*Review*

*Med Ultrason 2023, Vol. 25, no. 4, 453-465*
**DOI:** 10.11152/mu-4194

# Hip sonography according to Graf: practical notes for the student, the examiner and the reviewer

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**Abstract**

Since the publication of Professor Reinhard Graf's work in 1980, Graf's technique has become the gold standard for screening Developmental Dysplasia of the Hip (DDH) in many European and non-European countries. Despite the fact that it is supported by robust literature evidence, there is criticism about its reliability and reproducibility, questioning several aspects of the diagnostic procedure. There is, however, concern, based on recent literature, about the quality and reliability of the published data, which may, in many cases, be based on inadequate scans, and therefore any conclusions drawn have to be questioned. The aim of this review is to demonstrate the most important aspects of Graf's technique, to clarify the potential sources of confusion and to flag up the most common errors and mistakes made, either during the ultrasound examination, or during the reporting procedure. Furthermore, this review can be used as a guide for reviewers and editors and should help to enhance the quality control of publications on this subject.

**Keywords:** Developmental Dysplasia Hip; Ultrasound; Graf

## Introduction

Since the publication of Professor Reinhard Graf's work in 1980 [1], which described a sonographic technique for the examination of the neonatal infant hip, Graf's technique has eventually become the gold standard for screening Developmental Dysplasia of the Hip (DDH) in Central Europe, especially in Germany, Austria and Switzerland and is rapidly spreading to other European and non-European countries [2,3]. There is still debate about the appropriate screening policy (universal vs. selective) [4], even though the results which come from the universal-screening countries (mainly Austria and Germany), strongly support universal over selective screening [5,6].

The cause for disagreement on the most effective screening policy, may be primarily the different health policies in different countries, and depends heavily on the priorities in the allocation of resources. Furthermore, a reluctance to change practice, may be closely related to inadequate dissemination of information and in some cases, lack of acknowledgement of the published results achieved in Austria, Germany and recently, Mongolia [2,5-9].

This was one of the main reasons for the formation of the International Interdisciplinary Consensus Committee on DDH Evaluation (ICODE), which aims to inform the scientific community worldwide, about the clear benefits of early, universal sonographic screening for DDH with the (unmodified) Graf's protocol, and the advantage of early, sonographic-driven treatment [10].

On the other hand, there is criticism about the reliability and reproducibility of Graf's technique, question-

Received 23.05.2023 Accepted 14.06.2023
Med Ultrason
2023, Vol. 25, No 4, 453-465
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ing several aspects of the diagnostic procedure [11–17]. A very recent publication raised concern about the quality of the published literature on the subject, by simply evaluating the quality of the published images, which were found to be suboptimal or even, non-diagnostic, in a significant number of publications [18]. This raises concerns about the quality and reliability of the published data, which might, in many cases, be based on inadequate scans and therefore, any conclusions drawn in such papers have to be questioned. Publication of any results that are based on a specific sonographic technique, without ascertaining that the technique is correctly applied, is unacceptable from a scientific point of view.

The purpose of this review is to flag the most common errors and mistakes made, which may either occur during the US examination, or during the reporting procedure, and to list the anatomical structures and landmarks, that have to be identified in any sonogram, without exception. Furthermore, this review can be used as a guide for reviewers and editors and may aid to enhance the quality control of publications on this subject.

## Graf's ultrasound scanning technique

Graf's technique is a standardized sonographic method for the detection of DDH [19]. In order to produce a diagnostic sonogram, certain steps have to be followed in a very specific order, during every sonographic examination.

***1. Baby positioning / Scanning technique (including image projection)***

The use of the examination cradle (to position the baby correctly) and the probe holder (to fix and position the transducer) for every scan, is strongly recommended (fig 1). Scanning "freehand", without a cradle, with the baby lying either in a lateral or supine position, is strongly discouraged. The use of the examination cradle and the probe holder, help standardize the scanning technique and improve its reproducibility, by minimizing the risk of tilting errors, which result in non-diagnostic images. Tilting errors (which are due to complex sound phenomena including reflection, refraction and diffraction), may be caused by incorrect probe selection (use of non-linear probes), incorrect probe handling or incorrect positioning of the baby.

The projection of the image should always be in the right coronal position (same as imaging the right hip, with an a.p. hip x-ray), especially when the images are to be published or used for educational purposes (fig 2). In the event that rotation/mirroring of the image is not technically feasible, use of an external monitor is strongly advised (fig 3). The right coronal view offers better un-

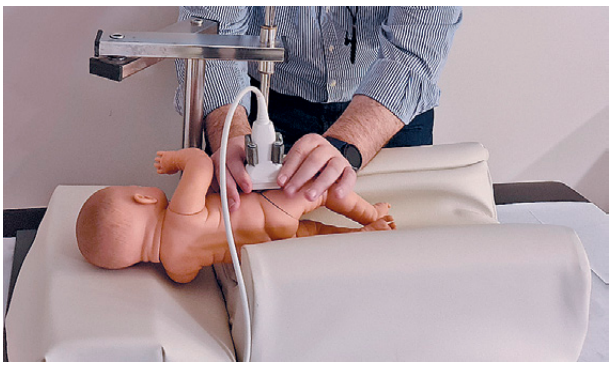

**Fig 1.** The use of the examination cradle (to position the baby correctly) and the probe holder (to fix and position the transducer) for every scan, is strongly recommended.

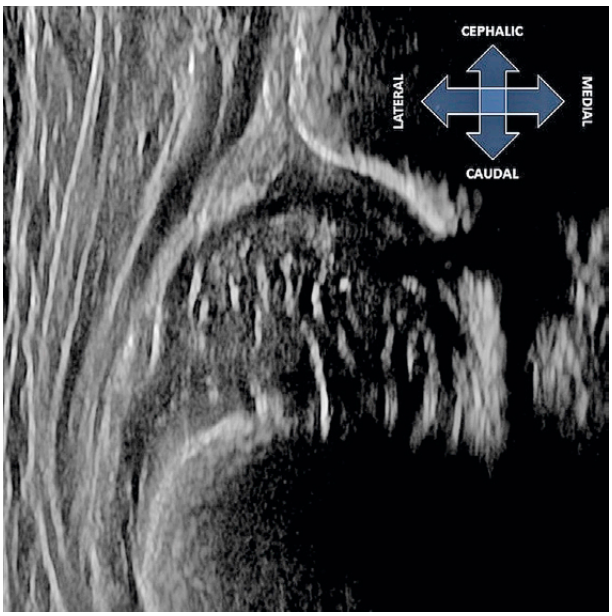


**Fig 2.** The projection of the image should always be in the right coronal position (same as imaging the right hip, with an a.p. hip x-ray), especially when the images are to be published or used for educational purposes.

