagnosing and treating DDH, also had the highest intraobserver agreements among the raters. The alignment in intraobserver agreements was probably due to the professional experience and skill levels of the raters.

The intraobserver agreements between the hip maturity evaluation prior to the measurements and the hip type evaluation after the measurements of the raters was good for prof2, fair for prof1 and spe2, and poor for res1, res2, and spe1, according to the intraclass correlation coefficient (ICC) (Table 7). The accuracy of the evaluations in distinguishing normal and pathological hips, without bony roof and cartilage roof measurements, was very low, even in the very experienced prof1 and prof2 raters whose ICCs were fair and good, respectively.

The bony roof and the cartilage roof measurements appear obligatory for the diagnosis of infantile DDH, as well as for its classification and follow-up treatment, even for very experienced pediatric orthopedic surgeons.

Interobserver agreements of hip morphology evaluations prior to measurements and hip type evaluations after measurements, in respect to different professional experience levels, are expressed in Table 6. The highest agreements were .808 (P < .001) between res1 and res2 in the evaluation of hip maturity and .892 (P < .001) between res1 and res2 in the evaluation of hip type. In the current study, the specialists had studied the Graf training program a long time ago; however, the residents had recently received their certifications in the Graf method. Moreover, the specialists may have interpreted information according to their clinical experience, whereas the residents may have used information taught in the training program without interpretation. These factors might explain the high interobserver agreements among the resident raters.

The diagnosis of the infant hip as DDH could not solely be made by careful evaluation of the ultrasound images obtained in the standard plane. The bony roof and cartilage roof measurements were obligatory for the diagnosis of infantile DDH, even for the very experienced pediatric orthopedic surgeons.

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Author contributions

OK and ASS participated in the design of the study and performed the statistical analysis. ASS conceived of the study, participated in its design and coordination, and helped to draft the manuscript. ASS and OK contributed to the writing and collecting of the data. All authors read and approved the final manuscript.

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