Osmangazi Tıp Dergisi
Osmangazi Journal of Medicine 2021;43(4):324- 331

Research Article / Araştırma Makalesi

Do Angle Measurements on Two Different Projections on Hip Ultrasonography Alter the Diagnosis in Patients Being Screened for DDH?

GKD için Taranan Bebeklerde Kalça Ultrasonografisinde İki Farklı Projeksiyondaki Açı Ölçümleri Teşhisi Değiştirir mi?

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Abstract

Hip ultrasonography with the Graf method is used worldwide. Four different projections can be used for the evaluation of sonographic images. The best projection with the lowest rate of wrong interpretation is the "standing-up right"-projection and the worst is the ''horizontal-cranial left" projection. The aim of this study was to show the concordance of two researchers using these two different projections. Hip sonographic evaluation according to the Graf method was applied to 166 infants (332 hips) comprising 84 males (50.6%) and 82 females (49.4%). The hip sonographic images were obtained in both the standing-up right and horizontal-cranial left projections. Two researchers independently measured the alpha and beta angles manually with a goniometer and classified the hip type. The alpha, beta angle measurement values, comparisons of the angles in both projections and for both researchers are presented in detail in Tables 1 and 2. The inter-observer agreement of the Graf types of hips was as follows; Graf types between researcher 1 and 2, Right hip- (standing-up right) Kappa value 0.84, Left hip- (standing-up right) Kappa value 0.77, Right hip- (horizontal-cranial left) Kappa value 0.67, Left hip- (horizontal-cranial left) Kappa value 0.64. The intraclass correlation coefficient (ICC) values of the agreement between the two researchers for all the measured hip angles were as follows; right angle ICC: 0.96, right angle ICC: 0.91, left angle ICC: 0.93, and left angle ICC: 0.59. Although the standing-up right projection is known to be the best projection with the lowest rate of wrong interpretation according to the Graf guidelines, the results of this study showed the evaluation of similar Graf hip types on the two projections. Therefore, the horizontal cranial left projection, which is considered to be the worst of the four projections, can be used safely for hip evaluation if the Graf checklist is followed appropriately.

Keywords: DDH, Graf-technique, Hip ultrasonography, Diagnosis, Interobserver reliability, Infant

Özet

Graf yöntemi ile kalça ultrasonografisi dünya çapında kullanılmaktadır. Sonografik görüntülerin değerlendirilmesinde dört farklı projeksiyon kullanılabilmektedir. En az yanlış yorumlama oranı ile "dik-sağ" projeksiyon en iyi ve ''yatay-baş sol" projeksiyon ise en kötü olanıdır. Bu çalışmanın amacı, iki araştırmacının bu iki değişik projeksiyondaki uyumunu göstermektir. Graf metoduna göre kalça sonografik değerlendirmesi 84 erkek (%50.6) ve 82 kız (%49.4) dan oluşan 166 (332 kalça) bebeğe uygulanmıştır. Sonografik görüntüler hem dik-sağ hemde yatay-baş sol projeksiyonda elde edilmiştir. İki araştırmacı birbirinden bağımsız olarak gonyometre ile elle alfa ve beta açılarını ölçmüş ve kalça tiplendirmesini yapmışlardır. Tablo 1 ve 2 de ayrıntılı olarak, alfa beta açı ölçüm değerleri, ve açıların her iki projeksiyonda ve her iki araştırmacıya göre karşılaştırması sunulmuştur. Kalçaların Graf tiplerinin gözlemciler arası uyumu şöyleydi; araştırmacı 1 ve 2 arasındaki Graf tipleri, Sağ kalça (dik-sağ) Kappa değeri 0.84, sol kalça (dik-sağ) Kappa değeri 0.77, sağ kalça (yatay-baş sol) Kappa değeri 0.67, sol kalça (yatay-baş sol) Kappa değeri 0.64 dür. Tüm ölçülmüş kalça açıları için iki araştırmacı arasındaki Intraclass Korelasyon Katsayısı (IKK) değerlerinin uyumu şöyleydi; sağ alfa açısı IKK: 0.96, sağ beta açısı IKK: 0.91, sol alfa açısı IKK: 0.93, ve sol beta açısı IKK: 0.59. Dik-sağ projeksiyon, Graf' ın yönergelerine göre en az yanlış yorumlama oranlarına sahip olsa da, bu çalışmanın sonuçları iki projeksiyonda da Graf kalça tiplerinin değerlendirmesinin benzer olduğunu gösterdi. Bu nedenle, dört projeksiyon içinden en kötüsü olan yatay-baş sol projeksiyon, eğer Graf'ın kontrol listesine doğru bir şekilde uyulursa kalça değerlendirmesinde güvenli bir şekilde kullanılabilir.

