Ultrasound Obstet Gynecol 2007; **29**: 697–703
Published online in Wiley InterScience (www.interscience.wiley.com). **DOI:** 10.1002/uog.4009

Standardization of three-dimensional images in obstetrics and gynecology: consensus statement

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KEYWORDS: 3D ultrasound; gynecology; image standardization; obstetrics; orientation; transabdominal ultrasound; transvaginal ultrasound

ABSTRACT

Standardization of the display of ultrasound images has so far only been achieved in transabdominal two-dimensional (2D) sonography. In contrast, there is a lack of uniformity in the demonstration of transvaginal 2D ultrasound images. The described non-uniformity frequently leads to confusion in the assessment of an image, in particular with regard to the accurate anatomical assignment of left/right and dorsal/ventral. Three-dimensional (3D) sonography offers a unique opportunity to avoid this confusion in the interpretation of ultrasound images, because, independent of primary volume acquisition, the volume can always be rotated so that the stored object can at all times be visualized in a known anatomical position, rendering it of no importance whether the image acquired transvaginally is demonstrated from above or from below. This will also be important in allowing fusion of ultrasound image data with computed tomographic, magnetic resonance and/or positron emission tomography images. In this article we suggest that standardization of transabdominal and transvaginal 3D images does not only provide the inexperienced physician/sonographer with a guide to spatial orientation, but also serves to avoid erroneous topographical interpretations. Copyright © 2007 ISUOG. Published by John Wiley & Sons, Ltd.

INTRODUCTION

Current three-dimensional (3D) ultrasound technology, which allows the storage of complete volumes, has the capacity for routine clinical application. All objects stored in these volumes can be represented in the multiplanar mode as well as in the form of a surface or a transparent image. The major advantage of the multiplanar (or 'triplanar') mode is that it enables simultaneous visualization of all three mutually perpendicular sectional planes on the display screen. The ultrasound unit is equipped with three rotary controls, allowing the sectional planes to be rotated so that the object of interest may be viewed in the correct anatomical position, i.e. in the so-called textbook view[1], which, in turn, provides the optimal starting point for further volume analysis.

While the freedom of 3D sonography in demonstrating a large number of sagittal, coronal, transverse and oblique section planes within a defined volume offers diagnostic advantages, the less experienced diagnostician frequently finds spatial orientation difficult. This is due to the fact that the image's cranial, caudal, ventral (anterior), dorsal (posterior), right and left edges as known from two-dimensional (2D) sonography no longer correspond to the edges of the display screen, but to the object itself[2]. Thus, uncontrolled rotation of the individual sectional planes of an object stored at an oblique angle in the volume may result in it being visualized at such an odd angle that, the inexperienced sonographer in particular may no longer be able to differentiate the right from the left side, or the ventral from the dorsal view.

With the two-fold purpose of providing sonographers lacking extensive experience in the application of 3D sonography with a guide to better orientation, and enabling an internationally uniform image display, the International Society of Ultrasound in Obstetrics and Gynecology 3D Focus Group has attempted to standardize the image display in transabdominal and transvaginal 3D sonography.

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DISPLAY MODE IN 2D SONOGRAPHY

With respect to the standardization of image display in 2D sonography, an international consensus on a uniform image display of the fetus or the uterus has thus far only been reached for the transabdominal approach (Table 1 and Figure 1)[3].

An international agreement on a uniform image display has not yet been reached for transvaginal 2D sonography[3–5]. Globally, there are now essentially two different display modes: in Germany as well as in several other European countries, the images acquired using a transvaginal probe are shown in a such a way as to allow it to be differentiated at a glance from a transabdominal image[3,5,6]. This is accomplished by displaying the transvaginal sonographic ultrasound image on the display screen with the probe position at the bottom of the screen (Table 2 and Figure 2a,b). Conversely, primarily in the United States, South America and some Asian countries, the transvaginal image is displayed like a transabdominal one, i.e. with the probe position at the top of the screen (Table 2 and Figure 2c,d)[3–5].

