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How do we do it?
Practical advice on imaging-based techniques and investigations

Three-dimensional ultrasound examination of the fetal central nervous system

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INTRODUCTION

Three-dimensional (3D) ultrasound examination has been used to evaluate the fetal central nervous system (CNS)[1–16]. Different approaches have been suggested that may be employed in both basic and dedicated examinations. The purpose of this paper is to illustrate the practical details of the different techniques described so far.

BASIC PRINCIPLES AND TERMINOLOGY

The technique used to obtain an ultrasound volume is adequately described by three elements: (1) the section that is used to start the acquisition of the volume (referred to in the following as the 'start' scan); (2) the angle of rotation of the mechanical sweep of the motorized probe; and (3) the quality of the acquisition that can be varied by the operator and depends on the number of sections obtained during the acquisition. Both the angle of rotation and the quality of the volume influence the acquisition time and, when this is too long, the probability of movement artifacts increases. Tailoring the size and quality of the volumes to the specific diagnostic requirements is important because it increases the efficiency of the scan. In the following we provide information for each of the applications discussed.

The modalities for the analysis of ultrasound volumes have been described in depth previously[4,16,17]. The multiplanar mode is most frequently used for assessment of the fetal CNS[6,10,13,14]. With this mode of display, the plane parallel to the acquisition plane or 'start' appears in the upper left corner of the screen and is identified with the letter A; the plane perpendicular to A but parallel to the ultrasound beam is identified with the letter B and appears in the upper right corner. The plane that is both perpendicular to the 'start' scan and the ultrasound beam is defined as C, and is frequently referred to as the coronal plane[17] (Figure 1). The terminology may sound confusing at times. As discussed later, when dealing with the fetal brain, the coronal plane of the volume typically demonstrates a sagittal or axial section of the fetal head[13].

Although 3D ultrasound imaging can be used in many ways to evaluate the fetal (CNS), we have found that in practice there are mainly two useful applications: the multiplanar analysis of volumes obtained with an axial approach[6,13] and the multiplanar analysis of volumes obtained from a sagittal or coronal approach[12,14]. 3D ultrasound examination can assist in evaluation of the spine[18] and is particularly helpful in early neurosonographic studies[1–3,5,19]. It may also be used to improve the quality of two-dimensional (2D) images. These aspects are described separately below.

THREE-DIMENSIONAL VOLUMES OF FETAL BRAIN OBTAINED BY AN AXIAL APPROACH

One of the major difficulties with sonographic examination of the fetal anatomy is obtaining views that

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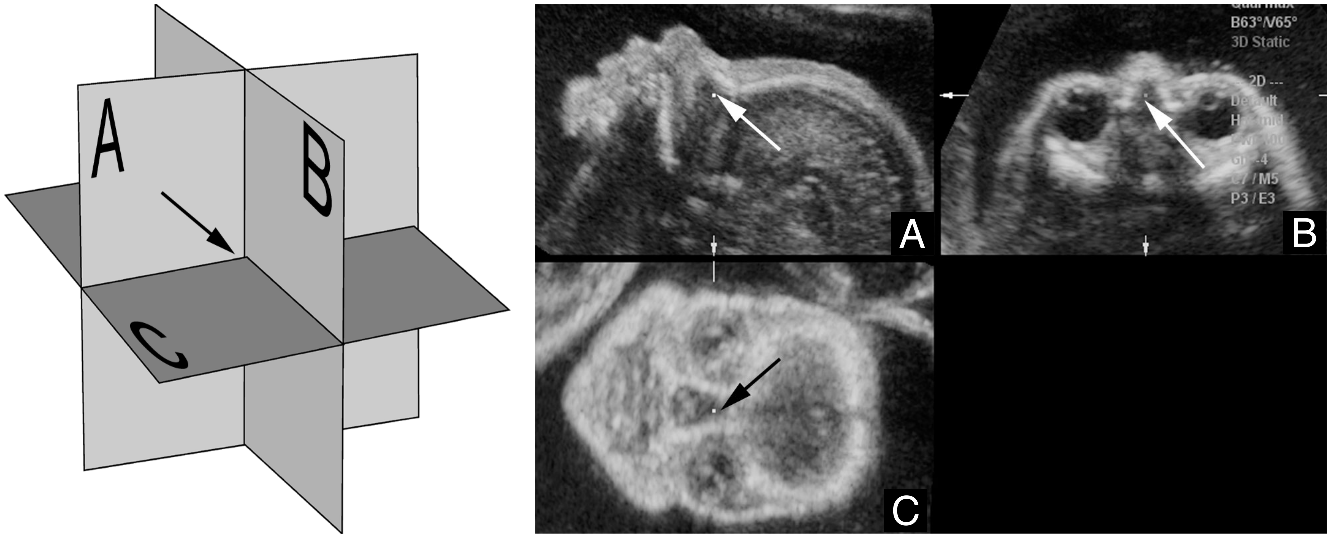

Figure 1 Schematic representation of multiplanar analysis of ultrasound volumes, with corresponding multiplanar analysis of the fetal face. A is the plane parallel to the acquisition or 'start' scan; B and C are the reconstructed orthogonal planes. The C-plane is also commonly referred to as the coronal plane. The arrows indicate the points that represent the intersection of the three planes.

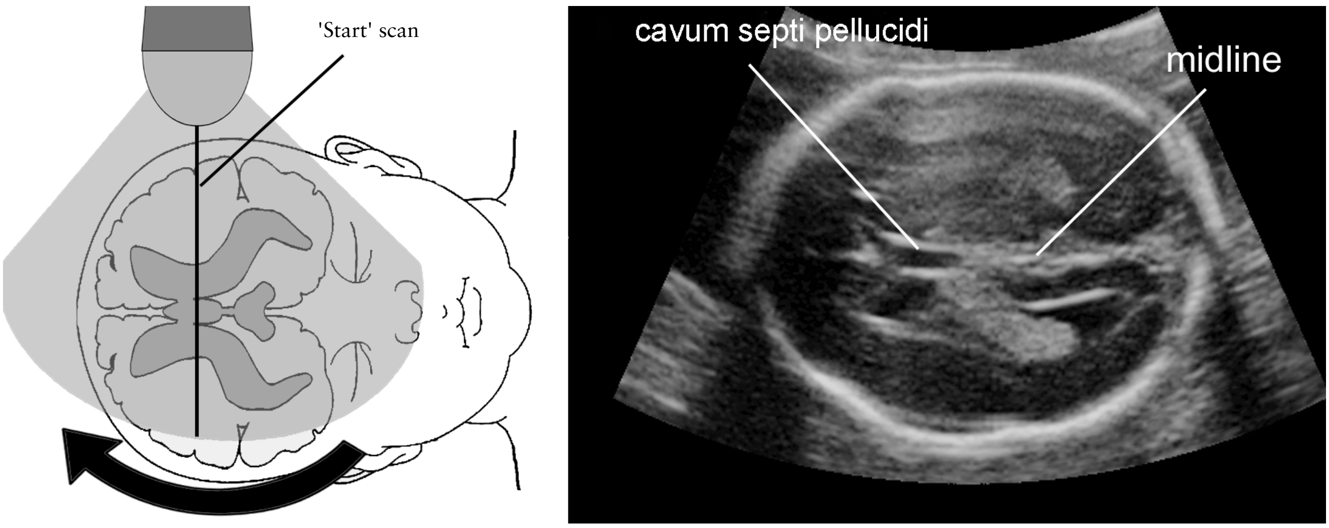

Figure 2 Schematic representation of acquisition of an ultrasound volume of the fetal brain by an axial approach, with corresponding ultrasound image. The transducer is positioned parallel to the fetal head at the level of the cavum septi pellucidi. The incident sound beam is at a right angle to the midline echo.

are not easily accessible. At mid-gestation, most fetuses are in a horizontal position, and transverse and coronal sections are usually easy to obtain. These scanning planes, however, have many limitations. While examining the fetal head, one of the most important views is probably the so-called median one[20], which provides unique information on intracranial structures such as the corpus callosum and the cerebellar vermis. Unfortunately, this scanning plane is particularly difficult to obtain. Several approaches have been described, but they all require considerable ability, time and, frequently, a vaginal examination[9].

3D ultrasound imaging allows visualization of a virtual median plane from a volume that has been acquired from an axial approach[6,13,17]. The 'start' scan is parallel to the skull base and demonstrates the cavum septi pellucidi, which is about halfway between the skull base and the parietal calvarium (Figure 2). In the second trimester of gestation, a mechanical sweep with an angle of rotation of 45° usually includes the entire cephalic pole. In later gestation, the angle has to be increased and an angle of 60° is usually necessary in the advanced third trimester. Static volumes acquired with low to medium quality are adequate and this helps to minimize movement artifacts.