Anahtar Kelimeler: GKD, Graf teknik, Kalça Ultrasonografisi, Teşhis, Gözlemciler arası güvenilirlik, Bebek

Received 30.01.2021 Accepted 12.02.2021 Online published 12.02.2021

Cite this article as:
Gunay C, Aynaci AM, Do Angle Measurements on Two Different Projections on Hip Ultrasonography Alter the Diagnosis in Patients Being Screened for DDH?, Osmangazi Journal of Medicine, 2021, 43(4):324-331 Doi: 10.20515/otd.871107

1. Introduction

Hip ultrasonography started to be used for patients with Developmental Dysplasia of the hip (DDH) with the Graf technique described by Prof. Reinhard Graf in 1985. It is now widely accepted as the primary method for screening, diagnosis and follow-up of treatment of DDH in newborns (1). Since the acceptance of its utility, hip ultrasonography (USG) has come into widespread use in daily practice in many countries. Before hip USG, the most common physical examination manoeuvres used for detecting DDH were the Barlow and Ortolani manoeuvres (1). In addition to these physical examination tests, the most frequently used imaging method for both diagnosis and treatment of DDH was pelvis radiography. However, there are disadvantages to radiography for the evaluation of DDH, including the risk of radiation and that only bony structures can be seen. In the first months of life, most bony parts of the femoral head and acetabulum remain cartilaginous, which limits the use of plain radiographs for the diagnosis in infants younger than 6 months (2). Therefore, hip sonography has become important in diagnosis, especially in the first six months of an infant's life. The advantages of USG in the detection of DDH include the absence of radiation and the ability to visualise soft tissue structures such as the labrum, hyaline cartilage, and hip capsule. Hip sonography is performed in many centres by orthopaedic surgeons, radiologists, and paediatricians. Generally, orthopaedic surgeons and radiologists take the sonographic images in different ways. Radiologists usually take sonographic views in the horizontal-cranial left-sided position, and state that the images are taken in the anatomic position of the infant lying in the cradle. Orthopaedic surgeons generally take images in both the standing-up right and horizontal-cranial right-sided positions. Graf reported four different projections and stated that the best projection with the lowest rate of wrong interpretation was the "standing-up right" projection (3).

The aim of this study was to investigate whether there is a difference in both classification and angle measurements according to the Graf method between two different sonographic projections. The study hypothesis was that the evaluations made on two different projections (standing-up right and horizontal cranial-left) would be reliable and consistent with each other.

2. Materials and Methods

This retrospective study was approved by the hospital Institutional Review Board Ethics Committee. Informed consent was obtained from all the parents of the children included in the study. USG screening of the hip for DDH according to the Graf method was performed at our centre. Paediatricians referred the infants to the Radiology Department for evaluation of the hip joints especially between 4-6 weeks of life. All hip sonographies in this study were performed by the second author (AMA). For the evaluations, a 7.5 MHz linear probe was used with the two different projections of horizontal-cranial left (Fig.1a,1c) and standing-up-right position (Fig.1b,1d) and at least two sonographic views obtained for each hip joint. Two researchers then independently measured the alpha (α) and beta (β) angles with a goniometer (1) on the sonographic print-outs. The researchers measured 4 sonographic views for both the right and left hip for both projections. Three lines were drawn on the sonograms as follows; the first line was drawn parallel to the iliac wing, the second line was drawn from the lower point of the os ilium to the turning point of the bony roof (from concavity to convexity), and the third line was drawn from the turning point to the labrum. The alpha angle was calculated between the first and second lines, and the β angle was calculated between the first and third lines. After calculating the angle values, the Graf types of the hips were determined according to the Graf classification. The measured angles from the two different projections were recorded separately for each patient and the results of the two researchers were compared with each other.

