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Opinion

Fetal cerebral ventricular measurement and ventriculomegaly: time for procedure standardization

In this issue of the Journal, Melchiorre *et al.*[1] provide clear, up-to-date, evidence-based answers to the questions most commonly raised by the diagnosis of isolated mild fetal ventriculomegaly. While the issues raised by the authors are important and represent a real challenge in fetal medicine, in our experience first and foremost must be to establish whether the ventriculomegaly actually exists, which is itself a challenge in the absence of a clear and standardized method of measurement.

To measure the ventricle reliably is particularly problematic when the ventricular measurement is close to the standard threshold of 10 mm, a situation that is often referred to as 'borderline ventriculomegaly'. We share the view of Melchiorre *et al.* that this expression should be avoided, as it suggests the presence of a gray zone which is inappropriate in the context of a biometric parameter with a fixed cut-off value. In clinical practice, when faced with a 'borderline' measurement, some physicians will record it as being just below the threshold so as to be considered normal, while the vast majority, due to pessimism or prudence, tend to diagnose ventriculomegaly. As a result, in our department, a large number of fetuses referred for ventriculomegaly between 10 and 12 mm have normal ventricular measurements when we examine them (Figure 1).

Difficulty in measurement may also explain the large variation in incidence of isolated mild ventriculomegaly, which, according to various studies in low-risk populations, has been found to be between 1/50 and 1/1600[1]. The issue was recently revisited by Levine *et al.*[2] in an interesting analysis of the frequency and causes of disagreement in diagnosis of fetal ventriculomegaly[2]. They showed that differences of opinion between physicians in the diagnosis of ventriculomegaly were prevalent; among four physicians, all highly experienced at high-risk obstetric ultrasound, disagreement regarding the presence of ventriculomegaly on ultrasound was encountered in 10% of 196 cases. Interestingly, in cases that were subject to disagreement, the physcians who indicated that ventriculomegaly was present consistently recorded a larger ventricular atrial diameter (mean, 10.2 mm) than did those who indicated that ventriculomegaly was absent (mean, 8.4 mm). For a given fetus, the variation in ventricular diameter among the four physicians was 0.3 mm. As suggested by Hilpert *et al.*[3], if disagreement in 10% of cases can be encountered in an expert medical population, with a variation in ventricular diameter measurement of 0.3 mm, we might expect these values to be even higher in a less-trained medical population.

The consequences of such difficulties in measurement are important since ventriculomegaly is the pivotal finding for diagnosing central nervous system (CNS) pathology, justifying invasive procedures such as fetal karyotyping and generating considerable parental anxiety regarding the postnatal outcome[1,4]. Even when there is a false-positive test result on the initial routine ultrasound examination and the diagnosis is ultimately rejected, the anxiety generated does not dissipate easily. These issues regarding the measurement of the lateral ventricles and the medical and psychological consequences therefore justify revisiting the standardization of the measurement technique.

The reference method of sonographic ventricular measurement was described by Cardoza *et al.* in 1988[5]. The potential measurement error on sonographic evaluation was reported 2 years later by Heiserman *et al.*[6], who found that measurement of the lateral ventricle can be subject to error due to an off-axis image plane, an angled measurement, or an improper choice of ventricular boundary, all of which tend to lead to false-positive test results[6].

We provide here an image-scoring method similar to the one published by Herman *et al.* for nuchal translucency measurement[7], which can be used either as the first step in quality control or, at the very least, as an auto-evaluation tool in routine practice. Our image-scoring method builds on previously published recommendations (including the method initially described by Cardoza *et al.*[5]) and makes use of improved anatomical details provided by modern equipment, which enables clear delimitation of the atrium independently of the choroid plexus. This scoring method is based on two sets of three criteria (summarized in Table 1). The primary criteria (Criteria 1–3) provide the adequate reference image to perform atrial width measurement, while the secondary criteria (Criteria 4–5) ensure a high quality of measurement by appropriate caliper placement on an optimally magnified image.

The first set of criteria evaluates the quality of: the axial plane, the anatomical level, and the site of measurement of the atrial width.

