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Assessment of fetal Sylvian fissure operculization between 22 and 32 weeks: a subjective approach

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KEYWORDS: gyration; operculization; prenatal; subjective assessment; Sylvian fissure; ultrasound

ABSTRACT

Objective *Sylvian fissure operculization (SFO) is a dynamic process throughout gestation and is a reliable feature of fetal cortex gyration that is amenable to prenatal ultrasound examination. This study aimed to define a subjective and reproducible method for SFO assessment.*

Methods *This was a cross-sectional study of the sonographic anatomy of SFO conducted over a 9-month period in 200 fetuses with normal anatomical ultrasound examination at 22–32 weeks of gestation. We used a standardized view in an axial cerebral plane. SFO was scored according to a pre-defined scoring sheet based on the degree of overriding of the insula by the temporal lobe across gestational age. Because of the nested nature of the dataset, linear mixed effects models were used for concurrent assessment of inter- and intraobserver agreement of this scoring method. Subject-specific variance of the score was derived for each week of gestation from the whole repeated-measures dataset and the 5th and 95th percentiles of the score (mean score$_{week} \pm 1.645$ SD$_{subject,week}$) were determined.*

Results *The inter- and intraobserver agreement correlation coefficients were 0.91 (0.89–1.00) and 0.95 (0.93–1.00), respectively, with a standard error of measurement < 1 scoring unit, which corresponds to an accuracy of within 1 week. A reference chart was fitted, showing the increase of the SFO score between 22 and 32 weeks, along with age-specific 5th and 95th percentiles.*

Conclusion *A simple scoring evaluation of the SFO is a reliable method for its assessment at between 22 and 32 weeks of gestation. Copyright © 2008 ISUOG. Published by John Wiley & Sons, Ltd.*

INTRODUCTION

The fetal cortex undergoes significant changes throughout its development, providing a smooth cerebral surface at 14 gestational weeks and becoming a complex association of sulci and gyri at the end of the pregnancy[1]. A major landmark of gyration is the development of the Sylvian fissure on the lateral convexities of the cerebral hemispheres, the 'operculization' process[1]. Because the operculum encompasses areas important for language and speech, auditory function and secondary somatic sensory and motor function, developmental arrest or a malformation of this vital area may cause significant impairment with developmental delays[2]. Sylvian fissure operculization (SFO) is the feature of fetal brain gyration that can be most easily assessed prenatally, using ultrasound. Axial, coronal and parasagittal views are used, but their combined use is restricted to skilled operators because of increasing technical difficulties as pregnancy progresses, especially late in gestation. Most publications reporting the prenatal ultrasonographic evaluation of SFO have depicted morphological changes through gestation without specifying the sonographic methodology[3]. A quantitative assessment of SFO based on simple sonographic methodology is required to improve the detection of migration disorders[4]. The aims of our study, therefore, were first to produce a standardized method of assessment of SFO between 22 and 32 gestational weeks and to evaluate the reproducibility of this method, and second to construct a method-specific SFO reference chart.

PATIENTS AND METHODS

Ultrasound assessment

Ultrasound evaluation was performed transabdominally by two operators (E.Q. and L.G.), using high-frequency

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probes (Voluson 730 Expert ultrasound machine (GE Medical Systems, Zipf, Austria), equipped with a 4–8-MHz probe or Siemens Acuson Antares ultrasound system (Siemens AG Healthcare Sector, Erlangen, Germany), equipped with a 6–10-MHz probe).

An axial cerebral view was defined precisely in order to standardize the anatomical level of the examination of SFO. This plane was below the level of the plane at which the biparietal diameter is measured, and was characterized by the presence of three anatomical landmarks: the ambient cisterna, the third ventricle, and the inferior part of the cavum septi pellucidi at the level of the columns of the fornix (Figure 1a).