**Fig 3.** Use of an external monitor is strongly advised, in the event that rotation/mirroring of the image is not technically feasible *(Courtesy of Dr Foteini Terzidou, Drama, Greece)*.

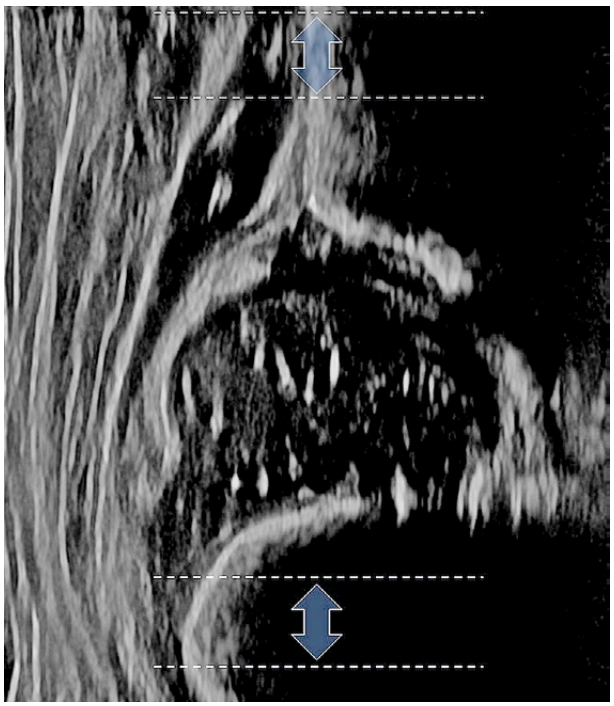

**Fig 4.** The hip joint should occupy at least two thirds of the image, extend cranially up to a few millimeters above the proximal perichondrium and clearly demonstrate the chondro-osseous border, caudally.

derstanding of the anatomy (or the pathology) of the hip joint, thus further standardizing the diagnostic procedure [20].

Magnification of the images should be adequate in order to safeguard the quality of reporting: The hip joint should occupy at least two thirds of the image, extend cranially up to a few millimeters above the proximal perichondrium and clearly demonstrate the chondro-osseous border, caudally (fig 4). These criteria should also serve as a requisite for the assessment of the quality of published material.

***2. Anatomical identification (Checklist 1)***

It is of utmost importance that certain anatomical landmarks are identified in every hip scan. Anatomical identification serves as the first quality checklist (Checklist 1), which has to be performed for every scan (fig 5), without exception.

The usual sources of error of the procedure, are summarized below:

*Chondro-osseous border*: the chondro-osseous border is the sonographic term used to describe the border/junction between the cartilaginous and the bony part of the proximal femur, in the metaphyseal area (fig 6). The chondro-osseous border can have very specific shapes, depending on the age of the baby. The chondro-osseous border should always be identified, in any image, regardless of the position of the femoral head. A sonogram without a clearly defined chondro-osseous border is non-diagnostic (fig 7)!

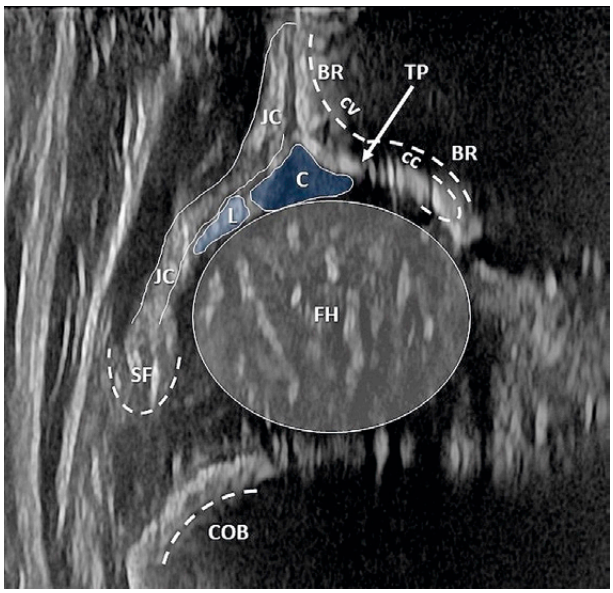


**Fig 5.** It is of utmost importance that certain anatomical landmarks are identified in every hip scan. Anatomical identification serves as the first quality checklist (Checklist 1), which has to be performed for every hip scan (COB: chondro-osseus border, FH: Femoral Head, SF: Synovial Fold, JC: Joint Capsule, L: Labrum, C: Cartilage, BR: Bony Roof, cc: concavity, cv: convexity, TP: Turning Point).

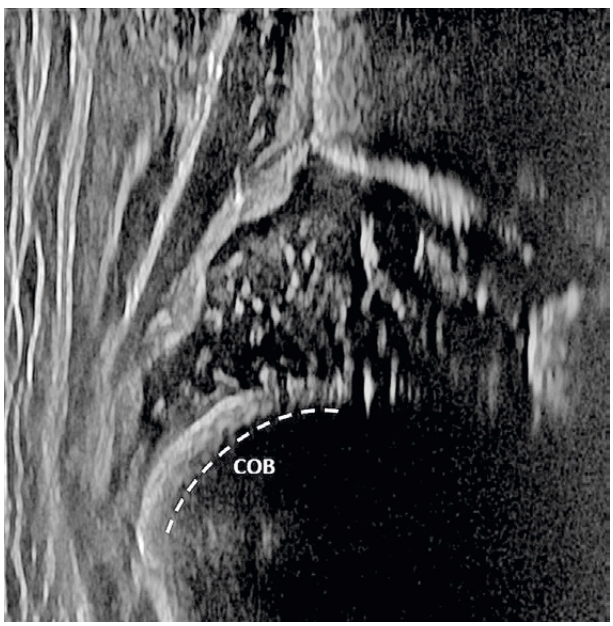


**Fig 6.** The chondro-osseous border (COB) is the sonographic term used to describe the border/junction between the cartilaginous (cephalic) and the bony (caudal) part of the proximal femur, in the metaphyseal area of the bone.