Criterion 1 (Score 0–2) provides a strict axial plane. The midline structures should be equidistant from the proximal and distal calvarial margins (Criterion 1a, Score 0–1) and perpendicular to the ultrasound beam (Criterion 1b, Score 0–1). Regarding Criterion 1a, Heiserman *et al.*[6] have demonstrated that an off-axis image plane provides

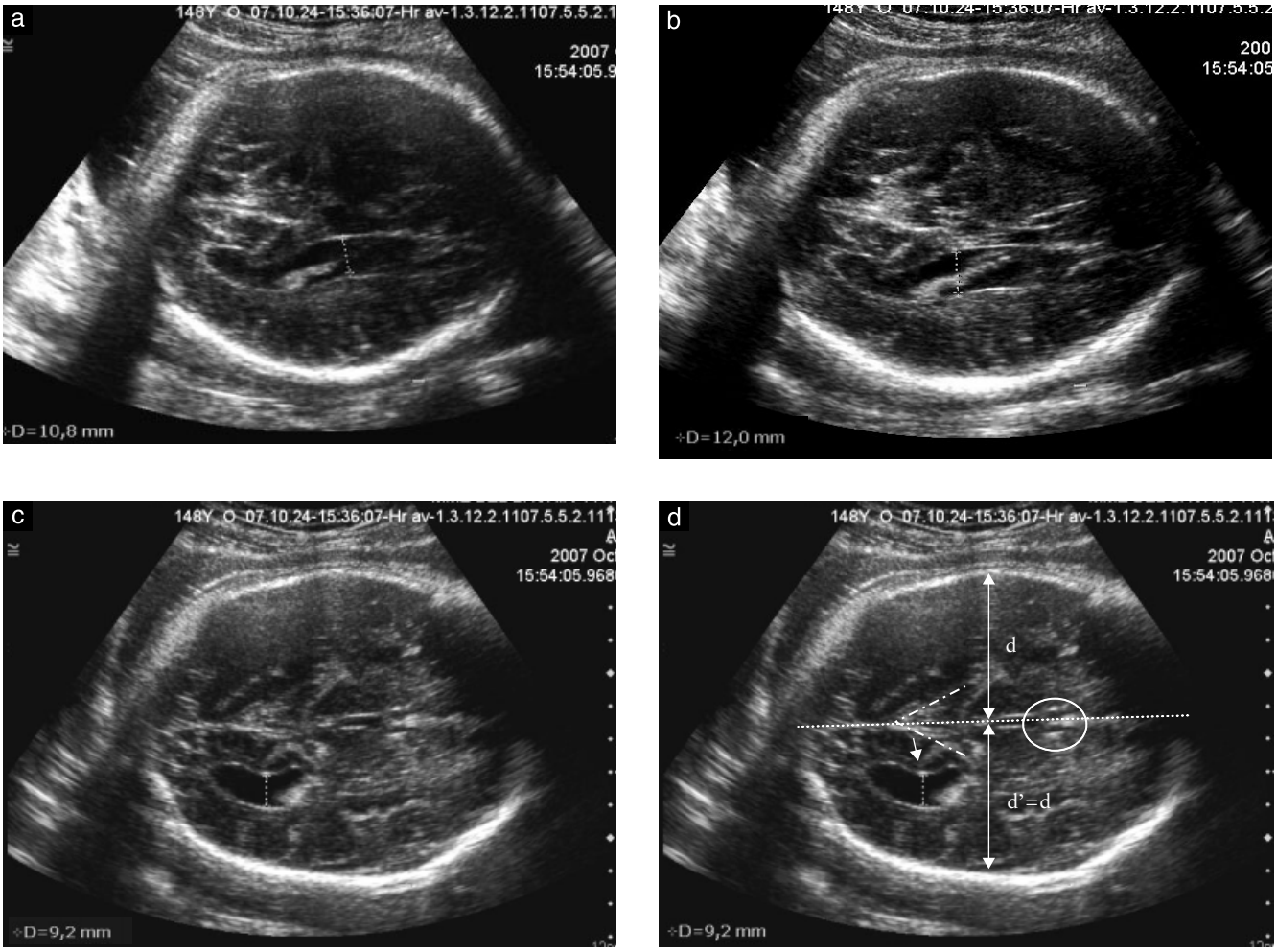

Figure 1 Ultrasound images in a patient referred for mild ventriculomegaly at 32 weeks' gestation. In this oblique axial image, in which none of the primary criteria aimed at providing an adequate reference image to perform atrial width measurement (a,b) nor the caliper placement criteria (b) have been met, the ventricle measurement varies from 10.8 to 12 mm. In an image in which all the anatomical and technical requirements (Table 1) have been met (c,d), the atrial width is below the cut-off of 10 mm, with an optimal total score of 7, using our image-scoring method. Note the visualization of the anterior (fornix columns, circle in (d)) and posterior (V shape of the ambient cistern, dotted line in (d)) anatomical landmarks, not identified on image (a,b). The midline (thin dotted line in (d)) is perpendicular to the ultrasound beam and equidistant to the calvarial margins (i.e. d=d', double-headed arrows). Measurement is performed opposite the deepest part of the internal parieto-occipital sulcus (small arrow).

Table 1 Image-scoring method

Criterion	*Score*	*Anatomical/technical requirements*
Primary criteria		
1. Strict axial plane	0–2	1a. Midline structures equidistant from proximal and distal calvarial margins 1b. Midline perpendicular to ultrasound beam
2. Adequate anatomical level	0–1	Anterior landmark: cavum septi pellucidi or fornix columns Posterior landmark: fluid-filled triangular V-shape of the ambient cistern
3. Location of the atrium	0–1	Measurement performed opposite the internal parieto-occipital sulcus
Secondary criteria		
4. Caliper placement	0–2	4a. Measurement perpendicular to inner and outer borders of the ventricle 4b. 'On to on' measurement (junction of ventricular lumen and ventricular wall)
5. Adequate image size	0–1	Axial transventricular plane occupying the whole screen with visualization of both proximal and distal calvarial margins

Maximum total score is 7.

an off-axis measurement of the atrium (angled obliquely through the atrium) and overestimates the atrial width (Figure 1). Application of Criterion 1b increases the reflection of the sonographic ventricular wall, which helps in caliper placement and avoids the classical error of inappropriate caliper placement on the internal margin of the cerebral hemisphere instead of on the internal part of the ventricular wall[8].