Based on our experience and on the existing literature[5], we postulated that the overriding of the insula by the temporal lobe begins earlier in gestation and is more stable across gestation compared with that by the frontal lobes. According to this assumption, we chose an axial

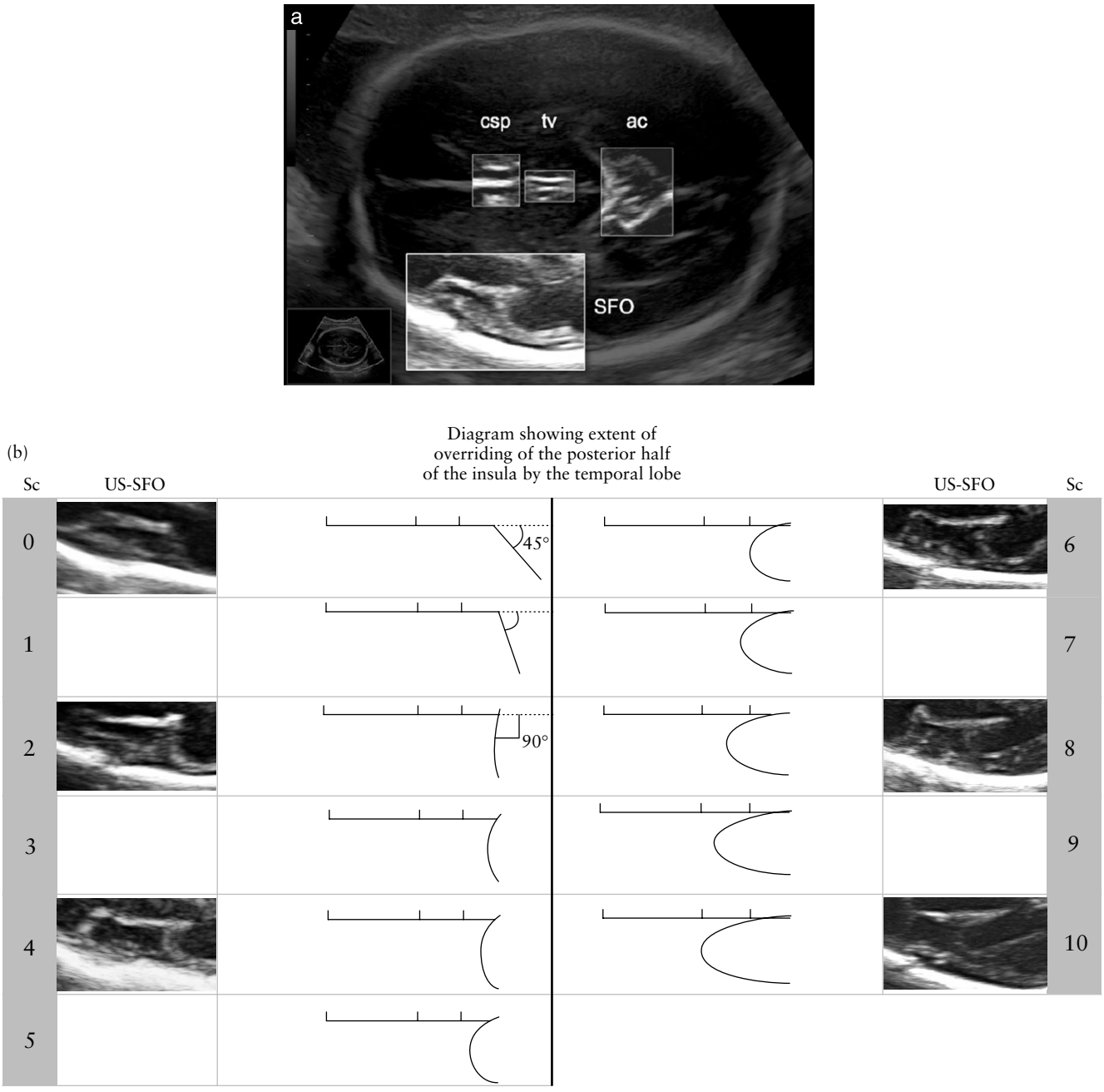

Figure 1 (a) Standardization of the ultrasound assessment of fetal Sylvian fissure operculization (SFO) using an axial view of the fetal brain defined by three anatomical landmarks: ambient cisterna (ac), third ventricle (tv) and the inferior part of the cavum septi pellucidi at the level of the fornix columns (csp). (b) Scoring-sheet: semiquantitative assessment of the overriding of the insula by the temporal lobe, using a scale ranking from 0 to 10. Horizontal lines represent the orientation of the insula. For Scores 0, 1 and 2, the angle between the insula and the temporal lobe is indicated, while for scores 3–10, curved lines represent the temporal lobe overriding the posterior half of the insula (Score 4 = posterior half of insula is 1/4 overridden; Score 6 = 1/2 overridden; Score 8 = 3/4 overridden; Score 10 = entirely overridden). Sc, score; US, ultrasound evaluation of SFO.