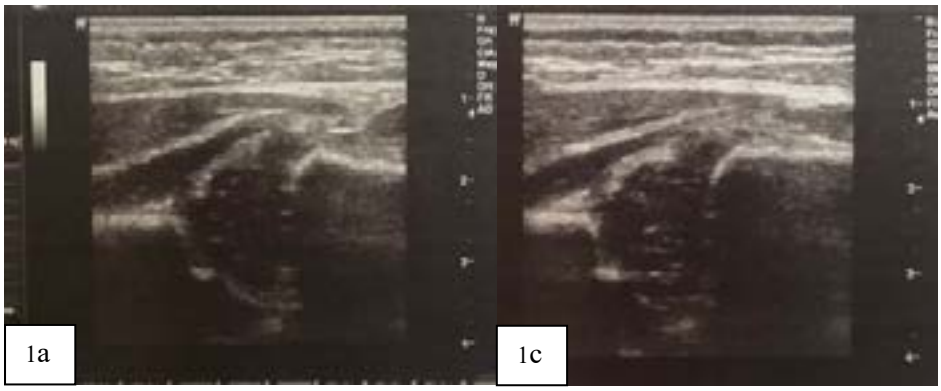

Figure 1a. Right Hip ultrasonography in Horizontal-cranial left position (Graf type 1 hip)
Figure 1c. Left Hip ultrasonography in Horizontal-cranial left position (Graf type 1 hip)

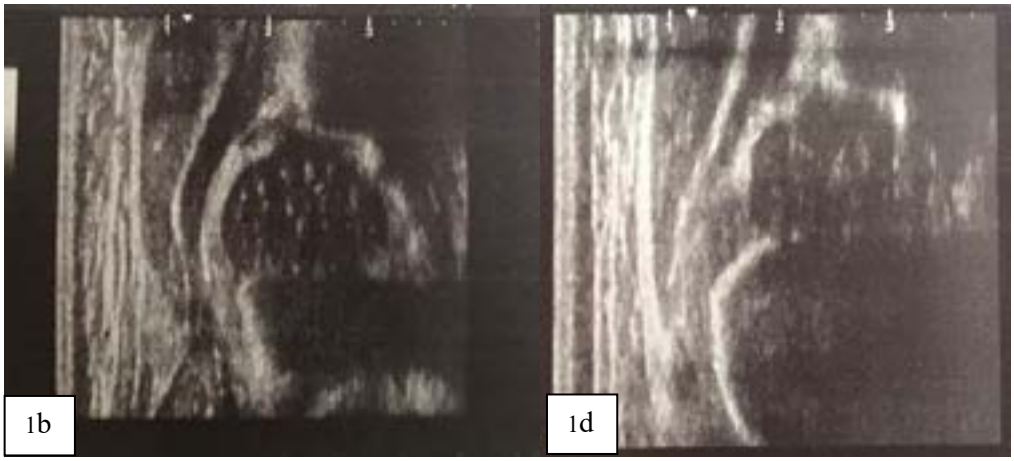

Figure 1b. Right Hip ultrasonography in Standing-up right position (Graf type 1 hip)
Figure 1d. Left Hip ultrasonography in Standing-up right position (Graf type 1 hip)

Statistical analysis

Data obtained in the study were analyzed statistically using IBM SPSS statistics vn 22 software. For the α and β angle value comparisons, ANOVA analysis was used. The Sidak test was applied to pairwise comparisons of the angle measurements. The Kappa test was used for both intra and inter-observational agreement analysis of the Graf types of the hips. The Intraclass Correlation Coefficients (ICC) were calculated in evaluation of the agreement of hip angles. A value of $p<0.05$ was considered statistically significant.

3. Results

Retrospective evaluation was made of 166 infants (332 hips), comprising 84 males (50.6%) and 82 females (49.4%) with a mean age at presentation of 46.10 days (range: 4-125 days). A total of 332 hips were evaluated by two raters and classified according to Graf type. The mean± standard deviation (SD) values of the α and β angles on the two different projections according to researchers (R) 1 and 2 are presented in detail in Table 1. The pairwise comparisons of the measured α and β angles on both projections are presented in Table 2. The mean differences between the angle values and the *p* values of all the comparisons between the measured angles are shown in Table 2. The statistically significant *p* values are presented in italic and bold style format in Table 2. The numbers of hip Graf types on both projections identified by the two researchers are presented in Table 3. The results of the agreement of Graf types of hip