Criterion 2 (Score 0–1) provides an adequate anatomical level by the visualization of an anterior and a posterior anatomical landmark. In the methodology of Cardoza *et al.*[5], the atrium is measured on an axial image obtained through the thalami nuclei at the level of the smooth posterior margin of the choroid plexus. In the International Society of Ultrasound in Obstetrics and Gynecology (ISUOG) guidelines for sonographic examination of the fetal CNS[9], measurement is performed on a transventricular axial plane, using the cavum septi pellucidi and the choroid plexus as the anterior and posterior landmarks, respectively. Since the choroid plexus is not the best landmark with which to locate the atrial width (as argued below, see Criterion 3), we suggest including the fluid-filled triangular V-shape of the cistern of the great cerebral veins (also called 'ambient' cistern) as the posterior landmark (Figure 1c and d). The main advantage of this choice of posterior landmark, which is consistently and easily identified on the transventricular axial plane, is that whenever an off-axial plane or an inadequate anatomical level is chosen, the V-shape disappears. Regarding the anterior landmark, in our experience, it can be easier and more reproducible to use the level of the fornix columns (at the base of the cavum septi pellucidi) rather than the level of the cavum septi pellucidi itself (Figure 1c and d).

Criterion 3 (Score 0–1) provides a reliable anatomical landmark with which to locate the atrium (Figures 1–3). Cardoza *et al.*[5] used the glomus of the choroid plexus to locate the atrium. However, depending on the shape of the choroid plexus and the degree of dilatation of the ventricles, the location of the glomus may change within the lateral ventricle (Figure 3). Improvements in our knowledge of neuroanatomy suggest a more fixed and valuable anatomical landmark, namely the internal parieto-occipital sulcus, which can now be located thanks to improvements in technology. This sulcus, which can be depicted sonographically as a slight depression on the inner border of the hemisphere as early as 20 weeks, is located at the convergence of the parietal and occipital horns, which precisely define the atrium. This sulcus becomes deeper in the third trimester, so that the atrium is located opposite the deepest part of the internal parieto-occipital sulcus before it joins the calcarine fissure which extends parallel to the internal ventricular wall. Even though Heiserman *et al.*[6] have shown that the placement of the anterior or posterior calipers on the long axis of the ventricles is typically not an important source of measurement error, the exact identification of the atrium using the internal parieto-occipital sulcus is useful in ventriculomegaly follow-up. Moreover, in our experience, a measurement performed with calipers placed too posteriorly can lead to a false-positive result when the atrial width is close to 10 mm in the third trimester, due to potential focal enlargement of the occipital horn (Figure 4).