Table 1 Standardization of display frame orientation in two-dimensional transabdominal ultrasound*

Display on screen	*Anatomical orientation*
Sagittal section	
Left side of screen/image	Cranial
Right side of screen/image	Caudal
Upper side of screen/image	Ventral
Lower side of screen/image	Dorsal
Transverse section	
Left side of screen/image	Right
Right side of screen/image	Left
Upper side of screen/image	Ventral
Lower side of screen/image	Dorsal

*This standardization applies if the woman being scanned is facing the operator.

Table 2 Current display frame orientation in two-dimensional transvaginal ultrasound*

	Anatomical orientation	
Display on screen	*Europe*	*USA/Asia/ South America*
Sagittal section of the true pelvis		
Left side of screen/image	Dorsal	Ventral
Right side of screen/image	Ventral	Dorsal
Upper side of screen/image	Cranial	Caudal
Lower side of screen/image	Caudal	Cranial
Coronal section of the true pelvis		
Left side of screen/image	Right	Right
Right side of screen/image	Left	Left
Upper side of screen/image	Cranial	Caudal
Lower side of screen/image	Caudal	Cranial

*This standardization applies if the woman being scanned is facing the operator.

DISPLAY MODE IN 3D SONOGRAPHY

Primary multiplanar image

In 3D sonography the primary multiplanar image shows all three mutually perpendicular sectional planes (orthogonal image planes) immediately after volume acquisition. These three images are at all times interdependent. In Figures 3–8, this dependency becomes apparent in the progress of the clockwise rotation. The respective corresponding sectional planes are marked by lines in the peripheral areas and the fulcrum is shown as a dot. In the system presented here, the rendered surface view can further be introduced as a fourth image.

In the interests of an internationally uniform system of image display, we believe that image documentation in 3D sonography should be aimed at enabling instant assessment, based on the primary multiplanar image (i.e. immediately after acquisition of the volume), of whether the fetus is in a vertex or a breech presentation, or whether the uterus is anteverted or retroverted at the

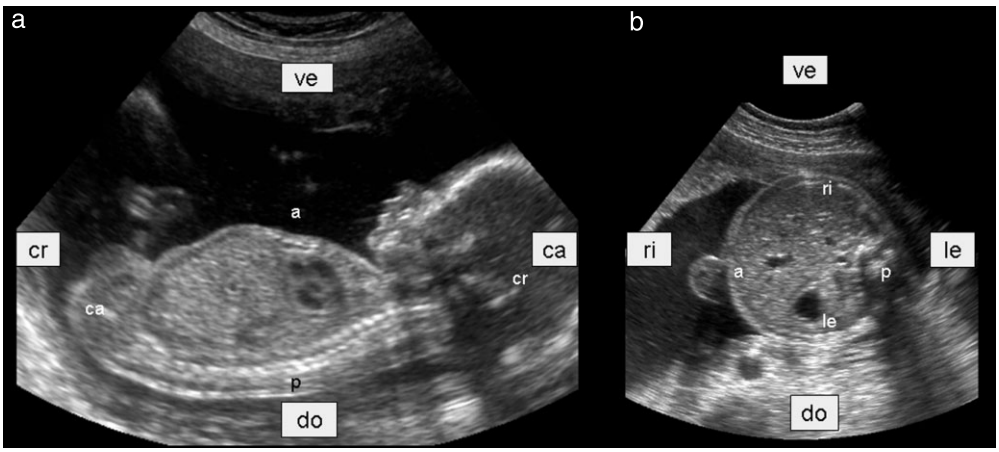

Figure 1 Transabdominal ultrasound images of a fetus with vertex presentation: sagittal (a) and transverse (b) sections. Labels in boxes refer to the anatomy of the mother, while labels without boxes refer to that of the fetus. a, anterior; ca, caudal; cr, cranial; do, dorsal; le, left; p, posterior; ri, right; ve, ventral.