When the volume is displayed in multiplanar mode (Figure 3) and the C-plane is aligned along the midline echo demonstrated in the A- and B-planes, a median view of the brain is visualized (Figure 4)[17].

We have previously demonstrated that there is a good correlation between median planes obtained directly

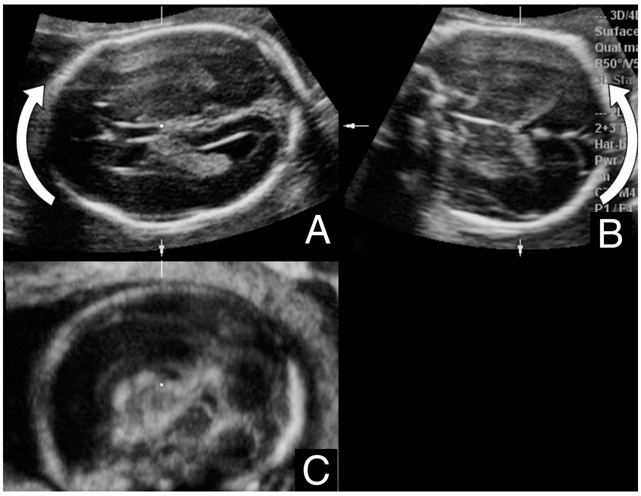

Figure 3 Multiplanar analysis of the ultrasound volume obtained from the 'start' scan displayed in Figure 2. The arrows indicate the direction of the rotation required to align the midline with the C-plane. A, B and C, orthogonal planes.

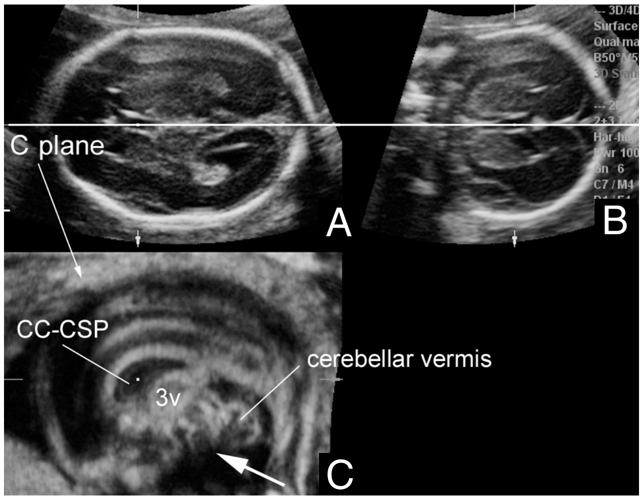

Figure 4 Ultrasound images showing the same volume as that in Figure 3. Once the A- and B-planes have been rotated so that the midline is aligned with the C-plane, a median view of the brain is demonstrated, in which it is possible to recognize the comma-shaped anechoic complex formed by the combination of the corpus callosum (CC) and the cavum septi pellucidi (CSP), the area of the third ventricle (3v) and the cerebellar vermis. The brainstem and part of the cerebellar vermis are obscured by the acoustic shadow cast by the skull base (large arrow). A, B and C, orthogonal planes.

with 2D ultrasound and those reconstructed with 3D ultrasound (3D median views)[13]. For example, measurements of structures such as the corpus callosum and the cerebellar vermis are closely related. However, 3D median views have a few shortcomings[11,13]. First, they do not usually allow differentiation between the corpus callosum and the inferior cavum septi pellucidi. A single comma-shaped sonolucent structure is most frequently seen, outlined superiorly by an echogenic line that, comparing the different planes, can be identified as the lower edge of the midline echo. Only rarely, with optimal visualization conditions, is the corpus callosum seen, and it appears as a sonolucent stripe interposed between the inferior cavum septi pellucidi and the superior midline (Figure 5). Second, visualization of the posterior fossa is hampered by acoustic shadowing of the petrous ridges of the skull base (Figure 4). This shadow usually spares the cerebellum but obscures the brainstem, thus preventing assessment of the normal relationship between these structures. This problem can be minimized, although not completely resolved, by keeping an angle of about 45° between the incident ultrasound beam and the midline when the volume is acquired (Figure 6). We have found that simultaneous representation of the cerebellum in the three orthogonal planes is valuable, as a comparison between sagittal and coronal planes is required to assess the presence and integrity of the vermis; this can be achieved easily by properly positioning the three orthogonal planes (Figure 7). By slicing the volume obtained with axial planes in different directions, it is also possible to obtain other views of the brain, such as the oblique-1 view[20], which demonstrates the three horns of the lateral ventricle, and a view of the

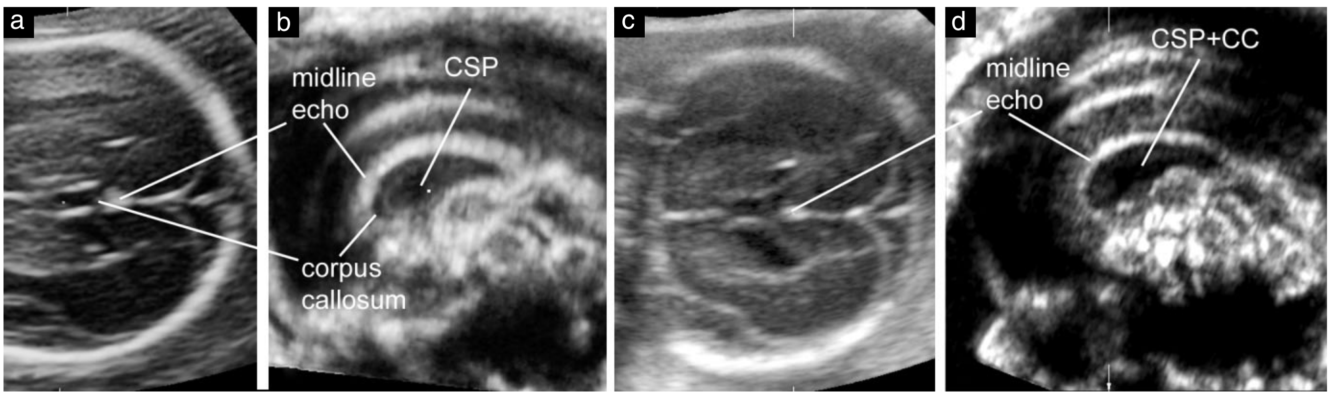

Figure 5 Ultrasound images in (a) and (b) were obtained from an ultrasound volume of unusually high quality; in (b) the reconstructed median plane allows recognition of the corpus callosum as an anechoic stripe with a thin echogenic contour that separates it from the underlying cavum septi pellucidi (CSP). More frequently, the two structures are not clearly separated and generate a single anechoic comma-shaped image on top of the third ventricle (b and c). In both cases, the thick superior echogenic contour is formed by the lower portion of the midline echo. CC, corpus callosum.

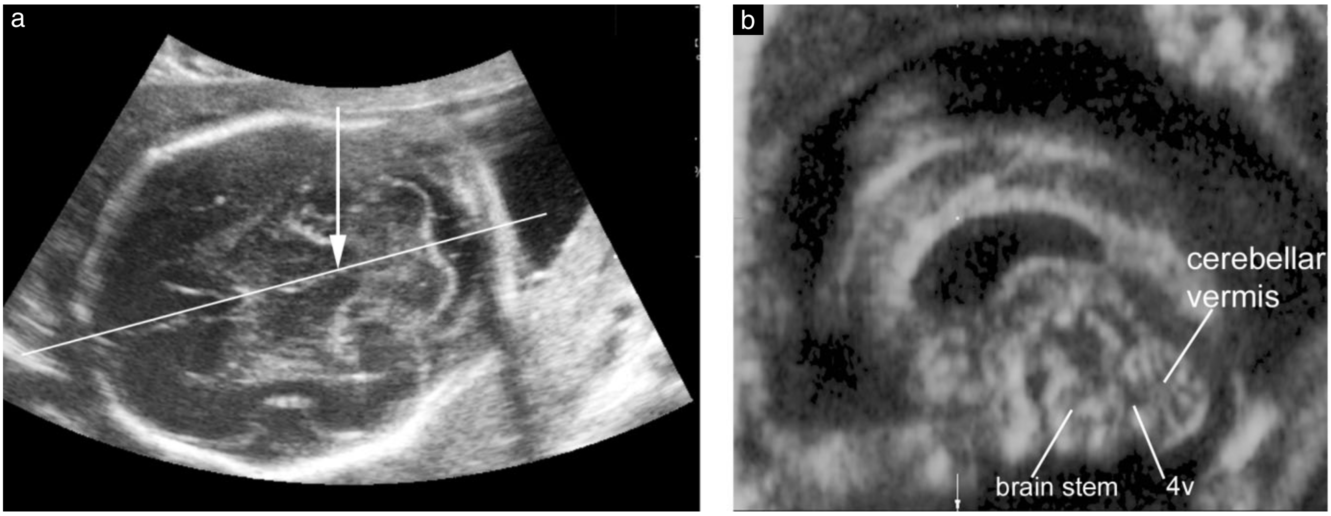

Figure 6 To avoid shadowing from the skull base and allow better visualization of the cerebellar vermis and brainstem, the volume is acquired by angling the transducer so that the incident sound beam (arrow) forms an angle of about 45° over the midline echo (line) (a). This allows better insonation of the posterior fossa, as shown in the corresponding reconstructed median plane (b); the cerebellar vermis and brainstem are now clearly outlined. 4v, fourth ventricle.