*Femoral head*: The ossific nucleus of the femoral head has been a source of confusion. What is visualized on ultrasound, is the most lateral part of the (non-spherical) ossific nucleus. Neither its size, nor its position in relation to the femoral head can be defined sonographically. So, assumptions about the position of the femoral head within the acetabulum, based on the ossific nucleus, should not be made and are incorrect (fig 8). It also has to be stressed, that it is not feasible to make any correlations between the ultrasound image and findings on x-ray of the same hip, as the ossific nucleus is visible on ultrasound much earlier than on x-ray (6-8 weeks difference) [19].

*Labrum*: the fibrocartilaginous labrum can always be identified with the help of the four definitions, which have been described by Graf [19]: (a) it is always in contact with the femoral head, (b) it lies medial to the joint capsule and exactly at the point where it is laterally separated by the femoral head, (c) it lies caudal to the "perichondrial gap" and (d) it lies lateral to the hyaline cartilage of the bony part of the acetabulum (bony roof). Common confusion of the labrum with a local thickening of the joint capsule (i.e., the ischio-femoral ligament) may be avoided with the use of these definitions (fig 9).

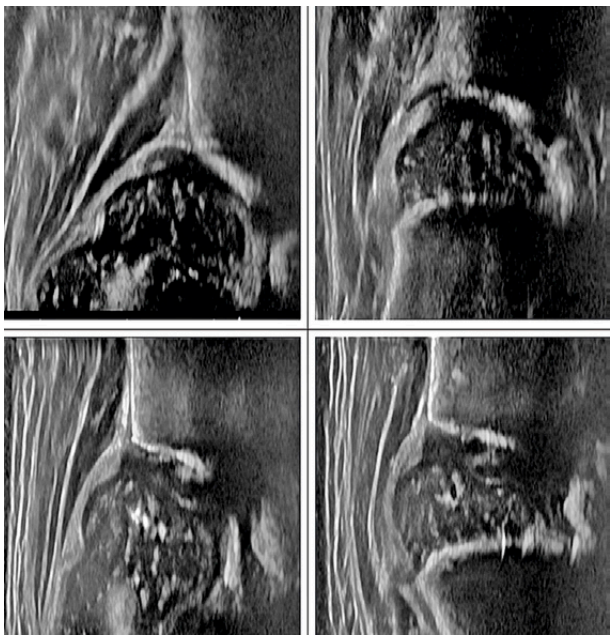

**Fig 7.** Example of scan images without a clearly defined chondro-osseus border. Those scans are considered non-diagnostic.

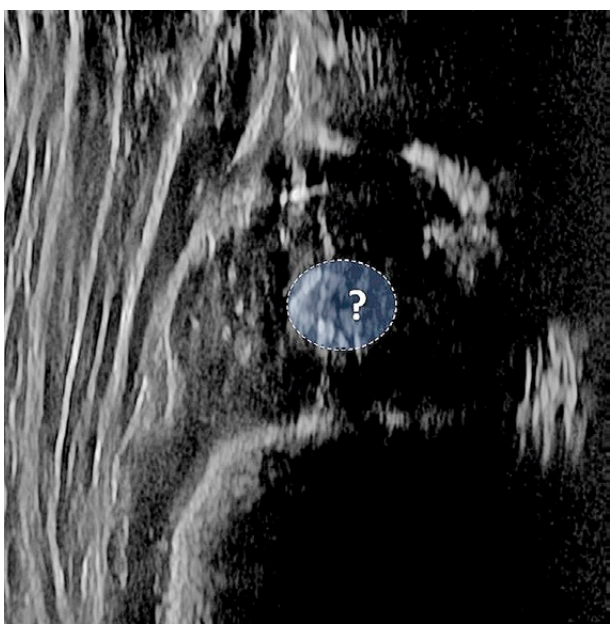


**Fig 8.** Any assumptions about the position of the femoral head within the acetabulum, based on the ossific nucleus, should not be made and are incorrect. Image demonstrates that the extent of medial part of the nucleus may not be calculated due to the acoustic shadow caused by the lateral (echogenic), comma-shaped part of the nucleus, which is clearly identified.

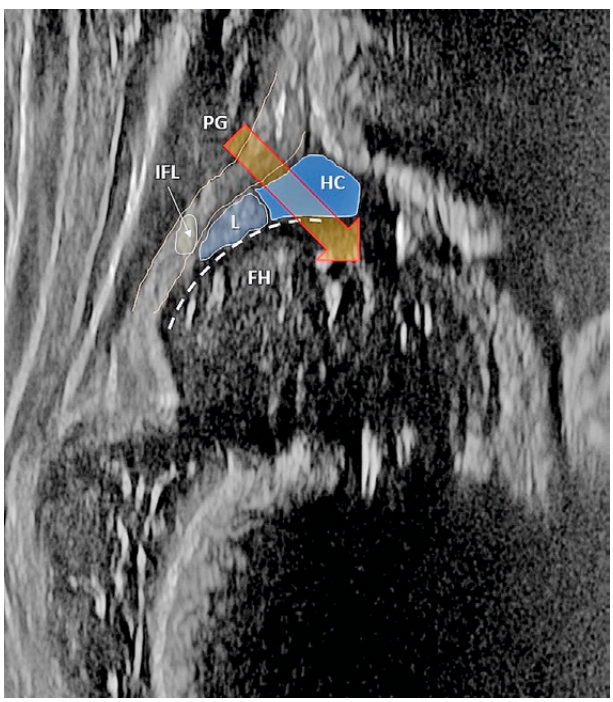


**Fig 9.** Based on simple rules, which have been thoroughly described by Graf, correct identification of the labrum is feasible: (a) it is always in contact with the femoral head, (b) lies medial to the joint capsule and exactly at the point where it is laterally separated by the femoral head, (c) lies caudal to the "perichondrial gap" and (d) lies lateral to the hyaline cartilage of the bony part of the acetabulum (bony roof). Common confusion of the labrum with a local thickening of the joint capsule (i.e., the ischio-femoral ligament) may be avoided with the use of the above-mentioned definitions (IFL: Ischio-Femoral Ligament, L: Labrum, HC: Hyaline Cartilage, FH: Femoral Head, PG: Perichondrial Gap, demonstrated by the arrow).