in the intra-observer evaluation were as follows; Researcher 1- right hip (standing-up right- horizontal cranial left) Kappa value 0.86, Researcher 1- left hip (standing-up right-horizontal cranial left) Kappa value 0.93, Researcher 2- right hip (standing-up right-horizontal cranial left) Kappa value 0.84, Researcher 2- left hip (standing-up right-horizontal cranial left) Kappa value 0.88. The inter-observer agreement of the hip Graf types was as follows; Graf types between Researchers 1 and 2, Right hip- (standing-up right) Kappa value 0.84, Left hip- (standing-up right) Kappa value 0.77, Right hip- (horizontal cranial left) Kappa value 0.67, Left hip- (horizontal cranial left) Kappa value 0.64. The intraclass correlation coefficient (ICC) values of the reliability of all the measured hip angles of the two researchers were as follows; Right α angle ICC: 0.96 (95% Confidence Interval (CI): 0.95-0.97), right β angle ICC: 0.91 (95% CI: 0.88-0.93), left α angle ICC: 0.93 (95% CI: 0.91-0.94), left β angle ICC: 0.59 (95% CI: 0.48-0.68).

Table 1. The Mean± Std. Deviation values of alpha (α) and beta (β) angles on two different projections according to Raters (R) 1 and 2

	SU-R-α	SU-R-β	SU-L-α	SU-L-β	HC-R-α	HC-R-β	HC-L-α	HC-L-β
R1	62.58±4.45	64.08±4.13	62.64±4.38	63.94±4.06	63.21±4.66	65.23±4.11	63.06±4.67	66.19±2.71
R2	63.68±4.67	65.63±3.87	62.98±4.81	66.70±4.35	63.74±4.43	65.98±3.69	62.89±4.33	66.36±5.81

Standing up-right/Right hip-α: SU-R-α
Standing up-right/Right hip-β: SU-R-β
Standing up-right/Left hip-α: SU-L-α
Standing up-right/Left hip-β: SU-L-β
Horizontal cranial-left/Right hip-α: HC-R-α
Horizontal cranial-left/Right hip-β: HC-R-β
Horizontal cranial-left/Left hip-α: HC-L-α
Horizontal cranial-left/Left hip-β: HC-L-β

Table 2. Pairwise comparisons of the measured alpha (α) and beta (β) angles on both projections by the two raters

	Mean Difference (Degrees)	p value
R1-SR-Right α/R1-HL-Right α	0.6	***0.04***
R1-SR-Right α/R2-SR-Right α	1	***0.001***
R1-SR-Right α/R2-HL-Right α	1.1	***0.001***
R1-HL-Right α/R2-SR-Right α	0.4	0.983
R1-HL-Right α/R2-HL-Right α	0.5	0.863
R2-SR-Right α/R2-HL-Right α	0	1
R1-SR-Right β/R1-HL-Right β	1.1	***0.001***
R1-SR-Right β/R2-SR-Right β	1.5	***0.001***
R1-SR-Right β/R2-HL-Right β	1.9	***0.001***
R1-HL-Right β/R2-SR-Right β	0.3	1
R1-HL-Right β/R2-HL-Right β	0.7	0.734
R2-SR-Right β/R2-HL-Right β	0.3	0.873
R1-SR-Left α/R1-HL-Left α	0.4	0.987
R1-SR-Left α/R2-SR-Left α	0.3	1
R1-SR-Left α/R2-HL-Left α	0.2	1
R1-HL-Left α/R2-SR-Left α	0	1
R1-HL-Left α/R2-HL-Left α	0.1	1
R2-SR-Left α/R2-HL-Left α	0	1
R1-SR-Left β/R1-HL-Left β	2.2	***0.001***
R1-SR-Left β/R2-SR-Left β	2.7	***0.001***
R1-SR-Left β-R2-HL-Left β	2.4	***0.001***
R1-HL-Left β-R2-SR-Left β	0.5	1

R1-HL-Left β-R2-HL-Left β	0.1	1
R2-SR-Left β-R2-HL-Left β	0.3	1

Table 3. Distribution of the Graf hip types on both projections according to the two raters