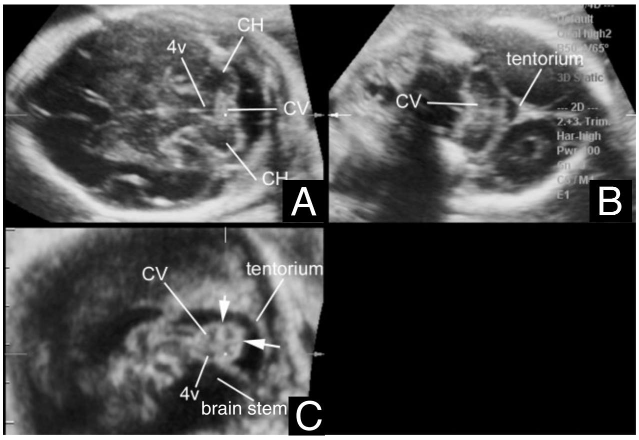

Figure 7 Simultaneous demonstration of the main anatomical landmarks attesting to the integrity of the cerebellar vermis with multiplanar analysis of an ultrasound volume of the fetal brain acquired by an axial approach. In plane A the presence of the cerebellar vermis (CV) is shown by echogenic tissue separating the fourth ventricle (4v) from the cisterna magna; the slightly less echogenic cerebellar hemispheres (CH) are seen on both sides of the vermis. In plane C the fourth ventricle and the two main fissures of the cerebellar vermis (arrows) are demonstrated. The position and insertion of the tentorium cerebelli on the occipital bone are also well visualized. A, B and C, orthogonal planes.

lateral surface of the brain, which demonstrates the Sylvian fissure (Figure 8). However, these views can only be demonstrated from the hemisphere distal to the transducer, as the proximal one is obscured by noise and artifacts.

In our experience, diagnosis of midline anomalies of the fetal brain can always be made accurately using 3D median views[13]. Although the corpus callosum is not usually visualized directly, agenesis is consistently associated with an absent or small cavum septi pellucidi, which is easily identified in the 3D median view (Figure 9). The different anatomic elements that allow characterization of the clinical entities of the Dandy–Walker complex (integrity and rotation of the vermis, depth of the cisterna magna and insertion of the tentorium) are usually well appreciated (Figure 10). Although the brainstem is partially obscured by acoustic shadowing in 3D median views, the posterior contour is usually well visualized, particularly when angled insonation is used, as described previously (Figure 6). Therefore, the relationship between the position of the vermis and the brainstem, which is a key feature of the Dandy–Walker complex, is usually well appreciated[13,21,22]. Accurate

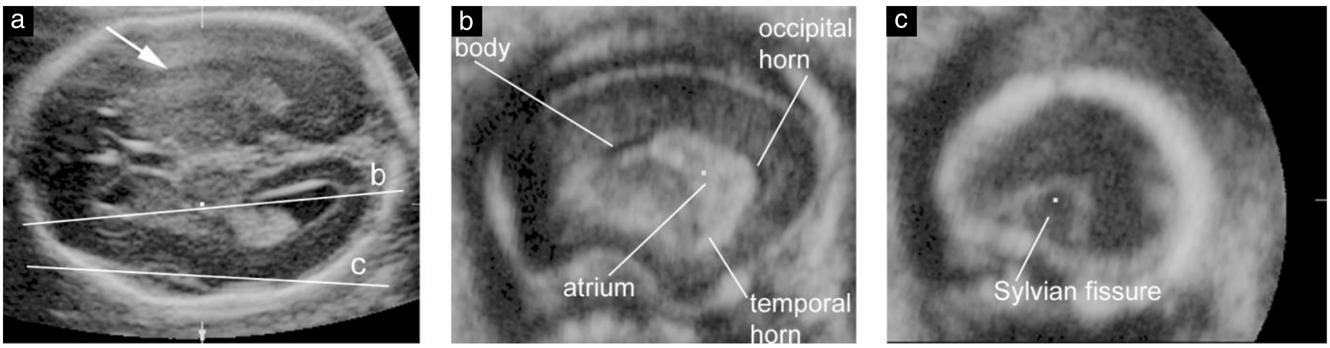

Figure 8 By adjusting the position of the C-plane in this volume obtained with an axial approach (a) it is possible to visualize sagittal views depicting the different portions of the lateral ventricle (b) and the Sylvian fissure (c). These images, however, can usually be obtained only from the hemisphere distal to the transducer. Noise and reverberations hinder the image of the proximal hemisphere (arrow).

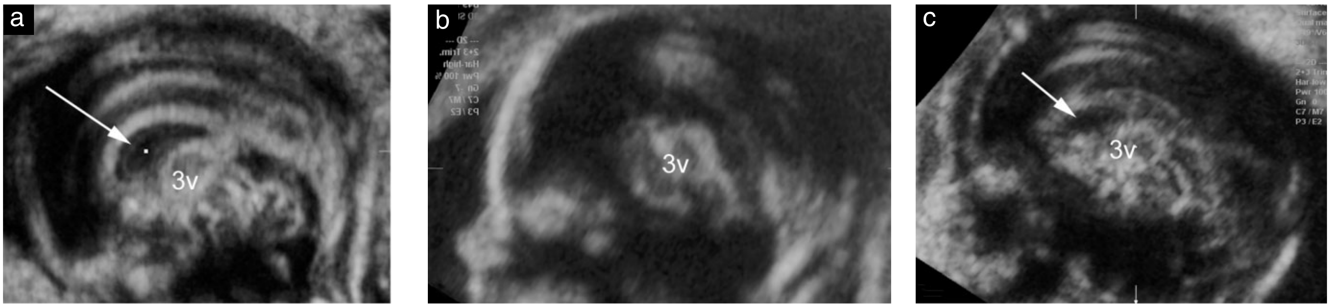

Figure 9 Three-dimensional median views demonstrating (a) a normal corpus callosum (arrow), (b) complete agenesis of the corpus callosum and (c) partial agenesis of the corpus callosum (arrow). Although this figure shows only the reconstructed median plane, diagnosis always requires a comparison with the other two orthogonal planes to ensure that the section is properly orientated. 3v, third ventricle.

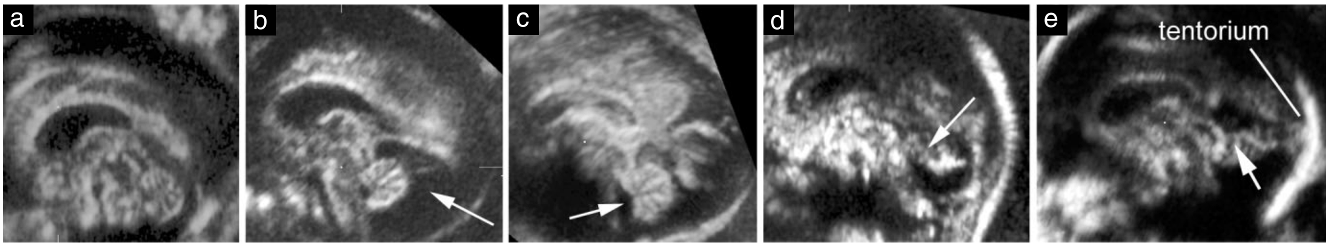

Figure 10 Three-dimensional median views comparing a normal posterior fossa (a) with different abnormalities, including: (b) megacisterna magna, which is a normally positioned and intact cerebellar vermis and a large cisterna magna (arrow); (c) Blake's pouch cyst, a superiorly rotated but seemingly intact cerebellar vermis (arrow); (d) vermian hypoplasia, a superiorly rotated and hypoplastic vermis (arrow); and (e) Dandy–Walker malformation, a superiorly rotated vermis (arrow) in association with superior displacement of the tentorium cerebelli. Although this figure shows only the reconstructed median plane, diagnosis always requires a comparison with the other two orthogonal planes to ensure that the cerebellar vermis is indeed present and that the scan is properly orientated.

diagnosis of the different clinical entities that form the spectrum of this condition (megacisterna magna, Blake's pouch cyst, vermian hypoplasia and Dandy–Walker malformation) has been reported by using the 3D median plane (Figure 10)[13]. Needless to say, the spectrum of vermian abnormalities that can be encountered is large, and experience with antenatal diagnosis is limited so far. The level of precision of the diagnosis remains unclear, and it is certainly possible that subtle pathologies may not be visualized accurately using the approach described.