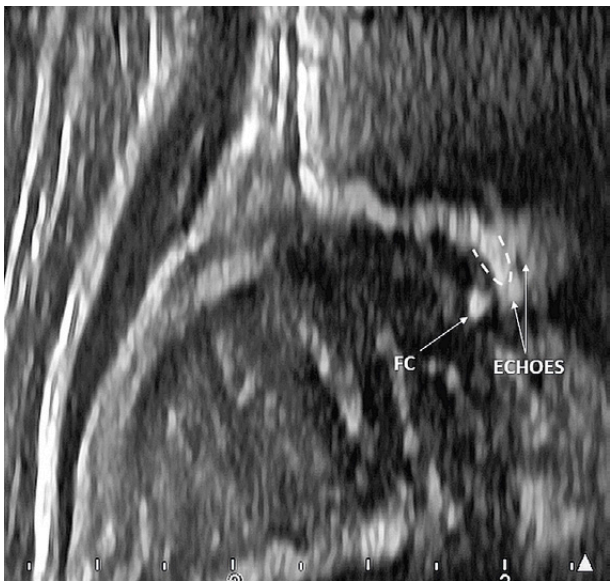


**Fig 10.** Attention must be paid when identifying the lower limb of the os ilium, as there are a few neighboring echogenic structures (including fat, sinusoids and the fovea centralis), which may cause confusion (FC: Fovea Centralis, ECHOES: refers to fat and sinusoids, dotted line delineates the borders of the lower limb of the os ilium).

*Lower limb of the os-ilium*: the lower limb of the os ilium defines the center of the acetabulum and is the most medial / caudal part of the ilium. Attention must be paid when identifying the lower limb of the os ilium, as there are a few neighboring echogenic structures (including fat, sinusoids and the fovea centralis), which may cause confusion (fig 10).

*The turning point (bony rim)*: the turning point is the point where the concavity of the acetabular roof, turns into the convexity. Identification of the turning point is required in order to decide whether the hip is centered and to take measurements. It is very important to start the identification process from the medial and caudal part of the ilium and follow the outline of the bony acetabulum to cranial and lateral, and not vice-versa (fig 11).

If the identification is started from cranial to caudal, a harmless ossification defect can be the cause for incorrect identification of the turning point, resulting in wrong measurements and wrong diagnosis (Fig 12). In the rare cases where an ossification defect is identified, the principle of line management for the acetabular roof line still applies (*see below*).

*Practical tips to identify dislocation*

With anatomical identification the position of the femoral head is clearly identified, and a differentiation between a centered and a decentered hip is generally feasible. There are simple, practical tips which may aid the novice sonographer to make this distinction.

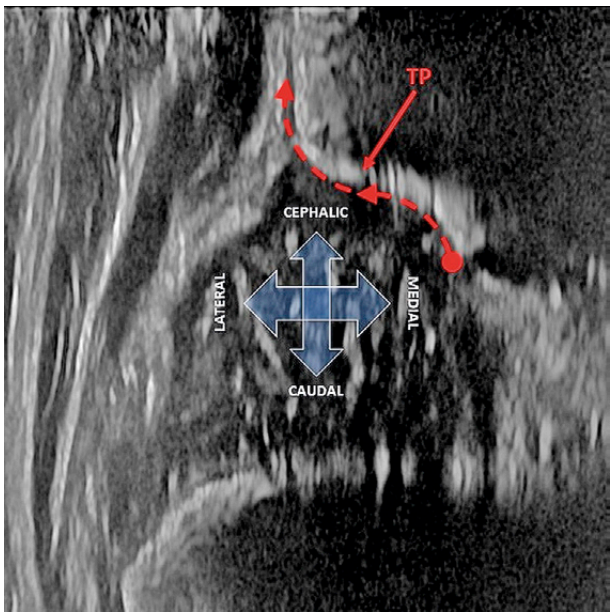


**Fig 11.** It is very important to begin the identification process from the medial and caudal part of the ilium and follow the outline of the bony acetabulum to cranial and lateral, and not vice-versa (TP: Turning Point, the dotted line and the arrows demonstrate the correct direction of the procedure of the identification process, i.e., medial to lateral).

**Fig 12.** If the identification is started from cranial to caudal, a harmless ossification defect can be the cause for incorrect identification of the turning point, resulting in wrong measurements and wrong diagnosis.

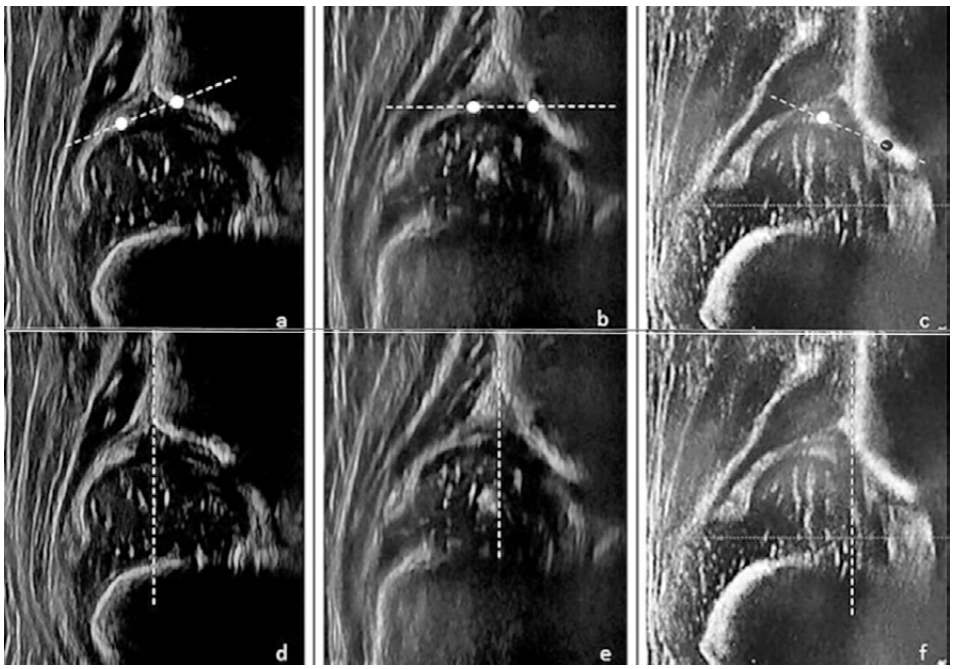


**Fig 13.** In centered hips, the turning point is above the labrum, in borderline cases (severely dysplastic hips) the turning point lies at approximately the same level as the labrum, and in dislocated hips, the turning point lies below the labrum (a,b,c). Depending on the amount of coverage of the femoral head by the acetabulum, the examiner gets a rough idea if the hip joint is likely to be centered or not (d,e,f).