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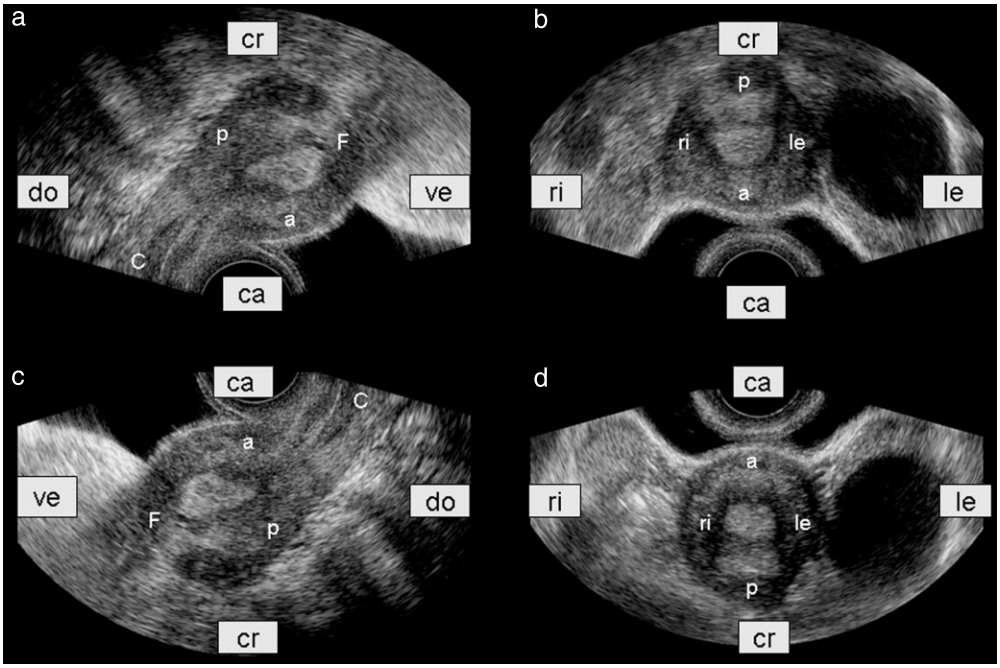

Figure 2 Transvaginal ultrasound images of an anteverted uterus and an ovarian cyst on the left in sagittal and coronal sections of the true pelvis: image displays typical of many European countries (a,b) and of USA, South America and Asia (c,d). The coronal scan through the pelvis shows the anteverted uterus in a transverse section (b,d). Labels in boxes refer to the anatomy of the patient, while labels without boxes refer to that of the uterus. a, anterior wall; C, cervix; ca, caudal; cr, cranial; do, dorsal; F, fundus; le, left; p, posterior wall; ri, right; ve, ventral.