THREE-DIMENSIONAL VOLUMES OF FETAL BRAIN OBTAINED BY A CORONAL OR SAGITTAL APPROACH

Coronal and sagittal views of the fetal head are best obtained by aligning the probe with the fontanelles and sutures of the upper calvarium. This approach allows the visualization of fine details of intracranial anatomy, particularly when using a high-frequency vaginal probe. This type of examination is also frequently referred to as a fetal neurosonogram and has many advantages over basic examinations performed with transabdominal axial views[9,20]. The 'start' scan is aligned either with the sagittal or the coronal suture (Figure 11). A wide angle of rotation is usually necessary to include the entire fetal brain, in general 60–80°. As subtle anatomic details of the fetal brain are revealed when using a high-frequency probe, we recommend acquiring volumes with medium to high quality. It is frequently necessary to manipulate the head of the fetus to align the probe adequately, which requires the use of both hands. For this reason, we have found that the availability of a foot switch to command the acquisition of the volumes is of considerable help. When the volume is analyzed in the multiplanar mode the A- and B-planes demonstrate sagittal and coronal views of the fetal head, depending on the start plane used, whereas the C-plane demonstrates an axial

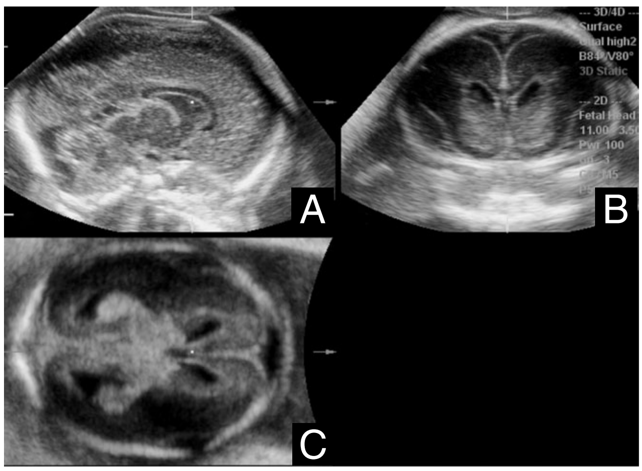

Figure 11 Multiplanar analysis of an ultrasound volume of the fetal brain at mid-gestation obtained with a transvaginal approach from the sagittal plane. A, B and C, orthogonal planes.

view (Figure 11). The volume may be examined using sequential slices in the coronal, sagittal or axial planes (Figure 12). By adjusting the position of the volume, views that demonstrate specific details of the fetal brain can be obtained. For example, by tilting the coronal plane of the fetal head from one side to the other it is possible to obtain the oblique-1 plane that demonstrates almost the entire lateral ventricle in a single image (the so-called three horn view)[14].

Visualization of the fetal brain with this approach is much better than that achieved with the standard axial technique. However, some acoustic shadowing continues to occur. In general, visualization of the frontal and parietal area is favored because of the large acoustic window of the bregmatic fontanelle. More posteriorly, the sagittal suture is thin, and this results in bilateral shadows (Figure 13). When performing a 2D ultrasound examination in real time this problem can be overcome by tilting the transducer so as to visualize the two sides sequentially. When analyzing a volume, clear visualization of both occipital lobes is usually impossible.

When the bregmatic fontanelle or the sagittal suture is used as an acoustic window, the frontal and parietal

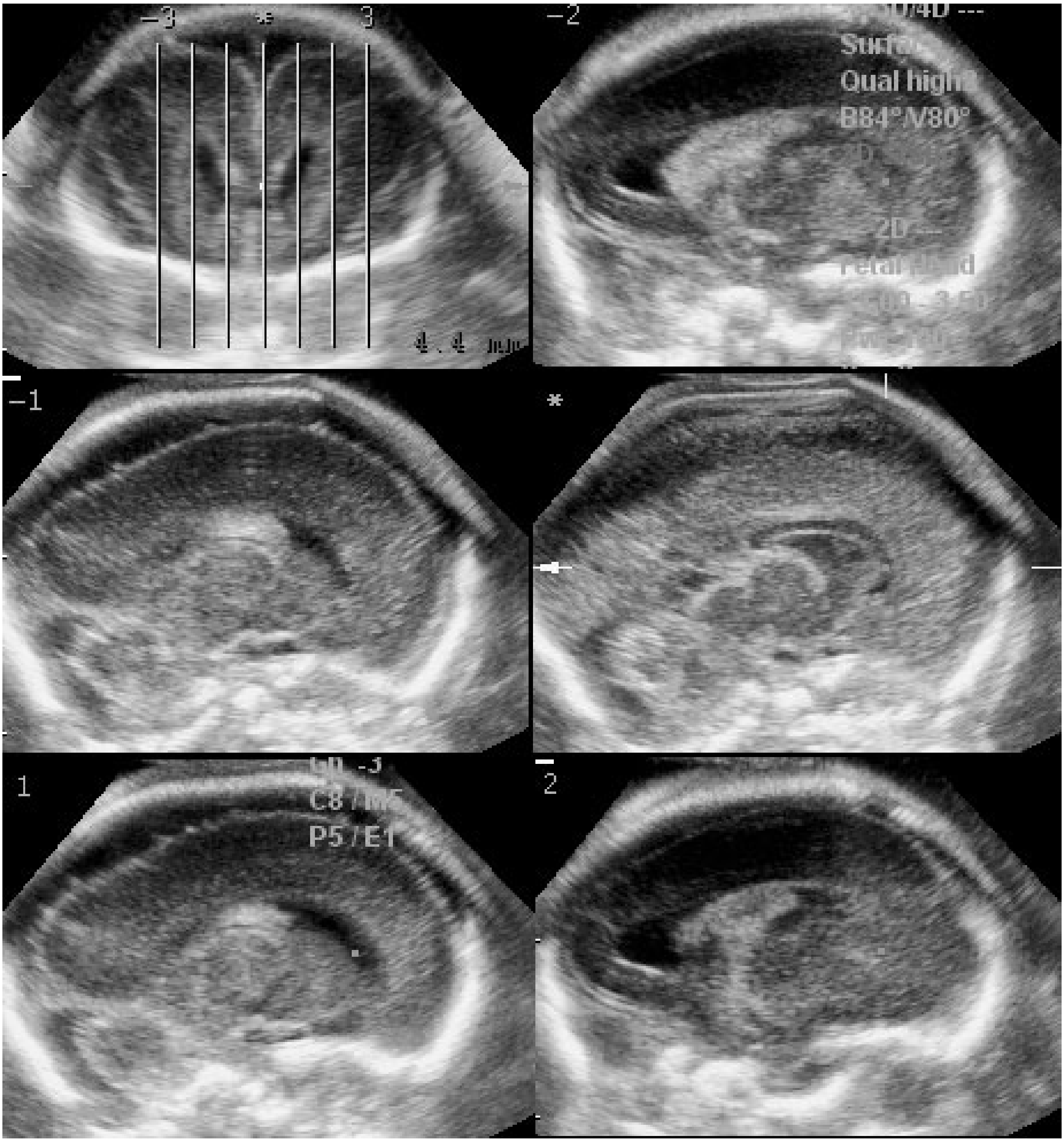

Figure 12 Multiple slices of the volume shown in Figure 11 orientated along the sagittal plane.

areas of the brain are usually well visualized, including structures such the superior subarachnoid cisterns, the convexity of the brain, the corpus callosum and lateral ventricles. However, the posterior fossa remains in the far field and is visualized suboptimally, particularly when using a high-frequency probe. The resolution is much enhanced if the posterior fontanelle is used as an acoustic window (Figure 14).

When the fetal brain is scanned with 2D ultrasound using sagittal and coronal planes the resolution of anatomic detail is usually very high. Visualization is not improved by adding 3D examination and there is the shortcoming of fixed acoustic shadows. The benefits of 3D ultrasound imaging in such cases lie in the speed at which a volume is obtained, thus allowing offline analysis at leisure that is not influenced by fetal movements ('navigating' in the volume scan), the precise identification of structures by comparing the three orthogonal planes, and the storage and exchange of data[12,14].