reference view in order to create a scoring sheet based on semiquantitative assessment of the advancing overriding of the insula by the temporal lobe between 22 and 32 weeks, using a scale ranking from 0 to 10. This period was chosen because it reflects the best time at which to detect most migration disorders and because, in France, ultrasound examinations are performed routinely at 22 and 32 weeks' gestation. For this scale, we defined six gross landmarks in the operculization process based on first the angle between the insula and the temporal lobe and then the extent of overriding of the posterior half of the insula. These six landmarks were as follows (Figure 1b): an angle of 45° corresponded to a score of 0; an angle of 90° corresponded to a score of 2; overriding of 1/4 of the posterior half of the insula corresponded to a score of 4; overriding of 1/2 of the posterior half corresponded to a score of 6; overriding of 3/4 of the posterior half corresponded to a score of 8; and overriding of the entire posterior half of the insula corresponded to a score of 10.

Study population

In this prospective, cross-sectional study, 200 pregnant women with an uncomplicated pregnancy between 22 and 32 weeks' gestation with normal ultrasound examination were enrolled over a 9-month period. The onset of pregnancy was dated according to first-trimester crown–rump length. Ultrasonography was performed for fetal size evaluation or for a follow-up assessment when an extracerebral abnormality was suspected initially. In all cases, pregnancies were uncomplicated, no fetal cerebral malformations were diagnosed or suspected, and fetal size was appropriate for gestational age. The images were stored for subsequent offline analysis by three examiners blinded to gestational age. Analysis was performed using the scoring sheet. In order to evaluate the intra- and interobserver agreement of the scoring method, three evaluations were performed by each examiner using random shuffling of the images. Each examiner was blinded to the results of his previous assessment.