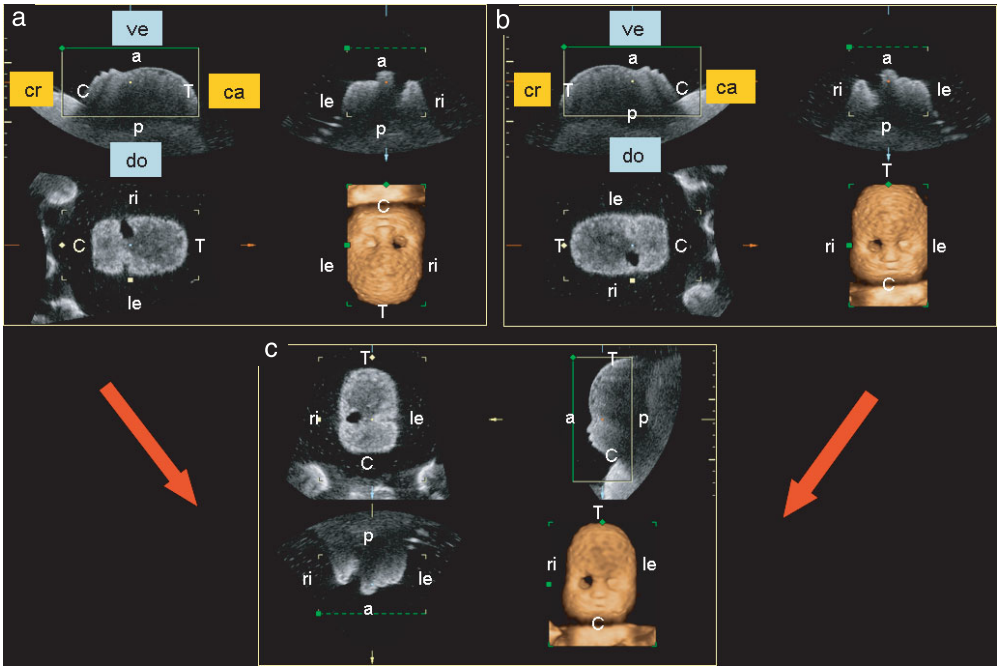

Figure 3 Sagittal view of a doll phantom in a water-bath. The right eye was hollowed out to enable differentiation between left and right. The primary images show the doll in vertex (a) and breech (b) presentations. The secondary image shows the doll in the 'textbook view', after rotation into an upright position, enabling an accurate side-guided assessment independent of the initial position in the primary image. It was necessary to change the direction of rendering to obtain the rendered image in (c). Labels in boxes refer to the anatomy of the 'mother', while labels without boxes refer to that of the doll. a, anterior; C, chin; ca, caudal; cr, cranial; do, dorsal; le, left; p, posterior; ri, right; T, top of the head; ve, ventral.

time of volume acquisition. This can be accomplished for both transvaginal and transabdominal 3D sonography by adjusting the setting so that the object of interest (embryo/fetus/uterus) is in an exact 2D longitudinal section before storing the volume. Should a wider lateral acquisition angle be required, the probe may be rotated by 90° to enable the acquisition of an additional volume. In transabdominal sonography this implies a

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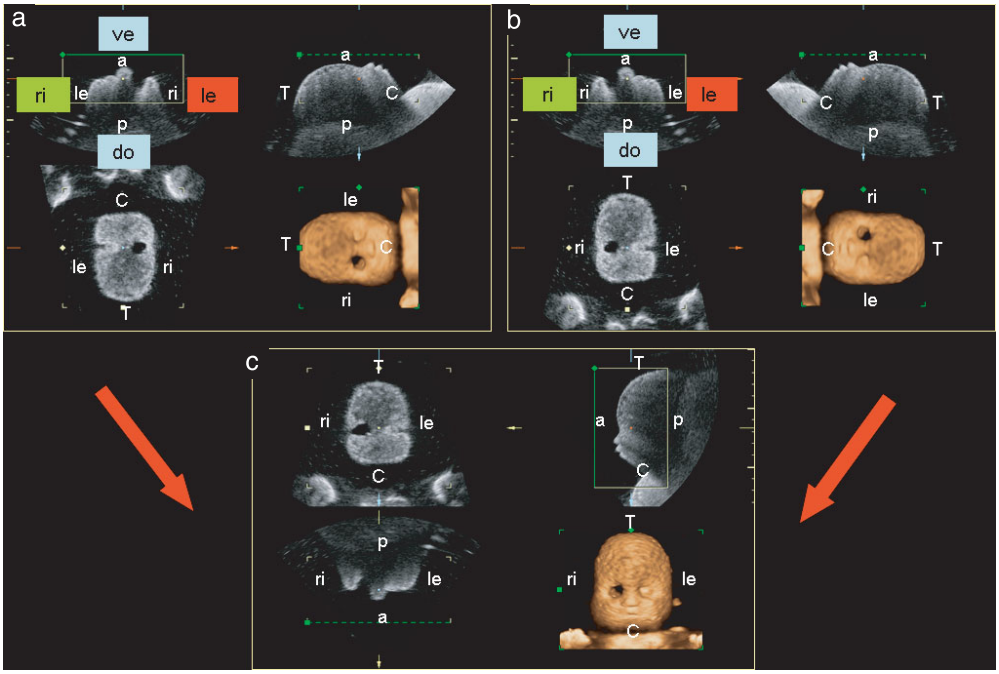

Figure 4 Transverse view of a doll phantom in a water-bath. The right eye was hollowed out to enable differentiation between left and right. The primary images show the doll in vertex (a) and breech (b) presentations. The secondary image (c) shows the doll in the 'textbook view', after rotation into an upright position, enabling an accurate side-guided assessment independent of the initial position in the primary image. Labels in boxes refer to the anatomy of the 'mother', while labels without boxes refer to that of the doll. a, anterior; C, chin; ca, caudal; cr, cranial; do, dorsal; le, left; p, posterior; ri, right; T, top of the head; ve, ventral.