The first is the relative position of the labrum to the turning point. In centered hips, the turning point lies above the labrum, in borderline cases (severely dysplastic hips) the turning point lies at approximately the same level as the labrum, and in dislocated hips, the turning point lies below the labrum (fig 13a,b,c).

A second practical trick is "eye-balling", which may further help to categorize the hip joint. A line extending parallel to the silhouette of the os ilium is drawn and the (approximate) silhouette of the femoral head is plotted. Depending on the amount of coverage of the femoral head by the acetabulum, the examiner gets a rough idea if the hip joint is likely to be centered or not (fig 13d, e,f).

It has to be stressed that both of these "tricks" are simply an aid for the examiner, helping them to get an overview of the morphology of the hip joint and preparing for the next steps of the examination, but can by no means substitute further formal assessment of the hip joint (as described below).

***3. Usability check (Checklist 2)***

The usability check (Checklist 2) confirms that the sonogram is in the "standard plane"; in other words, that the sound beam has followed the route, (a) through the (sonographic) center of the acetabulum (lower limb of the os ilium), (b) through the middle of the acetabular roof (straight silhouette of the os ilium) and (c) without any tilting effects due to wrong examination technique (fig 14).

**Fig 14.** The usability check (Checklist 2) confirms that the sonogram is in the "standard plane" (LL: Lower Limb, PLANE: parallel to the probe, L: labrum).

**Fig 15.** Do not accept any images, which do not fulfil the above-mentioned criteria, with one exception: if the femoral head lies in a different "plane" to the center of the acetabulum i.e., is dislocated (in which case, there will be no lower limb of the os ilium).

All centered hips should fulfil the criteria of the *Usability check*: the lower limb of the os ilium should be visible, the silhouette of the os ilium (plane) should be straight / parallel to the probe and the labrum should be clearly defined.

Do not accept any images, which do not fulfil the above-mentioned criteria, with one exception: if the femoral head lies in a different "plane" to the center of the acetabulum i.e., is dislocated (in which case, there will be no lower limb of the os ilium) (fig 15). When a hip starts to decenter, it is sometimes possible that the femoral head can still be visualized within the same plane as the center of the acetabulum ("standard plane"). In this case, the femoral head has started to move "upwards" but has not moved posteriorly yet.

*Tilting effects (Errors)*

Tilting effects constitute a major source of confusion and error. The term refers to all the complex sonographic errors which result from the use of the wrong probe type (non-linear probe) or incorrect scanning technique. The main types of tilting effects and their sonographic features are summarized in Fig 16. It is important to recognize the features of a tilting error at the time of the examination, because only then is correction possible.

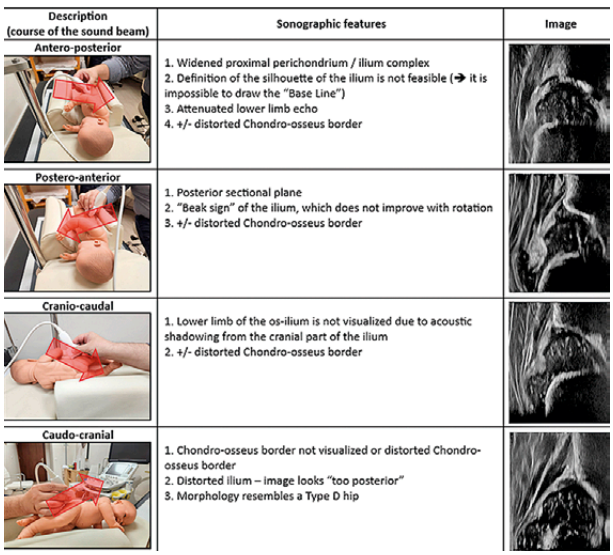


**Fig 16.** Classification of tilting errors and characteristic sonographic findings.

***Take home messages:***

- do not accept images without a clearly defined chondro-osseous border, which is a primary feature in most of the tilting effects;
- with a tilt, a "good hip" may be projected (and further categorized) as a "bad hip" (thus leading to overtreatment), however, a "bad hip" may not be converted to a "good hip" (Fig 17), as long as Checklists 1 and 2 are adhered to;
- before classifying a hip as "decentering" (Type D), ensure that this is not due to tilting (especially caudo-cranial tilting), by repositioning the baby and scanning again, at the same time.

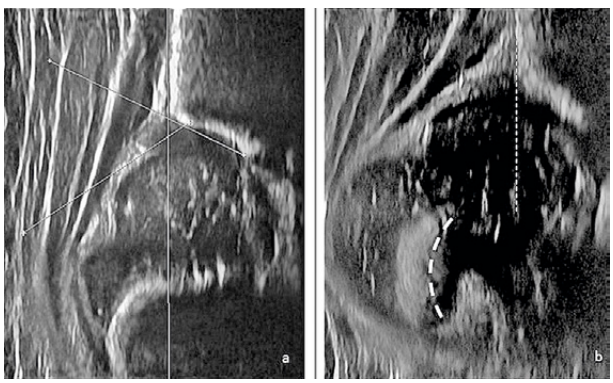


**Fig 17.** With a tilt, a "good hip" may be projected (and further categorized) as a "bad hip" (thus leading to overtreatment). An absolutely normal hip (a) is "converted" into a heavily dysplastic (or decentering) hip (b), by caudo-cranial tilting of the probe (straight dotted line is parallel to the silhouette of the os ilium, curved dotted line refers to the distorted chondro-osseus border).

Table I. Hip Types – morphological classification

| Hip Type | Bony roof | Bony rim | Cartilaginous roof |
|---|---|---|---|
| **Ia** | Good | Angular / Blunt | Covering the FH |
| **Ib** | Good | Angular / Blunt | Covering the FH |
| **IIa(+) / 0-12 wks** | Adequate | Rounded | Covering the FH |
| **IIa(-) / 6-12 wks** | Deficient | Rounded | Covering the FH |
| **IIb / >12 wks** | Deficient | Rounded | Covering the FH |
| **IIc (stable/unstable)** | Severely deficient | Rounded (→flattened) | Covering the FH |
| **D (decentering FH)** | Severely deficient | Flattened | Displaced |
| **III** | Poor | Flattened | Pressed upwards |
| **IV** | Poor | Flattened | Pressed downwards |

FH = Femoral Head

***4. Morphological classification***

Morphological (descriptive) classification is the categorization of the hip joints into different types, according to their morphology (Table I). It is based on the description of very specific structures of the acetabulum, namely the bony roof, the turning point (bony rim) and the cartilaginous roof (hyaline cartilage of the roof of the acetabulum) (fig 18).