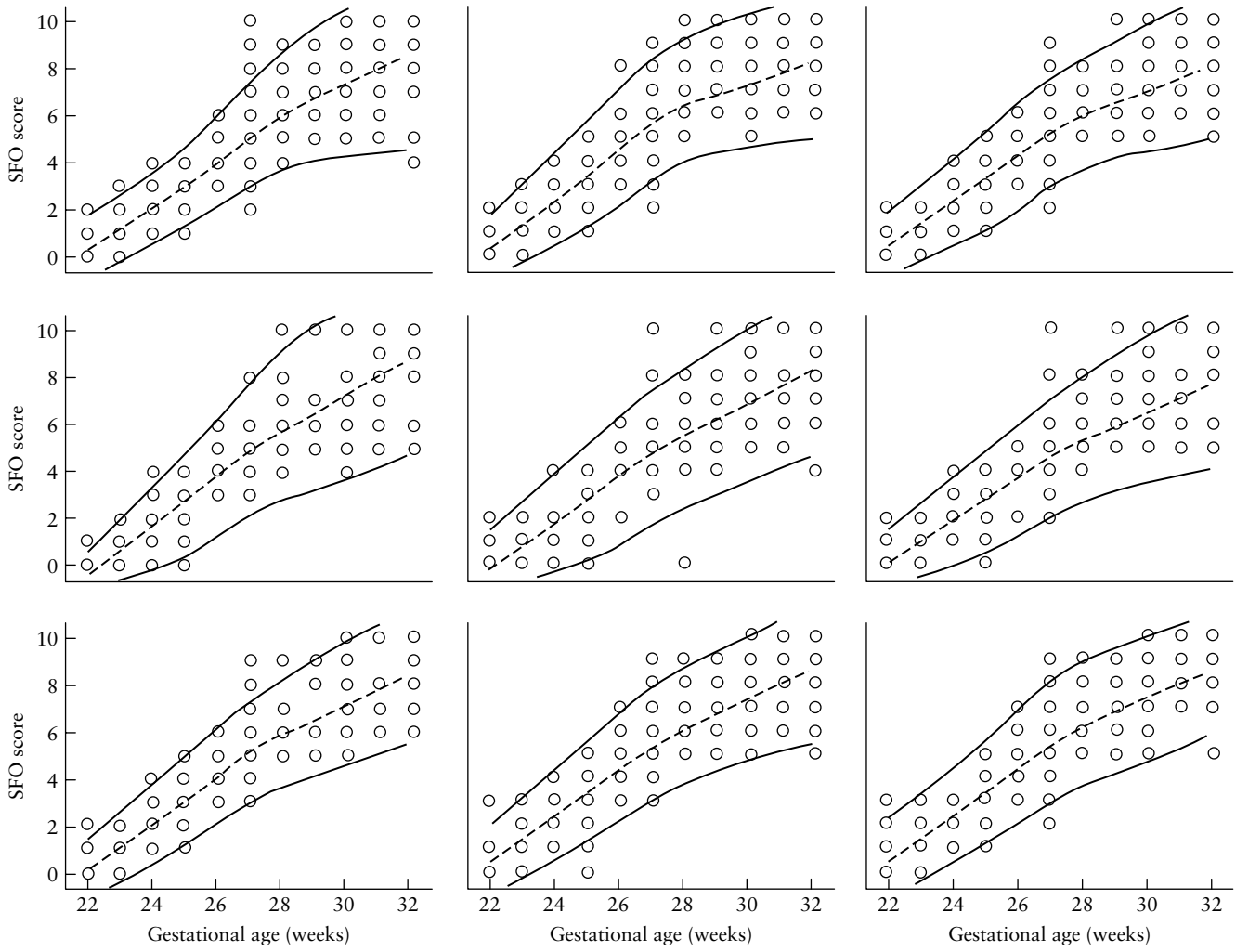

Figure 2 Graphs of the repeated measurements dataset for Sylvian fissure operculization (SFO) score (three observers, one for each row of graphs, with three measures per observer in each row) showing the relationship with gestational age using a non-parametric smoother for the mean (dashed lines) and 2 SD range (between solid lines). Because of the discrete nature of the variables, plotted points comprise several measurements.

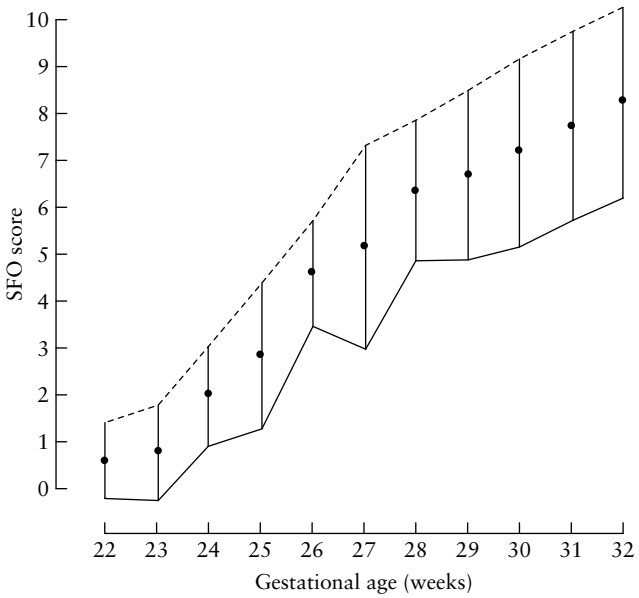

Figure 3 Reference chart for Sylvian fissure operculization (SFO) score between 22 and 32 gestational weeks with 5th (solid line) and 95th (dashed line) percentiles. Gestational age was based on crown–rump length.

Statistical analysis

Because of the nested and correlated nature of the dataset, concurrent assessment of both inter- and intraobserver agreement over the whole dataset was performed using a random intercept mixed effects model: $x_{i,j,k} = \mu + s_i + r_j + (sr)_{i,j} + \varepsilon_{i,j,k}$, where μ is the overall mean of the scores and s_i is the random component of the subjects, r_j is the random component of the raters, $(sr)_{i,j}$ is interrater error, modeled by the interaction, and $\varepsilon_{i,j,k}$ is intrarater error. As discussed by Bryk and Raudenbush[6], these results would have been identical to those of a two-way random factor analysis of variance. Reliability was assessed by intraclass correlation coefficients (ICCs) following Fleiss and Shrout[7,8]. The ICCs were computed as follows: $\rho_{\text{intra}} = \frac{\sigma_s^2 + \sigma_r^2 + \sigma_{sr}^2}{\sigma_{tot}^2}$ and $\rho_{\text{inter}} = \frac{\sigma_s^2}{\sigma_{tot}^2}$ and the standard error of measurement was computed as $SEM = \sqrt{\sigma_r^2 + \sigma_{sr}^2 + \sigma_e^2}$, where σ_s^2 is the subject variance, σ_r^2 is the rater variance, σ_{sr}^2 is the interobserver variance, σ_{tot}^2 is the total variance and σ_e^2 is the intraobserver variance. Similarly, gestational age and subject-specific standard deviation (SD_{GA}) of the scores were computed over the whole repeated measures dataset by random intercept mixed models performed for each week of gestation between 22 and 32 weeks. The 5th and 95th percentiles were then determined as $MEAN_{GA} \pm 1.645 \times SD_{GA}$. Using these values, a reference chart of the score was fitted over the 22–32-week range. The analysis was conducted using R version 2.5.0 with packages lme4, lattice[9].