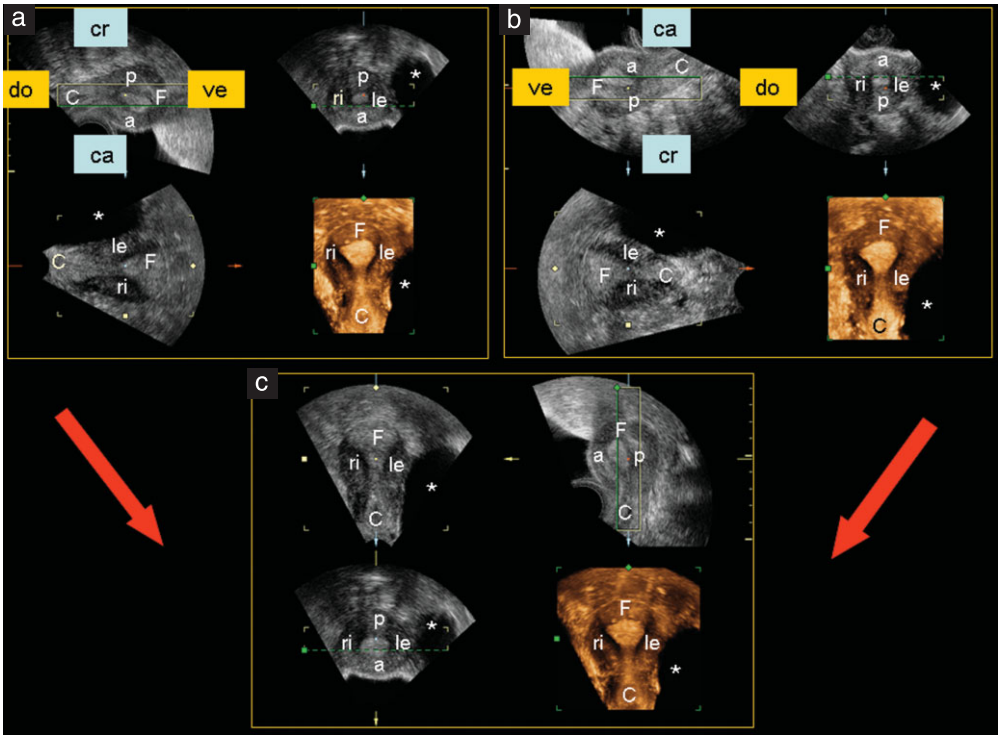

Figure 5 Sagittal view of the female pelvis showing an anteverted uterus and an ovarian cyst, left (*). The primary images show European (a) and US/South American/Asian (b) displays. The secondary image (c) shows the uterus after rotation into an upright position, visualized in the correct relationship with the display frame sides (ovarian cyst to the left (*)), independent of the initial position in the primary image. Labels in boxes refer to the anatomy of the patient, while labels without boxes refer to that of the uterus. a, anterior wall; C, cervix; ca, caudal; cr, cranial; do, dorsal; F, fundus; le, left; p, posterior wall; ri, right; ve, ventral.