The combination of 3D ultrasound with color Doppler imaging has been used to demonstrate the anatomic details of complex vascular malformations of the fetal brain[8,23] (Figure 15). More recently, visualization of the entire optic chiasma has been described[24].

THE FETAL SPINE

The use of 3D examination of the fetal spine has been addressed in several studies[3,18,25,26]. One of the main advantages is the possibility of visualizing the entire length of the bony elements of the spine of the

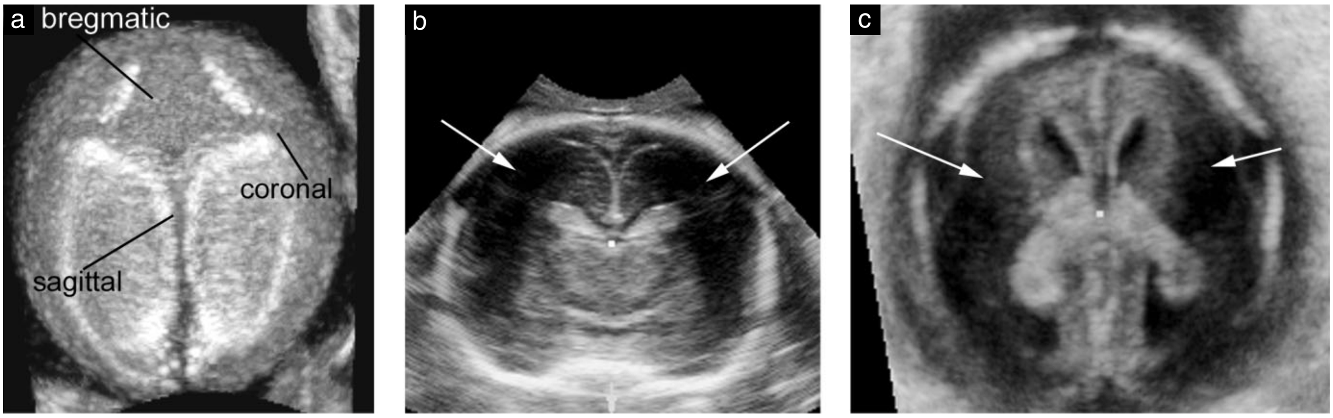

Figure 13 (a) Maximum mode ultrasound image of the superior fetal skull demonstrating the bregmatic fontanelle and sutures; (b and c) coronal and axial planes from the volume shown in Figures 11 and 12 demonstrating the distribution of acoustic shadowing from the bones of the calvarial convexity (arrows). The largest acoustic window is present in the most anterior portion of the brain due to the presence of the bregmatic fontanelle.

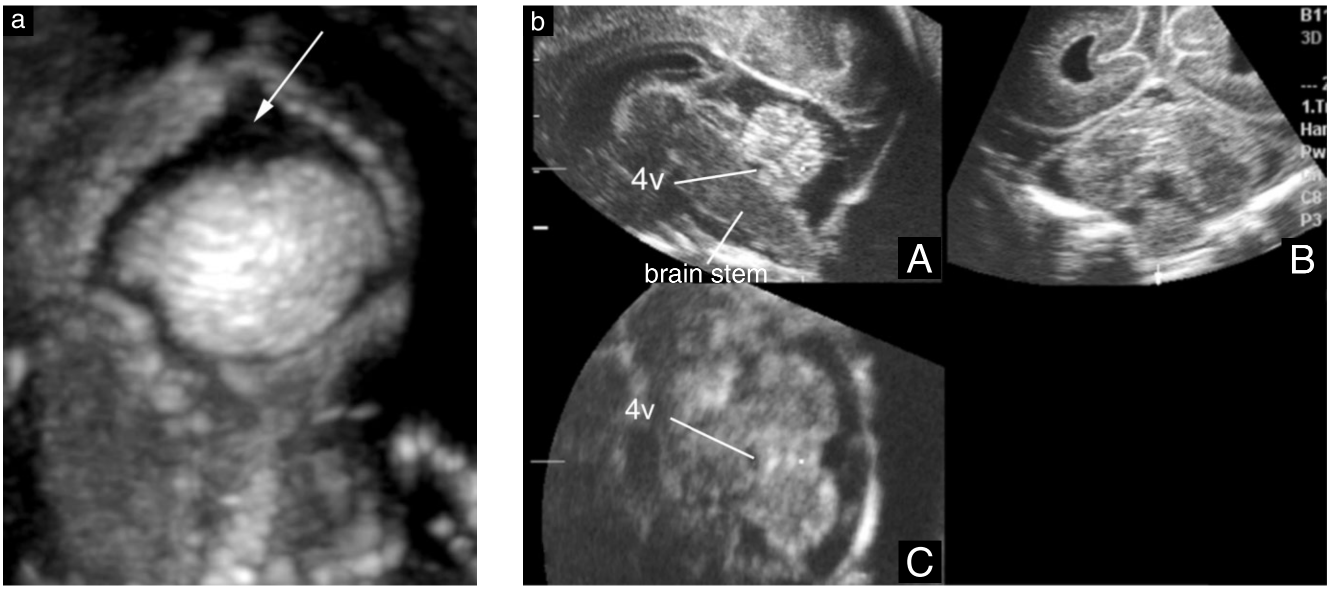

Figure 14 (a) Maximum mode ultrasound image of the back of the fetal head demonstrating the posterior fontanelle (arrow); (b) multiplanar analysis of an ultrasound volume of the fetal head obtained by transvaginal scanning using the posterior fontanelle as an acoustic window. The structures of the posterior fossa and the brainstem are seen more clearly than with the standard approach (shown in Figure 11). 4v, fourth ventricle; A, B and C, orthogonal planes.

mid-trimester fetus in one single image. The 'start' scan is a longitudinal view of the spine and the best results are obtained when the transducer is aligned with the mid-sagittal plane of the trunk from the back of the fetus. It is convenient to include the ribs in the view as reference and, in general, an angle of rotation of 30–40° is sufficient. As the bony elements are small and movements of the fetus frequently generate artifacts, good results are also obtained with four-dimensional (4D) ultrasound imaging, which generates volumes at very high frequency. The volume can be displayed conveniently either in multiplanar mode or in maximum mode, which simultaneously demonstrates the ossification centers of each vertebra (Figure 16). The images thus obtained are mostly useful for the assessment of bony defects such as hemivertebra, sacral agenesis and rib agenesis[25,27] (Figure 17). We have found, however, that a normal 3D image of the bony elements of the spine is not reassuring with regard to the presence of spina bifida. Spina bifida is associated with a distortion in the appearance of the

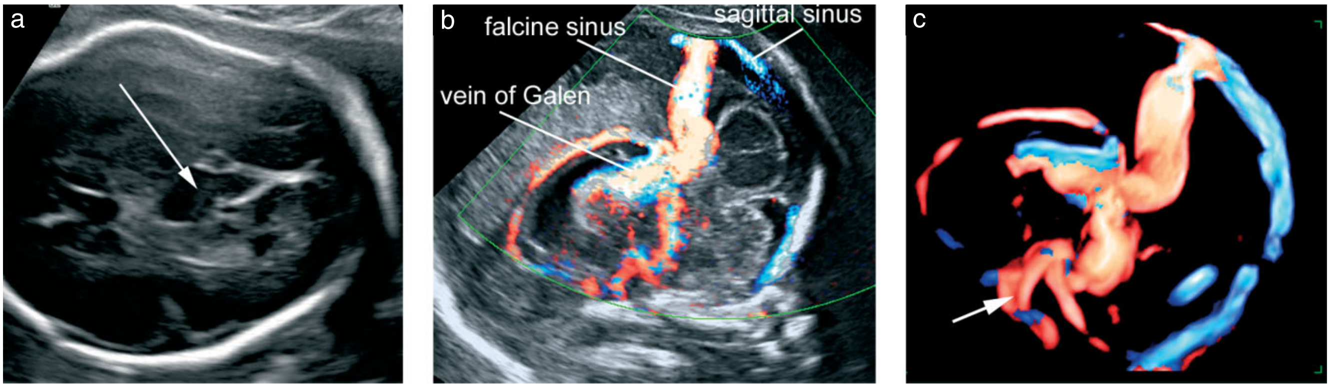

Figure 15 Ultrasound images of an aneurysm of the vein of Galen. (a) Two-dimensional image obtained transabdominally by an axial approach demonstrating the aneurysm (arrow); (b) transvaginal color Doppler image demonstrating that the aneurysmic vein of Galen does not enter the straight sinus but connects superiorly to the falcine sinus tract and drains into the superior sagittal sinus; (c) three-dimensional color Doppler rendering of an ultrasound volume obtained from a transvaginal approach demonstrating the different elements of the vascular malformations in a single image, including the multiple anastomoses between the arteries of the skull base (arrow) and the vein of Galen, which drains into the falcine sinus.