**Fig 18.** Morphological (descriptive) classification is the categorization of the hip joints into different types, according to their morphology. It is based on the description of very specific structures of the acetabulum, namely the bony roof (B ROOF), the turning point (bony rim) (B RIM) and the cartilaginous roof (hyaline cartilage) (C ROOF).

The first step is the categorization into centered (Types I and II) and decentered (dislocated) hips (Types III and IV).

Type I and Type II hips are both centered hips and the femoral head is covered by the acetabulum in both cases. The difference is the ratio of bony and cartilaginous cover. Type I hips have a relatively larger bony roof (mature hip joint) than Type II hips, and vice versa, the proportion of hyaline cartilage in comparison to bone is larger in Type II hips.

On the other hand, the main difference between a Type III and a Type IV hip is the position of the hyaline cartilage (not the labrum! the labrum is always in contact with the femoral head), which may be either pushed cranially by the dislocating femoral head, or, as the head

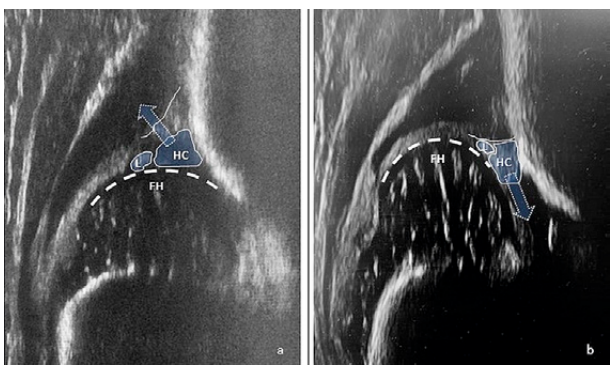


**Fig 19.** The main difference between a Type III and a Type IV hip is the position of the hyaline cartilage which may be either pushed cranially by the dislocating femoral head (Type III) (a) or, as the head continues to move upwards, caudally (Type IV) (b), thus forming an obstacle to reduction. Due to the fact that the cartilage appears hypoechogenic (when intact!), we may define its exact position by the shape and the position of the perichondrium, which is echogenic and is located external to the cartilage (FH: Femoral Head, HC: Hyaline Cartilage, L: Labrum, arrow shows the direction of displacement of the FH, white line delineates the external border of the perichondrium).

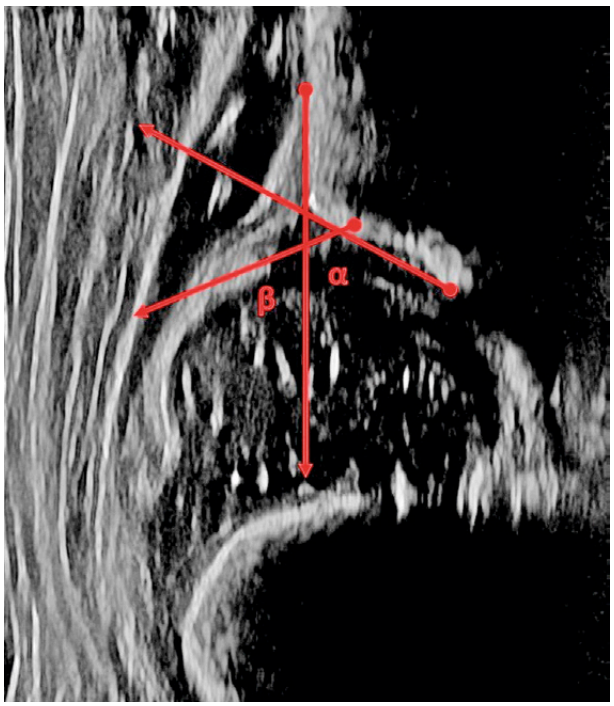


**Fig 20.** The Alpha angle (α) quantifies the morphology of the osseous part of the acetabulum ("the bony roof") and the Beta angle (β) quantifies the morphology of the cartilaginous part of the acetabulum ("the cartilaginous roof").

continues to move upwards, caudally, thus forming an obstacle to reduction. Due to the fact that the cartilage appears hypoechogenic (when intact!), we may define its exact position by the shape and the position of the perichondrium, which is echogenic and is located external to the cartilage (fig 19).

It is very important that the final type of the hip joint, after measurement, is in accordance with the expected hip type by the morphological classification. If this is not the case, then there is likely an error somewhere in the process (either wrong typing or problems with image quality) and the procedure should be repeated, aiming to identify the cause.

***5. Final classification***

Final classification is accomplished by measuring very specific angles: the Alpha angle and the Beta Angle. The Alpha angle quantifies the morphology of the osseous part of the acetabulum ("the bony roof") and the Beta angle quantifies the morphology of the cartilaginous part of the acetabulum ("the cartilaginous roof") (fig 20).

Measurement of the angles should have a very firm basis, so the definition of the lines which form the angles, has been very thoroughly described. However, it still constitutes a main source of error. The base line always starts from the insertion point of the proximal perichondrium to the periosteum of the os ilium and descends parallel to the silhouette of the os ilium. Despite the fact that it is vertical to the image in centered hips, it may not be so in dysplastic hips (fig 21). It is very important to correctly draw the base line because it is the base for all the measurements. The bony roof line starts from the lowest and innermost point of the echo of the lower limb of the os ilium and follows the curvature of the acetabulum, tangential to the bone. There is no second point for the definition of the bony roof line, which means that we do not draw the line for example, through the turning point. The line is just tangential to the bony roof and must not cut through any part of the bone (fig 22).

Finally, the cartilaginous roof line starts from the turning point (concavity to convexity) and goes through the middle of the echo of the labrum. So, in this case, there are two, very discrete points to refer to (see fig 20).