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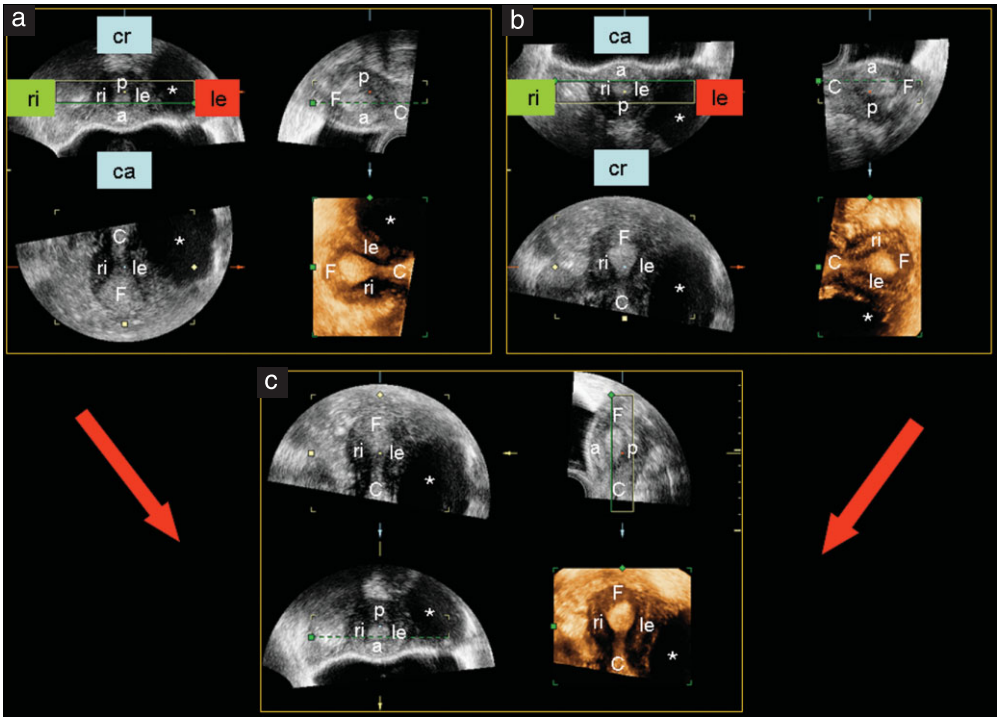

Figure 6 Coronal view of the female pelvis showing an anteverted uterus in a transverse view and an ovarian cyst, left (*). The primary images show European (a) and US/South American/Asian (b) displays. The secondary image (c) shows the uterus in the 'textbook view', after rotation into an upright position, enabling an accurate side-guided assessment independent of the initial position in the primary image (ovarian cyst to the left). Labels in boxes refer to the anatomy of the patient, while labels without boxes refer to that of the uterus. a, anterior wall; C, cervix; ca, caudal; cr, cranial; F, fundus; le, left; p, posterior wall; ri, right.