The second set of criteria guarantees a high quality of measurement via appropriate caliper placement. It comprises one criterion that has been published in the ISUOG guidelines[9] and an additional criterion relating to image size.

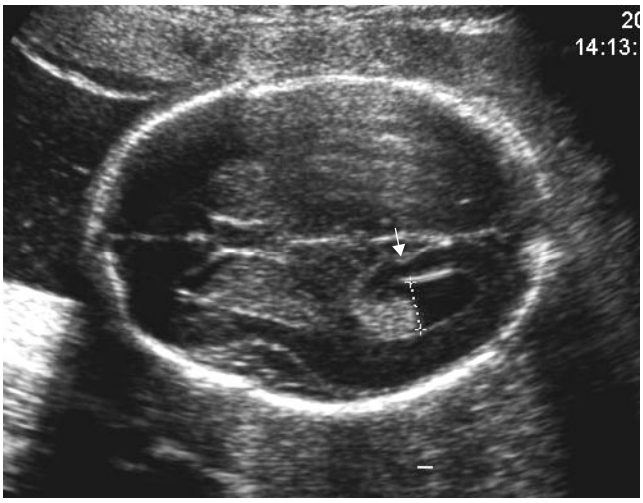

Figure 2 Ultrasound image showing cerebral ventricular measurement (atrium, calipers) at 20 weeks' gestation. The internal parieto-occipital sulcus is faintly visible at this age as a slight depression on the internal border of the hemisphere (arrow).

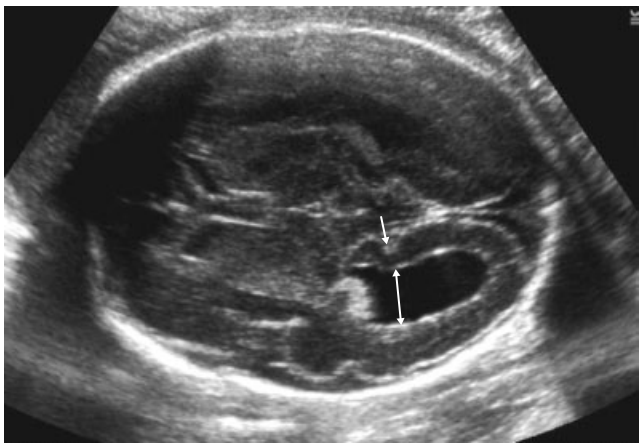

Figure 3 Ultrasound image showing cerebral ventricular measurement (atrium, double-headed arrow) at 28 weeks' gestation. At this stage of pregnancy, the internal parieto-occipital sulcus is clearly identified (arrow). Note that the measurement of the atrium is performed a short distance from the glomus of the choroid plexus, which moves with gravity within the lateral ventricle.

Criterion 4 (Score 0–2). The calipers should be placed perpendicular to the inner and outer borders of the ventricle (Criterion 4a, Score 0–1) and at the junction of the ventricular wall and ventricular lumen, i.e. 'on to on' or touching the inner edge of the ventricular wall (Criterion 4b, Score 0–1), as described in the ISUOG guidelines (Figure 5)[9]. Heiserman *et al.*[6] have shown that inappropriate caliper placement (perpendicular to the midline structures, outside or on the echogenic reflection from the wall of the ventricular atrium) leads to a relatively large number of false-positive results (Figure 1).