***Attention***: The three lines almost never cross at one point! Only rarely, in the case of a Type I hip with a sharp, angular formation of the turning point, may the three lines cross at one point. In any other case, the three lines form a triangle. Conversely, if the three lines cross

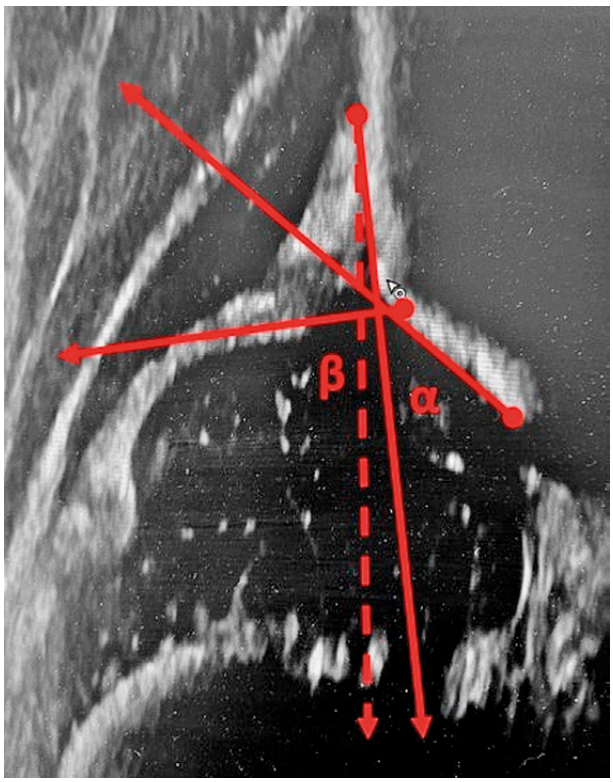


**Fig 21.** The Base Line always starts from the insertion point of the proximal perichondrium to the periosteum of the os ilium and descends parallel to the silhouette of the os ilium (despite the fact that it is vertical to the image in centered hips, it may not be so in dysplastic hips). In a dysplastic hip, as in this case, the continuous line and not the dotted one, is the correct one.

at one point, and the hip joint is not a Type I hip joint with a sharp, angular formation of the turning point, there is something wrong with the procedure.

The Alpha angle is the angle which defines the hip type. The Beta angle is used to differentiate between Type IIc stable and unstable hips and to define a Type D hip. Furthermore, the Beta angle offers an extra safety feature to ensure that the position of the bony rim (turning point) and the labrum have been correctly identified (medico-legal implications) and constitutes a research tool, as a prognostic value for future phenomena (including pincer impingement). Therefore, it should be very clear that in every scan, both angles, Alpha and Beta, should be measured.

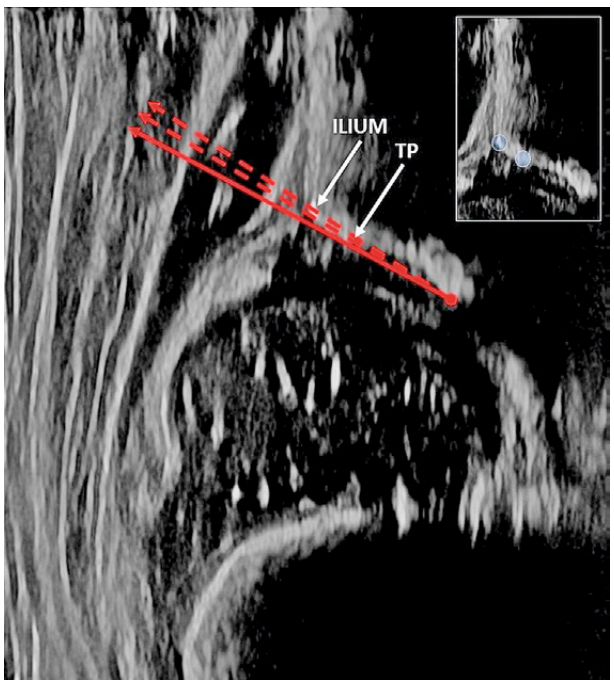


**Fig 22.** The bony roof line starts from the lowest and most inner point of the echo of the lower limb of the os ilium and follows the curvature of the acetabulum, tangential to the bone. There is no second point for the definition of the bony roof line, which means that we do not draw the line for example, through the turning point. The line is just tangential to the bony roof and must not cut through any part of the bone. In this case the continuous line refers to the correct bony roof line. Points of potential confusion are depicted in the embedded magnification box – dotted lines are incorrect, drawn through these points.

The final classification is summarized in Table 2.

Linear arrangement of the Alpha angle values, defines three separate "regions" (fig 23):

a) Alpha angle ≥ 60º: mature hips – all hips should measure at least 60º after 12 weeks (region a / green color).
b) Alpha angle ≥ 43º and ≤ 59 º: Type II hips (region b / yellow color).
c) Alpha angle < 43º: Type III and IV hips (decentered, dislocated hips), need immediate treatment (region c / red color).

***Attention***: The diagnosis of dislocation is made by description; measurement is rarely possible, as the femoral head is usually not in the standard plane)!

A major strength of the Graf technique is the subclassification of dysplasia. This includes the decision on whether a hip is physiologically immature or patho-

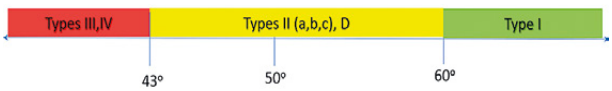


**Fig 23.** Linear arrangement of the Alpha angle values, defines three separate "regions": (a) Alpha angle ≥60º: mature hips – all hips should measure at least 60º after 12 weeks (region a / green color), (b) Alpha angle ≥43º and ≤59º: Type II hips (region b / yellow color), (c) Alpha angle <43º: Type III and IV hips (decentered, dislocated hips), need immediate treatment (region c / red color).

Table II. Hip Types – final classification

| Hip Type | Angles | Bony roof | Bony rim | Cartilaginous roof |
|---|---|---|---|---|
| **Ia** | α≥60º, β<55º | Good | Angular / Blunt | Covering the FH (*) |
| **Ib** | α≥60º, β>55º | Good | Angular / Blunt | Covering the FH |
| **IIa(+) / 0-12 wks** | α=50º-59º | Adequate | Rounded | Covering the FH |
| **IIa(-) / 6-12 wks** | α=50º-59º | Deficient | Rounded | Covering the FH |
| **IIb / >12 wks** | α=50º-59º | Deficient | Rounded | Covering the FH |
| **IIc stable/unstable** *(depending on stress-test)* | α=43º-49º , β<77º | Severely deficient | Rounded (→flattened) | Covering the FH |
| **D (decentering FH)** | α=43º-49º , β>77º | Severely deficient | Flattened | Displaced |
| **III** | α<43º | Poor | Flattened | Pressed upwards |
| **IV** | α<43º | Poor | Flattened | Pressed downwards |

FH = Femoral Head

logically dysplastic, and the detection of pre-dislocation, which obviously has implications on treatment decisions. Therefore, the most complicated region is the mid-region (b), as it further sub-classifies dysplastic hips into subtypes.