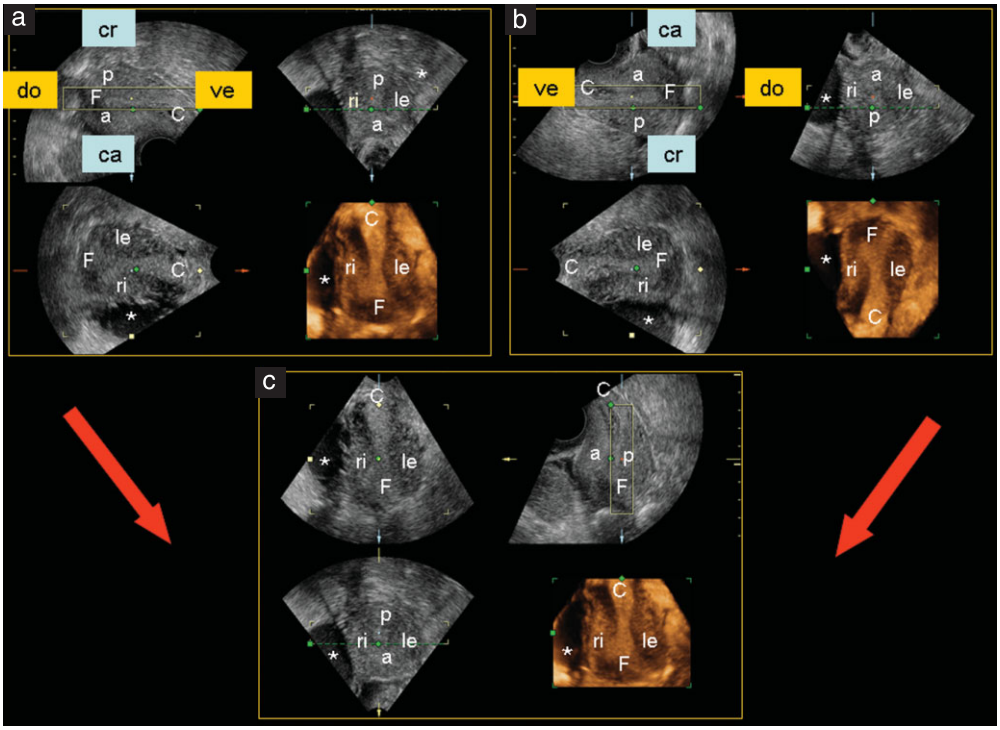

Figure 7 Sagittal view of the female pelvis showing a retroverted uterus and an ovarian cyst, right (*). The primary images show European (a) and US/South American/Asian (b) displays. The secondary image (c) shows the uterus after rotation into an upright position (i.e. uterus upside down in retroverted uterus), visualized in the correct relationship with the display frame sides (ovarian cyst to the right), independent of the initial position in the primary image. Labels in boxes refer to the anatomy of the patient while labels without boxes refer to that of the uterus. a, anterior wall; C, cervix; ca, caudal; cr, cranial; do, dorsal; F, fundus; le, left; p, posterior wall; ri, right; ve, ventral.

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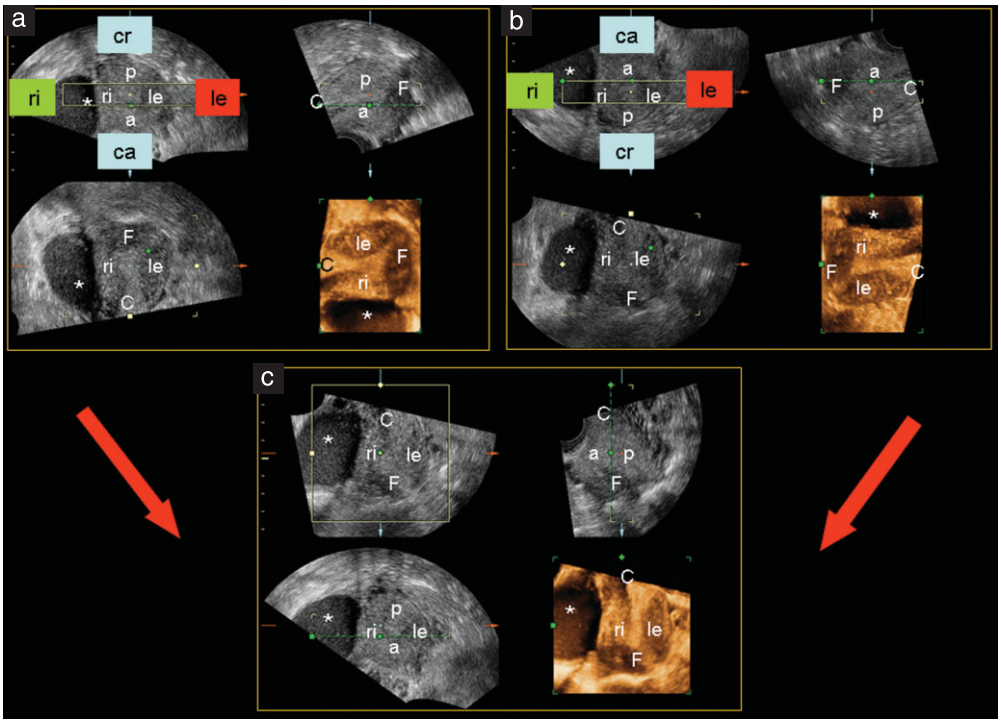

Figure 8 Coronal view of the female pelvis showing a retroverted uterus in a transverse view and an ovarian cyst, right (*). The primary images show European (a) and US/South American/Asian (b) displays. The secondary image (c) shows the uterus in the 'textbook view', after rotation into an upright position (i.e. uterus upside down in retroverted uterus), enabling an accurate side-guided assessment independent of the initial position in the primary image (ovarian cyst to the right). Labels in boxes refer to the anatomy of the patient, while labels without boxes refer to that of the uterus. a, anterior wall; C, cervix; ca, caudal; cr, cranial; F, fundus; le, left; p, posterior wall; ri, right.

volume acquisition arising from a transverse scan, and in transvaginal sonography a volume acquisition arising from a coronal scan.