RESULTS

Two hundred fetuses, including 15–24 fetuses per gestational week, were enrolled in the study. None developed any form of postnatal neurological impairment. The study-specific axial view (Figure 1a) was obtained successfully in all cases, allowing offline scoring in all cases. Figure 2 is a graphical display of the repeated measurements dataset, composed of three observers and three evaluations per observer, showing the relationship between the SFO scores of 200 fetuses and their gestational age. The interobserver and intraobserver ICCs were 0.91 (95% CI, 0.89–1.00) and 0.95 (95% CI, 0.93–1.00), respectively. The SEM was 0.84 scoring units. A reference chart for the score across the 22–32-week period is presented in Figure 3 along with the 5th and 95th percentiles.

DISCUSSION

Knowledge of milestones in the development of the fetal cortical surface and standardization of the examination of the main region of interest are two key factors for successful screening and diagnosis of complex fetal cerebral malformations. The normal process of cerebral cortical development follows a predictable timetable throughout gestation[1,10]. The primordial cerebral hemispheres are smooth until 14–16 weeks' gestation. The first primary fissure to appear, is the circular sulcus of the insula, i.e. the Sylvian fissure, on the ventrolateral wall of the hemisphere[11]. Around 20 weeks, the cerebral hemispheres start to grow more rapidly at the primitive parietal and temporal lobes around the posterior part of the insula, and growth of the frontal lobe begins to lag. This growth discrepancy in surface over bulk of individual lobes leads to earlier development of the posterior than the anterior operculum[11]. The indented smooth insular cortex and circular sulcus (peri-insular sulcus), which can be visualized by 19–22 weeks' gestation, are finally engulfed and overridden by the enlarged parietal, temporal and frontal opercula. The insula can be visualized after 32–34 weeks' gestation. The anterior portion of the insula is not overridden until after delivery, in the first 2 postnatal years. The bulky outgrowth of the posterior operculum (temporal and parietal lobes) develops faster than does the anterior operculum (frontal lobe). Thus, the major part of the process of operculization is from posterior to anterior.

The Sylvian fissure presents different sonographic patterns depending on the plane of examination selected (Figure 4). This important fact highlights the necessity of standardizing the examination plane of the fissure in an axial view, thus providing a simple and reproducible technique of analysis of the operculization process (Figure 1a). The Sylvian fissure can be compared to a triangle with a posterosuperior apex and an anteroinferior base (Figure 5). Due to this configuration, operculization is best assessed by visualizing the 'triangle' close to its base rather than its apex. We therefore chose such an axial plane with anatomical landmarks that are easy to visualize, a plane that is at a slightly lower level than that used to perform biparietal biometry.

Using transabdominal ultrasound, Droulle *et al.*[5] were the first to describe subjectively the physiological override of the insula by the temporal lobe throughout gestation. They highlighted the time frame of this process and