With an alpha angle between 50° and 59°, the main question is whether the immaturity of the hip joint is acceptable for the age of the infant. At the age of 12 weeks, all hips should have an alpha angle of (at least) 60° and if not, the term Type IIa hip changes to Type IIb hip after 12 weeks, purely because of the infant's age. Type IIb hips are considered pathologically dysplastic at this point and require treatment. The remodeling potential of the acetabulum is highest under the age of 6 weeks and still good up to the age of 3 months (12 weeks), so in order to maximize the acetabular remodeling potential for treatment, the decision on whether a hip is physiologically immature or pathologically dysplastic can be made earlier, after approximately 6 weeks of age (up to the age of six weeks, any alpha angle over 50° is acceptable, the joint is characterized as a Type IIa joint and should be rescanned to check the course of maturation). In other words, an Alpha angle of 55° would be acceptable for a 6-week-old infant (IIa+), but not for an 11-week infant (IIa-). All this information is contained in the "Sonometer", a simple measurement / classification aid, which summarizes all the information needed for classification purposes *(more information about the Sonometer may be found online: Essentials of Infant Hip Sonography According to Graf. Graf R, Lercher K, Scott S, Spieß T. Edition Stolzalpe Sonocenter 2017 - Page 21. http://graf-hipsonography.com/hipsonography.html)*.

On the other hand, type IIc hips ("critical range", severely dysplastic hips with an Alpha angle between 43° and 49°) are pathological and require treatment at any age.

***Attention:*** It is important to recall that decentered/dislocated hips are diagnosed by description and do not require any measurements! This is because measurements can only be made in the standard plane (Checklists 1 and 2) and dislocated hips are only in rare circumstances located in the standard plane, as described above.

***Assessment of stability***

Assessment of (sonographic) stability of the hip joint, has long been an issue of debate. Assessment of stability ("stress test"), according to the Graf's technique, is only performed in severely dysplastic hips (namely Type IIc hips), to assess the stability of the joint, which may further affect the selection and the duration of treatment (Type IIc stable vs. Type IIc unstable hips). Movements of the femoral head due to joint laxity (especially in very young neonates, under 2 weeks of age) and due to the elliptical shape of the femoral head, are acceptable in all other cases ("elastic whipping") and assessment of these movements in a well matured hip joint with good bony roof is useless. In simple terms, a "stress test" is only of value when the Alpha angle is in the range of 43° to 49° degrees (Type IIc range), otherwise it is of no clinical significance.

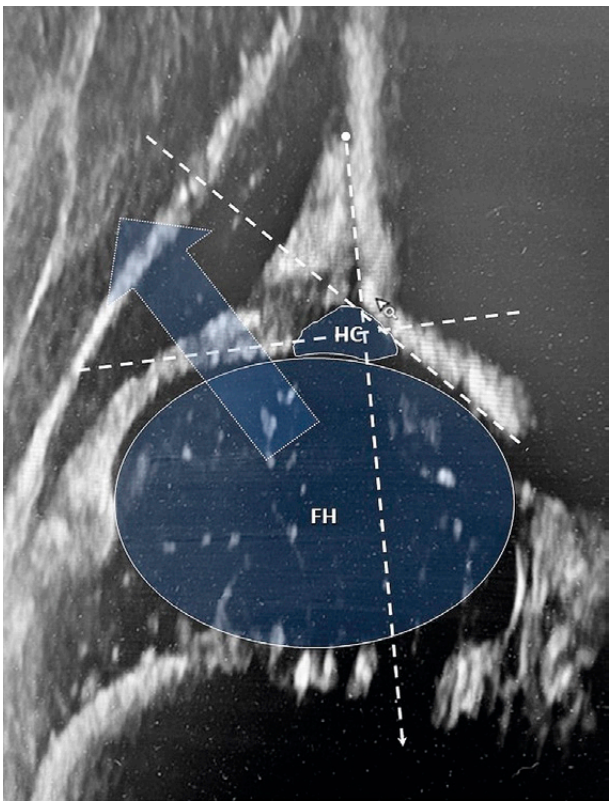


**Fig 24.** A Type D hip is a hip in the course of dislocation (FH: Femoral Head, HC: Hyaline Cartilage, the arrow shows the direction of displacement of the FH, dotted lines are the measurement lines).

Hip typing is always performed in the spontaneous (not stressed) position and not "at stress". A Type IIc hip, under "stress test", with a Beta angle >77° (Type D, "D" refers to "Decentering" or "Dislocating") is called a Type IIc unstable hip. On the other hand, a hip with an Alpha angle which is in the same range of 43° to 49° degrees, in spontaneous (not stressed) position, with a Beta angle > 77° is called a Type D hip.

***Attention***: Not a Type IID hip – Type II hips are centered hips. A Type D hip is a hip in the course of dislocation) (fig 24).

**Short discussion**

Graf's technique offers a quick and effective method for the detection and treatment of babies with DDH. As already mentioned, it is very important that the examiner

is trained to a high standard and follows the very specific steps of the Graf technique, in a ritual way. "Experience" by itself is useless if the technique is applied incorrectly and potentially, even passed on to trainees incorrectly.

This short (pictorial) review cannot, and must not, be considered a substitute, either for the training received in formal "hands on" courses, or for the information contained in detailed textbooks [19-21]. The aims of this document are:

(a) to highlight frequently asked questions during courses and well-known areas of confusion for the trainees (all authors share a considerable teaching experience),
(b) to aid reviewers with their decision-making process, by identifying some of the "red flags" for the acceptance of an image (we strongly recommend that publications without images proving that the technique has been applied correctly, should not be accepted, as the results and conclusions drawn could be incorrect),
(c) to offer a short "technical note" for hip sonography practice,
(d) to "refresh" the principles and the knowledge, which were published as a technical note by Professor Reinhard Graf a decade ago [22].

As a last note, it is very important that published literature meets the high standards, which are required for improvement of the quality of hip ultrasound as a diagnostic tool. Unfortunately, despite the fact that the technique has been in use for more than forty years, it is evident that the required level of excellence, has not been widely reached yet [18]. With the aim to aid in all the aspects of hip sonography (including training, education and audit), ICODE (International Interdisciplinary Consensus Committee on the Evaluation of DDH / www.icode.expert) was formed in 2018, offering significant scientific work on the subject [10].

**Conflict of interest:** none.

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