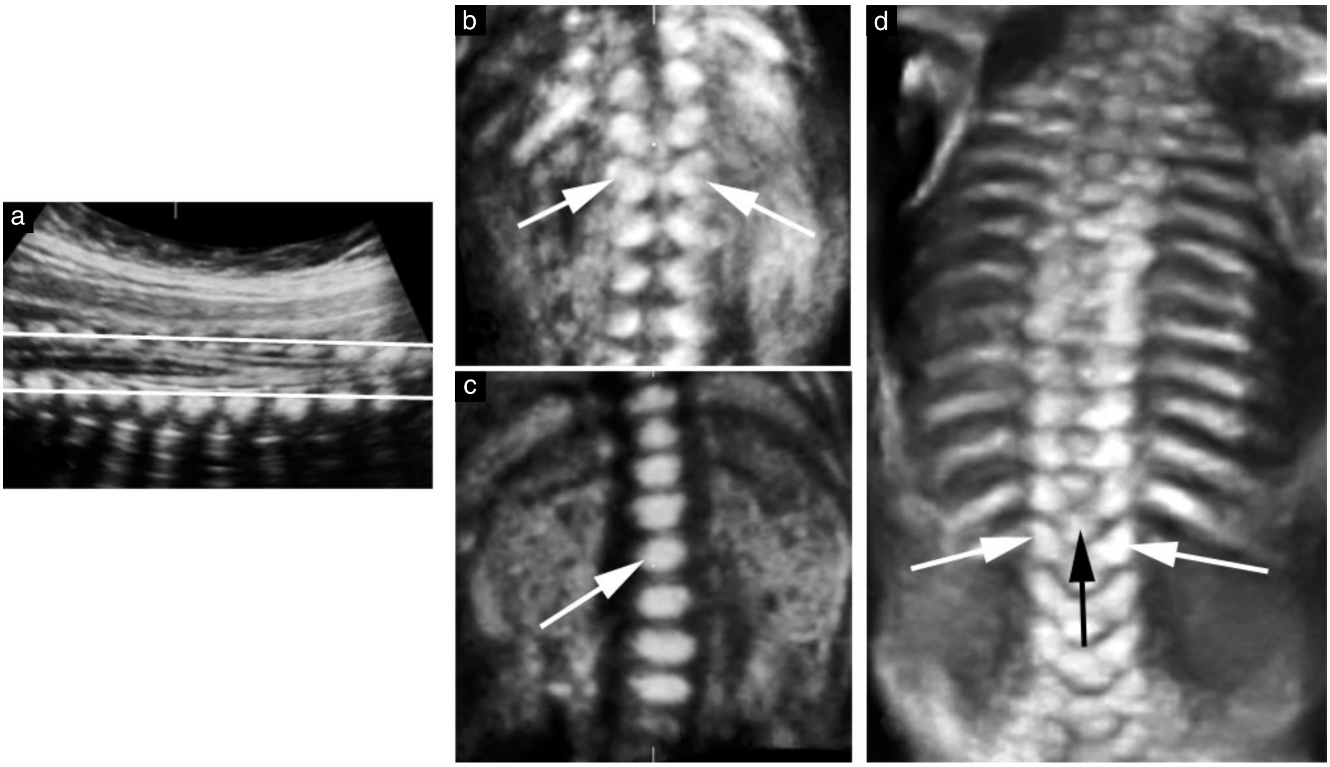

Figure 16 Three-dimensional ultrasound images of the fetal spine. The best results are obtained by using the sagittal view as a 'start' scan (a). In multiplanar mode, by moving the C-plane from posterior to anterior as indicated by the white lines in (a), it is possible to demonstrate the ossification centers (arrows) of the lateral processes (b) and of the vertebral bodies (c). Using maximum mode in a thin slice it is possible to visualize the three ossification centers simultaneously (arrows) (d).

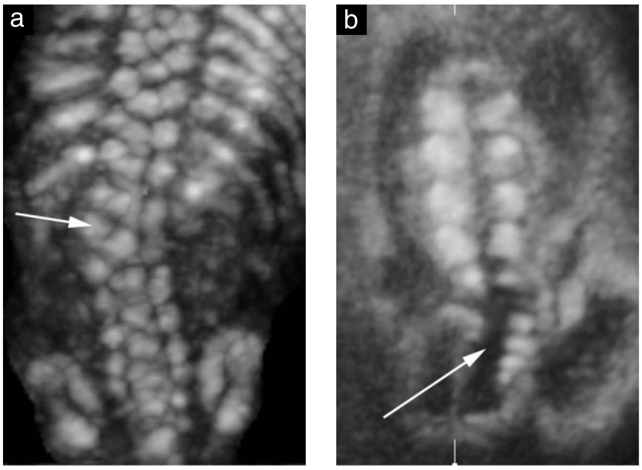

Figure 17 Bony defects of the spine. (a) Maximum mode rendering of fetal hemivertebra (arrow) acting as a wedge and causing an obvious distortion of the spine. (b) Partial sacral agenesis (arrow); closed spina bifida and a subcutaneous lipoma were also present.

ossified parts of the vertebrae, mostly lateral splaying of the posterior laminae. At times, however, the distortion can be mild and difficult to appreciate, particularly in the case of small and low defects (Figure 18). Furthermore, it is a non-specific finding that we have also documented in fetuses with vertebral anomalies but with an intact neural tube. Surface rendering of the volume can be used to demonstrate the cutaneous lesions of open spina bifida and the possible presence of a meningocele (Figure 19), but this may be cumbersome and offers no diagnostic advantage over standard 2D ultrasound examination. One interesting application of 3D ultrasound imaging in the multiplanar mode is to locate precisely the extent and position of a defect. When using standard 2D ultrasound scanning, the defective area of the spine is identified by obtaining a mid-sagittal view and then counting the vertebral segments starting from the lowest (usually corresponding to S4)[28]. With multiplanar 3D ultrasound examination, the vertebral segments are counted starting with the one connected to the last identifiable rib; this usually corresponds to T12[18] (Figure 20).

EVALUATION OF FETAL BRAIN IN THE FIRST TRIMESTER OF GESTATION

3D ultrasound examination has been used extensively in studies of fetal embryology[1,2,5,29], and has also allowed the very early diagnosis of selected CNS anomalies, including spina bifida[3] and holoprosencephaly[19]. First-trimester neurosonographic examinations are usually performed with transvaginal probes that are limited in terms of maneuverability, which frequently results in the inability to obtain views adequate for diagnosis. The advantage of 3D scanning is that obtaining a volume of the fetal cephalic pole is usually straightforward, and this can be resliced along appropriate planes later (Figure 21). At this time in gestation, the fetal cranium is not ossified and so the acoustic window is unlimited. In our hands, examination of the developing brain in the first trimester was much more rapid and successful when 3D rather than 2D ultrasound examination alone was used.