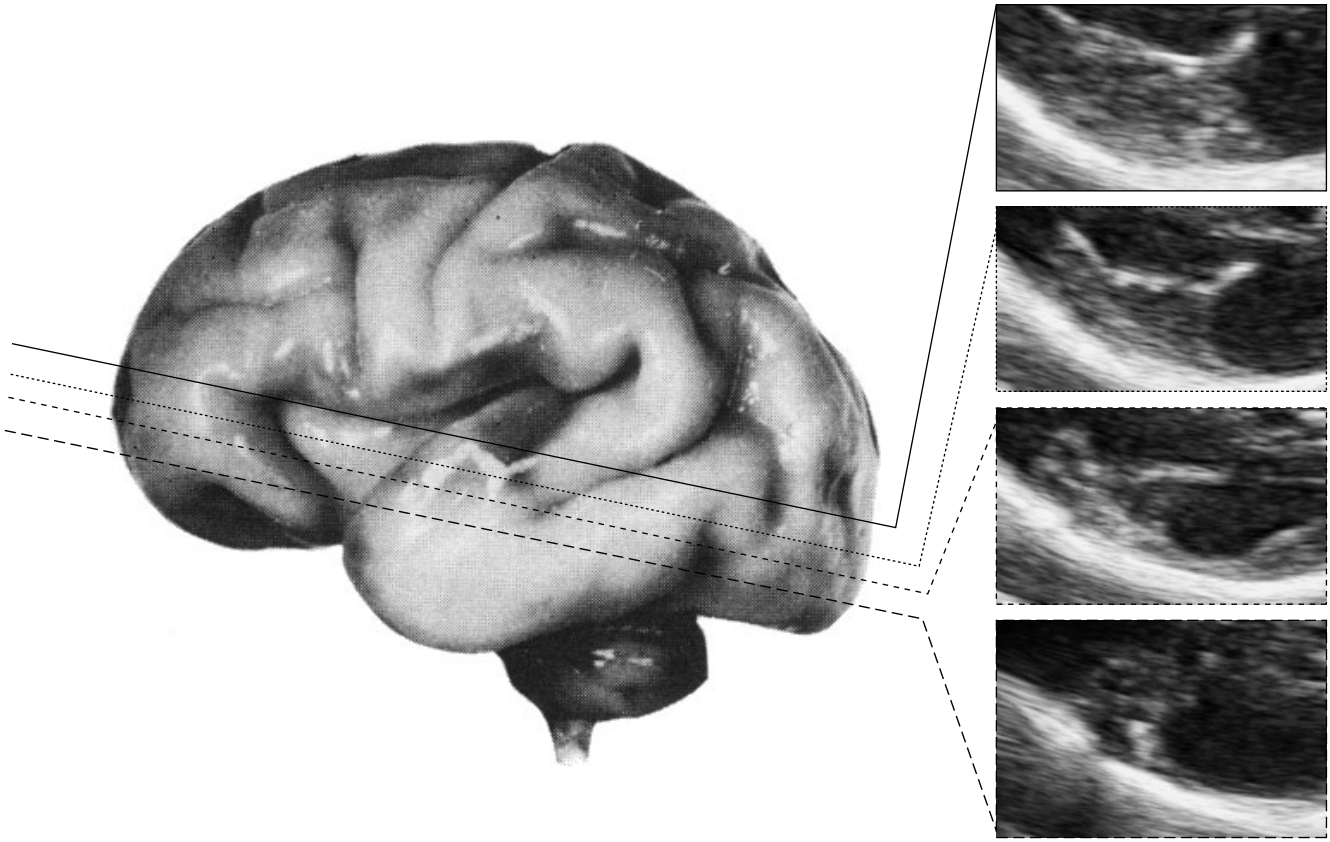

Figure 4 Diagram showing different levels of examination of the Sylvian fissure and corresponding ultrasonographic appearance in an axial view at 28 weeks' gestation.

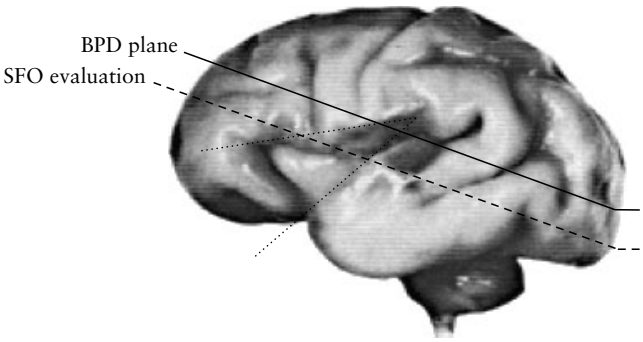

Figure 5 The standard levels for evaluation of the biparietal diameter (BPD) and Sylvian fissure operculization (SFO) are indicated. The dotted lines show how the Sylvian fissure is triangular in shape, the triangle having a posterosuperior apex and an anteroinferior base.

its anatomical correspondence. The sonographic developmental assessment of the fetal cerebral cortex using both transabdominal[10–12] and transvaginal[12,13] routes have since been described. Standardization of the method of evaluation was developed mainly by Monteagudo and Timor-Tritsch using anatomical landmarks[12,13]. In all of these studies, the examination corresponds to a detailed evaluation that is best performed by experienced operators using a combination of axial, coronal and parasagittal views. Our standardization of SFO assessment allows it to be performed by less experienced operators, especially in routine screening.