	Type 1	Type 2a	Type 2b	Type 2c
R-1 SU-Graf-R	142	20	0	4
R-1 SU-Graf-L	140	22	1	3
R-1 HC-Graf-R	140	22	0	4
R-1 HC-Graf-L	139	23	1	3
R-2 SU-Graf-R	145	18	0	3
R-2 SU-Graf-L	142	20	1	3
R-2 HC-Graf-R	143	20	0	3
R-2 HC-Graf-L	141	21	1	3

Standing up-right/Graf type-Right hip: SU-Graf-R
Standing up-right/Graf type-Left hip: SU-Graf-L
Horizontal cranial-left/Graf type-Right hip: HC-Graf-R
Horizontal cranial-left/Graf type-Left hip: HC-Graf-L

4. Discussion

Developmental dysplasia of the hip (DDH) is one of the most common musculoskeletal problems in newborns (3). DDH is characterized by an abnormal relationship between the femoral head and the acetabulum. These problems range from dysplasia, where the anatomy of the developing articulation surfaces is abnormal, to potential partial or complete dislocation of the hip joint over time. Hip ultrasonography, which was first described by Graf, has been used for the diagnosis and follow-up of DDH in children since the early 1980s (4). Since then, the use of hip sonography has spread worldwide (5). Hip sonography using this technique has reduced the conservative treatment rate and avoided over-treatment as well as operations and consequently, femoral head necrosis (3). In the Graf static method, a coronal plane image is obtained and qualitative evaluation is made of the hip bone and cartilage of acetabular components, and then classification is made based on the quantitative measurements between these components and the os ilium. The α angle represents the bony roof of the acetabulum and the β angle represents the cartilage roof (1). Graf reported that only ultrasonographic images in the standard plane are acceptable for measurement (3). In accurately defined anatomic sonographic examination, appropriate interpretation, and measurement techniques are carefully followed, and hip disorders in newborns can be easily managed using this method. If anatomical identification cannot be visualized or the standard plane is missing in a sonographic image, it is of no value and should not be used for diagnosis. In completely dislocated hips (Graf Type 3–4), non-standard sonograms can be used for the evaluation because the displacement of the femoral head avoids the visualization of the femoral head and the center of the acetabulum in the same frontal section (1).

Graf's technique of evaluation is based on a coronal image of the hip obtained from the lateral approach with the femur in anatomic position. This method emphasizes the angular measurements of acetabular landmarks, in addition to the assessment of hip position (6). All the anatomical structures previously stated by Prof. Graf (3), should be seen on the sonographic image. If the checklist is ignored, the interpretation of the image may be incorrect. A usability check (lower limb, plane, labrum) should also be kept in mind to be able to obtain more accurate results in hip sonography evaluation. Only sonograms in the standard plane are accepted for measurement (3). The Graf checklist (Fig. 2) should be checked when performing the hip sonography procedure. The Graf checklist contains the following anatomical structures; 1: Chondro-osseous border, 2: Femoral head, 3: Synovial

fold, 4: Joint capsule, 5: Labrum, 6: Cartilaginous roof, 7: Bony roof, and 8: Bony rim (concavity-convexity). If hip sonography is applied using this checklists, misdiagnosis can be prevented (3). Gunay et al. reported that except in special circumstances as previously mentioned by Professor Graf, Type 1 mature hips which have worsened over time are related to an initial incorrect diagnosis. It was concluded that if a Graf Type 1 hip was determined appropriately according to the Graf checklist, it will never worsen later in normal circumstances (7). In the current study, all the sonographic images met the Graf checklist criteria, and therefore the measurement results of the two raters were consistent with each other.

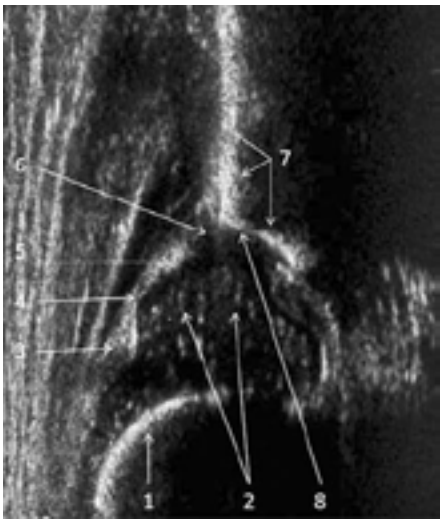

Figure 2. Standard sonogram and Graf checklist (1) (Figure 3, with the permission of Medical Ultrasonography Journal 2013, Vol. 15, no. 4, 299-303).