Criterion 5 (Score 0–1). Adequate image size requires magnification so that the entire axial transventricular plane occupies the screen, with clear visualization of

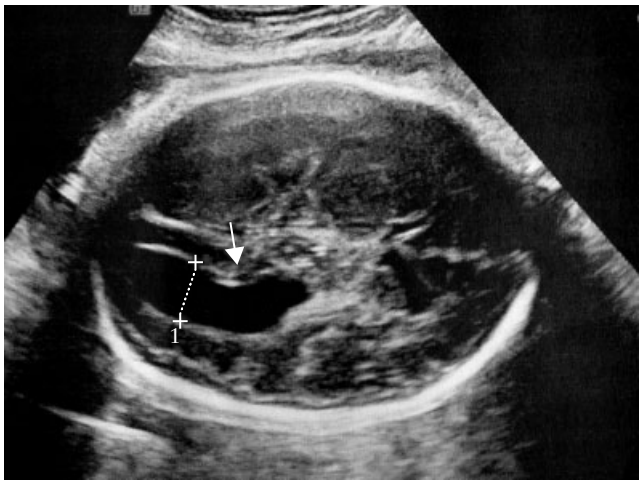

Figure 4 Ultrasound image in a patient referred for mild ventriculomegaly at 32 weeks' gestation. In addition to an off-axial image plane and lack of visualization of the anterior landmark (although the V-shape of the ambient cistern, the posterior landmark, is visible), the measurement of the atrium is performed with calipers placed too posteriorly in the occipital horn, leading to a false-positive diagnosis of ventriculomegaly. According to our image-scoring method, the image obtains a total score of 3–4, justifying reconsideration of the measurement. Note that both the internal parieto-occipital sulcus and, at its deepest part (arrow), the junction with the calcarine fissure are clearly identified.

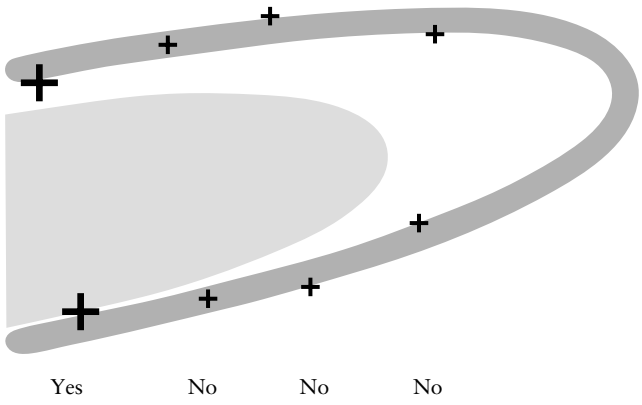

Figure 5 Correct caliper placement for measurement of ventricular atrial width, as described in the guidelines of the International Society of Ultrasound in Obstetrics and Gynecology[9]. Calipers are correctly placed (Yes) when touching the inner edge of the ventricle wall at its widest part, and aligned perpendicular to the long axis of the ventricle.

the proximal and distal calvarial margins. Excessive magnification on the atrium prevents a proper evaluation of the quality of the axial plane (Criterion 1), while absence of magnification may result in inappropriate caliper placement.

The total score is obtained as the sum of the scores for each criterion, the maximum possible score being 7. In our view, a total score < 5 would be associated with poor-quality ventricular measurement and would justify repeating the measurement. However, respecting the primary criteria provides a reference image which can be used to retrospectively modify cursor placement and reevaluate the measurement.

This image-scoring method has two main aims: to improve the measurement of the ventricles, which is especially important when their size is close to the cut-off for diagnosing ventriculomegaly, and to standardize the measurement in the follow-up of ventriculomegaly, especially when serial examinations are performed by different operators.

The main limitation of this method is that its application is strictly limited to measurement of the ventricle distal to the transducer. This drawback can be an argument for performing measurement on the coronal image in order to visualize both ventricles[1]. However, standardization of the method in the coronal plane is challenging, it being especially hard to obtain a strict coronal plane and to identify the exact location of the atrium.

In routine practice, standardization of the measurement of the distal atrium on the axial plane should be definitively the first step. To detect unilateral ventriculomegaly, visualization of the frontal horn on the proximal hemisphere gives valuable information on the global symmetry of the ventricles. In the case of ventricular asymmetry with the proximal ventricle significantly larger than the distal ventricle, measurement in the coronal plane may be proposed. When the measurement is close to 10 mm, before any invasive test is performed the patient should be referred to a center with a high level of expertise.

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