The use of this procedure ensures that of the three orthogonal images shown on the display screen it is in all cases the image at the top left which corresponds to that in the conventional sectional plane in 2D sonography (Figures 3a,b–8a,b). This has the advantage that the initial multiplanar image always allows the immediate identification of the position of the embryo/fetus or uterus at the time of volume acquisition, as in 2D ultrasound (Tables 1 and 2).

Secondary multiplanar image

The secondary multiplanar image depicts the individual orthogonal image planes after volume rotation. This image is aimed at presenting the object on the display screen in such a way as to allow the correct assignment of ventral and dorsal, as well as of right and left to the actual anatomy. This implies that the object of interest (embryo/fetus/uterus), independent of the primary position, has to be positioned in the sagittal section in an upright textbook view. For a uniform demonstration it is recommended that the volume is rotated so that the image at the top right always demonstrates the sagittal section (Figures 3c–8c). This ensures that the object of interest is visualized automatically in the correct position (i.e. where the right (or left) side of the fetus/uterus corresponds to the left (or right) side of the image) in the coronal and transverse planes, regardless of whether the presentation of the fetus is vertex or breech, or whether the uterus is anteverted or retroverted at the time of volume acquisition (Table 3 and Figures 3c–8c). To avoid confusion with the left and right sides in the retroverted uterus, it must be ensured that the uterus is shown in an upside-down position after the rotation in the sagittal plane (Figures 7c and 8c).

Table 3 Suggested standardization of display frame orientation in three-dimensional (3D) ultrasound (secondary image)

Display on screen	*Anatomical orientation*
Sagittal section of the true pelvis	
Left side of image	Ventral
Right side of image	Dorsal
Upper side of image	Cranial
Lower side of image	Caudal
Coronal section of the true pelvis	
Left side of image	Right
Right side of image	Left
Upper side of image	Cranial
Lower side of image	Caudal
Transverse section of the true pelvis	
Left side of image	Right
Right side of image	Left
Upper side of image	Dorsal
Lower side of image	Ventral

After standardized rotation of the 3D volume, the right (left) side of the display screen corresponds to the left (right) side of the fetus/uterus in the coronal and transverse planes.

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A further advantage of the standardized secondary multiplanar image may, in particular, be observed in transvaginal sonography: it is completely unimportant whether, in the primary multiplanar image, the probe is visualized at the caudal (Europe) or at the cranial (USA/South America/Asia) image edge, because one can compensate for this difference by rotation of the individual image planes (Figures 5–8).

The availability of a uniform image display system is of tremendous importance, in particular for physicians/sonographers wishing to familiarize themselves with the application of 3D sonography, because it greatly facilitates orientation in the multiplanar as well as in other modes of image rendering (surface and transparent modes).

CONCLUSIONS

The following steps towards achieving a uniform system for the international display of 3D images are recommended:

1. In the primary multiplanar image, the object should be displayed so that the image at the top left always corresponds to that visualized in the 2D image prior to volume acquisition. This permits valid conclusions to be drawn on the position of the embryo/fetus/uterus at the time of volume acquisition.
2. In the secondary multiplanar image, the volume should be changed by rotation maneuvers to ensure that the embryo/fetus may at all times be visualized in an upright sagittal position in the image at the top right. The same is true for the anteverted uterus, while the retroverted uterus should be rotated into an upside-down position. This allows rendering of the fetus or uterus in such a way that the right (or left) side of the fetus/uterus in the coronal and transverse planes always corresponds to the left (or right) side of the image.

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