Graf described four view projections when performing hip sonography, and reported that the sonographic projections from best to worst were as follows; standing-up right position, horizontal-cranial right position, standing-up left position, and horizontal-cranial left position (3). Therefore in this study, the two sonographic views evaluated were the best projection and the worst projection according to Graf (3). However, it was thought that if the Graf usability and checklist rules were strictly followed, the angle measurements and the Graf classifications of the hips would show concordance even if the views were taken in different projections. The results of this study showed there were no statistically significant differences between the two projections in terms of angle measurements and Graf classifications even though the sonograms were evaluated and measured by an orthopaedic surgeon and a radiologist independently of each other. Another issue is that the amount of experience and training in hip ultrasonography has an important influence on the agreement of assessment of the hip joint. Both the raters in this study had more than 15 years of experience in hip ultrasonography. Previous studies have demonstrated that both the performance of USG and its interpretation influence the results and potential treatment (8). It has been reported that α angle measurements are more reliable and have more concordance than the measured β angles with both digital and manual measurement techniques. However, the same study showed that both measurement methods were reliable and concordant (9). The current study results were also in concordance with each other in terms of both angle measurements in different projections, although the β angles of the left hips had lower ICC (0.59) values compared to the others. Nevertheless, those β angle results did not influence the hip classification.

The diagnosis of DDH in the infant hip cannot be made solely by evaluation of the ultrasound images obtained in the standard plane without the bony roof and the cartilage roof measurements. In the Graf method, the diagnosis, classification, and follow-up treatment of infantile DDH strictly depends on the bony roof (α) angle and cartilage roof (β) angle measurements (1,10). Roovers et al. reported average standard deviations of 3.2° and 6° for the α and β angles, respectively (11). Graf stated deviations for both angle values of ± 4° (12). In another study, the angle values were compared by four groups of observers. The variability for the α angle was between 0° and 16°, and for the β angle it was between 0° and 26°. The standard deviation for the observers was lower for the α angle than for the β angle. It was stated that the study had produced similar results and could be regarded as comparably good according to literature (13). In the same study, although the variability of the α and β angles when measured on the same sonogram was high between observers, it did not lead to any false negative assessments since there was a tendency to classify hips as more severely affected than they actually were in cases of uncertainty (13). In the current study, both researchers made the hip classification of Graf type 2a instead of Graf type 1 on the right hips of 2 infants and on the left hip of 1 infant. However, the Graf type 2a hips, which were physiologically immature, returned to Graf type 1 mature hips in the latest follow-up. Therefore, these classifications did not change the final results in terms of defining type 1 mature hips. It was thought that these incorrect measurements made by both raters for three hips in this study was caused by the horizontal-cranial left position, which was previously defined by Graf as the worst projection. Nevertheless, with the exception of those three hips, all the other results were the same on the two projections.

In a study by Simon et al., the inter-observer agreement of ultrasonography measurements was investigated, and it was concluded that if the hip was immature there was no increase in the discrepancy in assessment between observers (13). Similarly, in the current study, it was thought that inter-rater agreement could be more difficult in hips which are borderline such as Graf type 2a, 2b and sometimes 2c, than fully dislocated hips such as Graf type D, 3 and 4.

This study had some limitations, primarily the low number of cases. Furthermore, each rater only measured the sonograms once, so despite inter-observer agreement, there was no evaluation of intra-observer agreement.

5. Conclusions

All the images in this study were taken according to the Graf checklist, and despite the use of two different sonographic projections to determine the angles and hip types, no major differences were determined between the two images according to the results of two independent raters. The standing-up right projection showed more agreement values between the raters than the horizontal-cranial left projection. Although Graf stated that the best projection with the lowest rate of wrong interpretation was the standing-up right projection, the results of the current study showed similar Graf hip types on both the standing-up right and the horizontal-cranial left projections. Thus, if the checklists are strictly followed, the horizontal-cranial left projection can also be safely used for the evaluation of hip joints in infants.

Acknowledgement

We would like to thank Prof. Dr. Ertuğrul ÇOLAK for his support at the statistical analysis of this study.

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