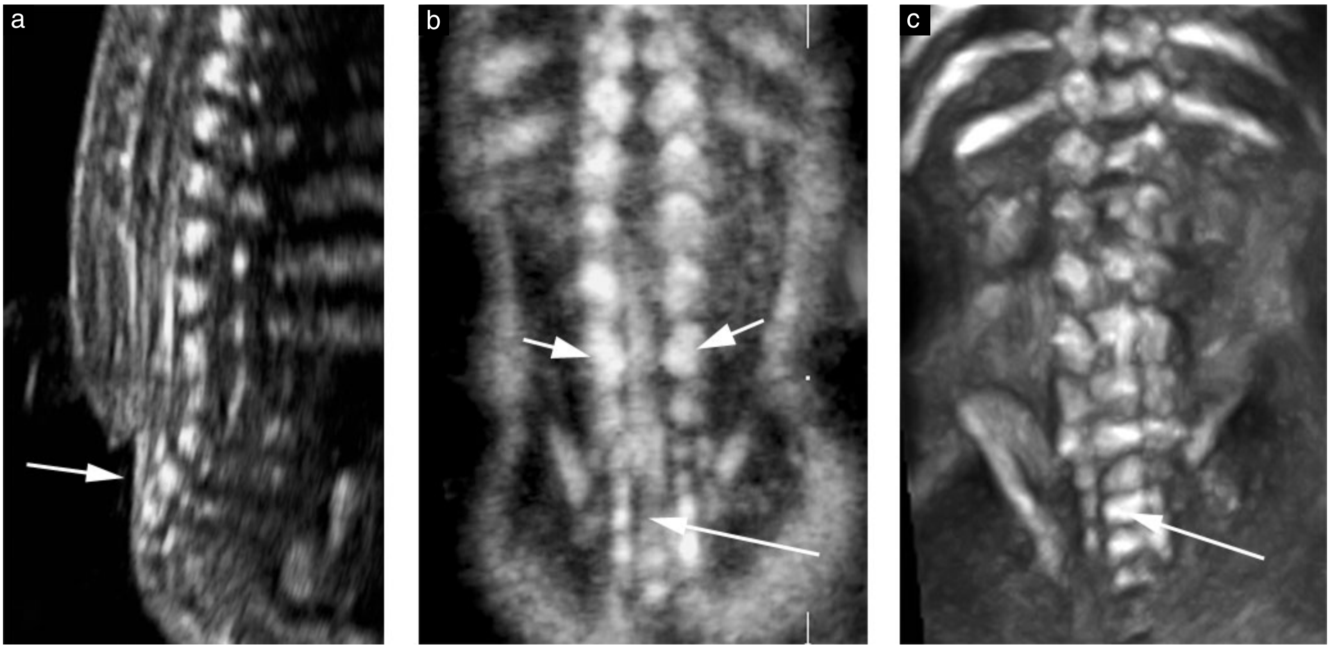

Figure 18 Fetal sacral spina bifida. The lesion of the neural tube and overlying soft tissues is well demonstrated by two-dimensional ultrasound examination (arrow) (a), but three-dimensional ultrasound rendering results in only subtle and non-specific findings (b and c). In multiplanar mode, an increased separation of the lateral processes is noted in the sacral area (long arrow) and it is also possible to visualize an unusual separation between the lateral processes in the area above the lesion (short arrows) (b); in maximum mode the findings are even more subtle (c).

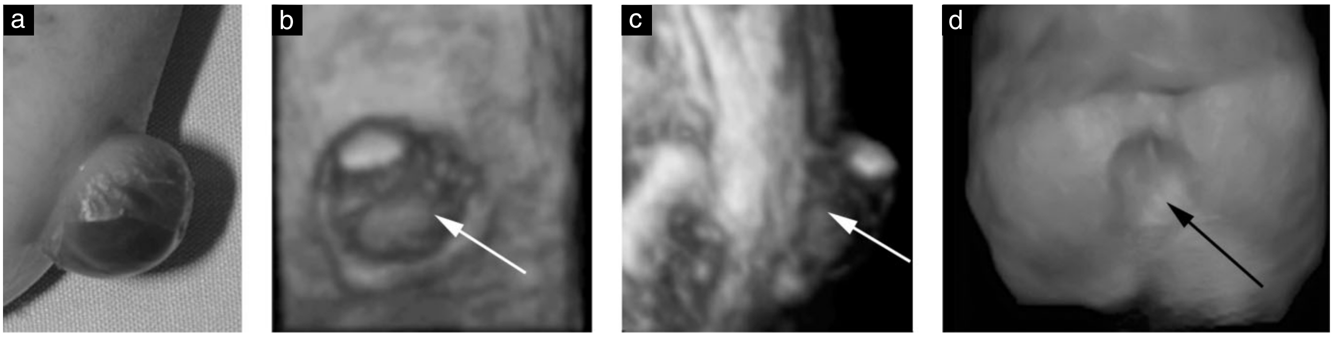

Figure 19 The postnatal appearance of myelomeningocele (a) is compared with surface rendering of antenatal ultrasound volumes (b and c); (d) surface rendering of myelocele. The arrows indicate the superficial lesions associated with the neural tube defects.

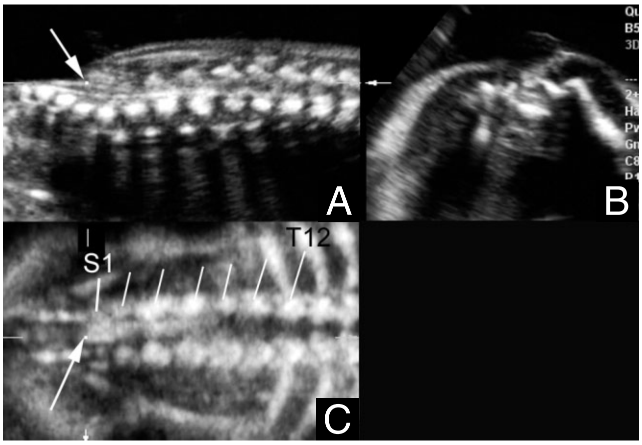

Figure 20 Assessment of the level of spina bifida using three-dimensional ultrasound. In the sagittal plane (A) the point indicating the intersection of the orthogonal planes (arrow) is positioned at the upper level of the neural defect, which is well visualized in this view; in the coronal plane (C) the number of vertebral elements (lines) between the last rib (usually corresponding to T12) and the defect, indicated by the intersection of orthogonal planes (arrow), is counted; in this case, involvement of the segment S1–S5 was correctly predicted. A, B and C, orthogonal planes.

IMPROVING THE QUALITY OF TWO-DIMENSIONAL IMAGES WITH THREE-DIMENSIONAL ULTRASOUND: VOLUME CONTRAST IMAGING

Volume contrast imaging (VCI™) (GE Medical Systems Kretztechnik, Zipf, Austria) is an application of 3D ultrasound that involves displaying a thin slice from an acquired volume. One of the main purposes of this technique is to decrease ultrasound artifacts. By superimposing and adding different layers of tissue, speckles and noise pixels that are generated at random are reduced or eliminated, while anatomic structures are enhanced (Figure 22). This results in an image with fewer noise pixels and greater contrast resolution. It has yet to be demonstrated whether VCI increases the amount of information over that provided by standard multiplanar visualization. However, the images tend to be smoother and the interface between different tissues is more immediate to the eye. VCI can be used as a postprocessing technique for static volumes that have already been acquired (static VCI) or as a modality for rendering in 4D mode (VCI in the coronal plane; VCI-C). We have adopted static VCI with a slice thickness of 1–3 mm as the modality of choice to demonstrate

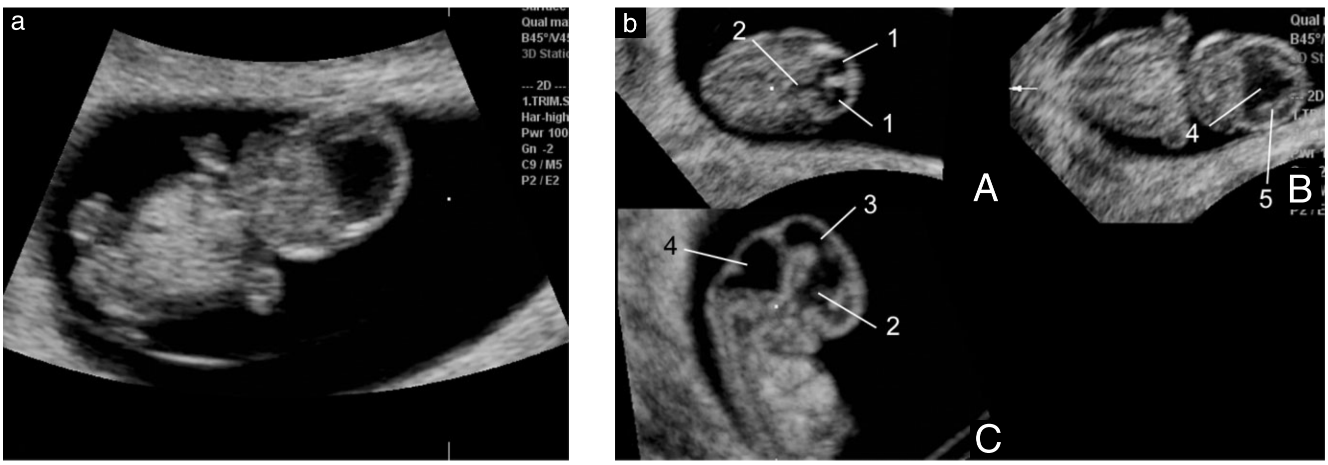

Figure 21 Transvaginal examination of an embryo at 9 weeks and 5 days. Although the oblique position of the embryo is not favorable for analysis of the brain vesicles (a, 'start scan'), a volume can be obtained and the embryo aligned along a more convenient angle. Multiplanar analysis (b) allows clear definition of subtle anatomical details (1, hemisphere; 2, diencephalon; 3, mesencephalon; 4, rhombencephalon; 5, choroid plexus of rhombencephalon). A, B and C, orthogonal planes.