Using a scoring sheet and a semiquantitative assessment, we defined the progressive overriding of the insula by the temporal lobe on a scale of 0 to 10. Our results demonstrate that the subjective evaluation of SFO is reproducible and reliable. The graphs in Figure 2 show a widening of the confidence intervals after 29 weeks that corresponds to the increase in the normal variability in SFO morphology. For example, the approximate mean SFO score at 32 weeks of gestation is 8, ranging in normal fetuses from 6 to 10 (Figure 3).

Figure 6 illustrates use of the chart with two fictitious examples displaying scores within and below the normal range, the latter strongly raising the suspicion of delayed cortical maturation. This semiquantitative assessment of SFO represents a reliable approach to the sonographic evaluation of fetal brain maturation and can be used to depict either delayed maturation or pathological anomalies of the operculization process, which can reflect more diffuse gyral anomalies[14]. Finally, this method can be used both in first-line screening or in second-line detailed assessment of the fetal brain[14,15].

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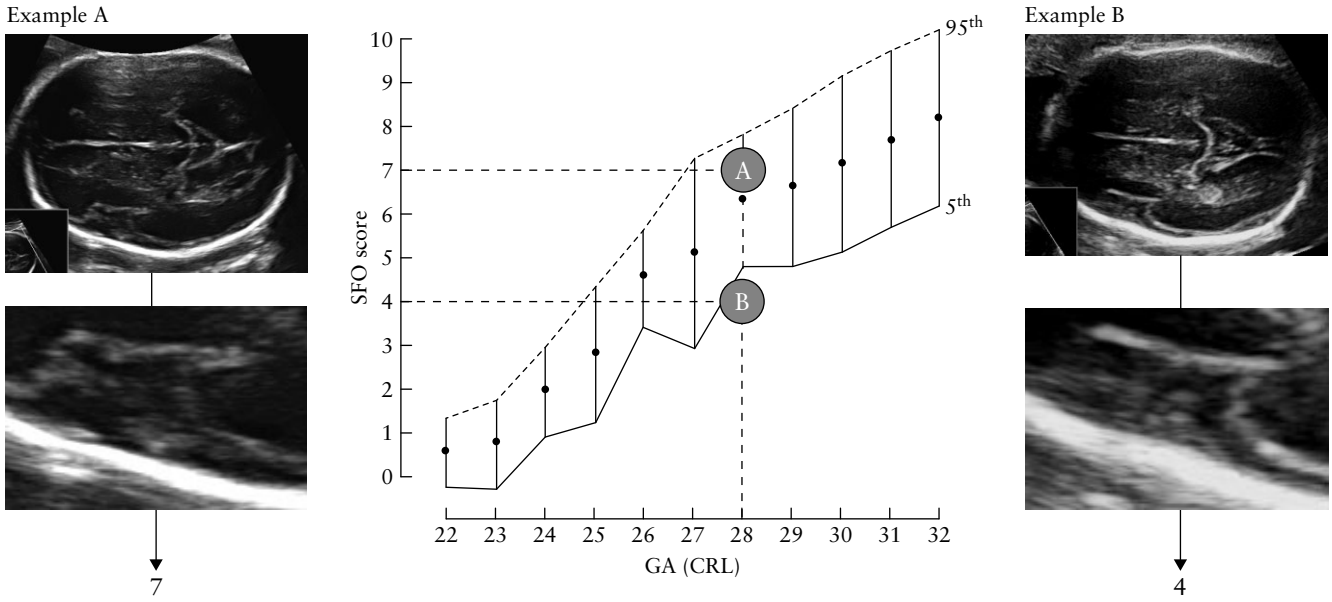

Figure 6 Two fictitious examples of 28-week fetuses illustrate the use of the reference chart. Example A: at this age, a score of 7 is within the normal range. Example B: at the same age, a score of 4 is below the 5th percentile, indicating abnormal gyration. GA (CRL), gestational age based on crown–rump length.

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