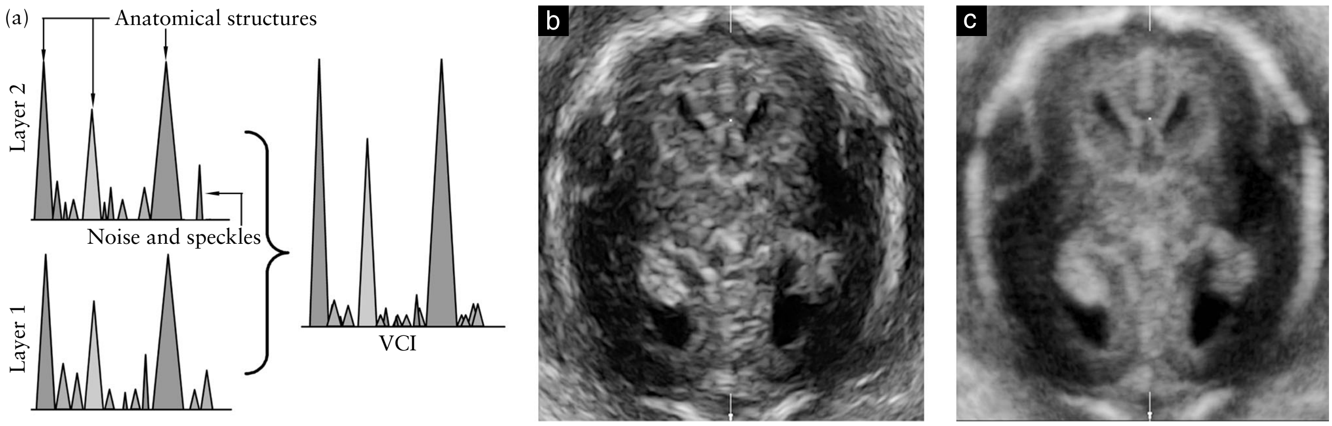

Figure 22 (a) Schematic representation of the physical principles of static volume contrast imaging (VCI); the superimposition of different layers of tissue allows a better signal-to-noise ratio. The effect of VCI is demonstrated by comparing images obtained from the same ultrasound volume, displayed using a standard planar mode (b) and with VCI with a thickness of 3 mm (c).

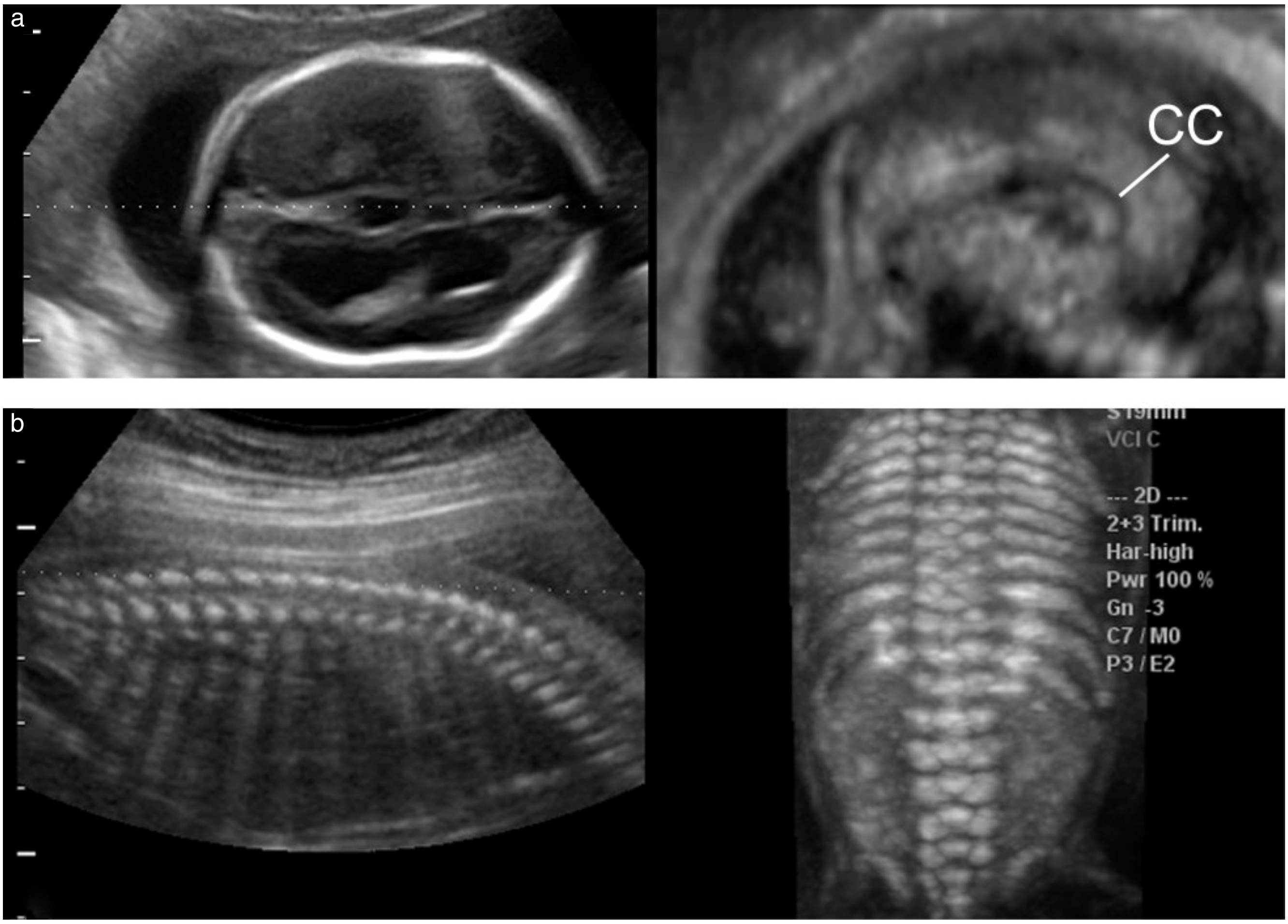

Figure 23 Dynamic volume contrast imaging of the fetal brain (a) and fetal spine (b). CC, corpus callosum. The 'start' scans are on the left and the rendered coronal planes are on the right.

multiplanar analysis of the fetal brain. Indeed, all the figures demonstrated in this article have been obtained by using this application. Dynamic VCI (VCI-C) is also available (Figure 23). This allows elaboration of the median plane in almost real time; the main advantage is minimization of movement artifacts that are occasionally encountered when acquiring static volumes. VCI-C has been employed to construct nomograms of cerebellar measurements[15] and has been found to be as effective as static 3D imaging in reconstructing median planes from transverse scans[13]. We admit, however, our preference for static volumes. Indeed, a static volume of medium quality of the fetal head can be obtained rapidly and has the advantage of allowing better navigation in the three orthogonal planes. This is particularly useful when dealing with complex anatomy[12]. The main application of VCI-C in the fetus in our experience so far has been in the demonstration of the skull bones (Figure 14a) and fetal spine (Figure 23). In this case the slice thickness is in the range 5–15 mm.

COMMENT

3D ultrasound imaging is being used increasingly in obstetric examinations. It remains to be demonstrated whether this tool will have a measurable impact on the prenatal diagnosis of fetal anomalies. However, there is a general consensus that some benefits exist, at least in terms of facilitating fetal examination and data storage. At present, 2D ultrasound examination remains the basis of fetal diagnosis for many reasons. However, in the specific setting of sonographic evaluation of the fetal CNS, 3D imaging is helpful in that it allows acquisition of scanning planes along different directions from that of the incident sound beam. It has been pointed out that 3D ultrasound imaging does not overcome the physical limitations of ultrasound and that sections reconstructed from ultrasound volumes are far less accurate than those obtained by direct insonation; images should therefore always be interpreted with caution[11,13]. Indeed, we expect that fetal neurosonograms performed by expert sonologists will continue to consist mainly of 2D images as these allow sharper resolution of anatomic details, which may be critical particularly when dealing with abnormal cases. However, reconstructed planes are useful for the rapid assessment of normal anatomy in standard examinations as well as for assessment of abnormal cases when direct scans cannot be obtained[13]. Early examination of the fetal brain is an exception in this regard, mainly because, in the first trimester, the unossified fetal cranium is not an obstacle to ultrasound transmission and images that are obtained by reslicing volumes are of almost the same quality as those obtained directly[3,4,19,30]. We suggest, therefore, that 3D ultrasound examination has many advantages if a first-trimester neurosonogram is indicated. Other applications of this technology have a less immediate impact on evaluation of the fetal CNS. However, the value of ultrasound volumes in terms of data storage, offline analysis and training should not be understated.

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