CERPO

Centro de Referencia Perinatal Oriente
Facultad de Medicina, Universidad de Chile

Seminario Nº88
Ecografía 3D-4D

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Introducción

La tecnología 3D se basa en transductores avanzados que tienen la capacidad de adquirir un volumen o secuencia de volúmenes.

Table 1: Overview of 3D/4D visualization modes applicable to prenatal diagnosis.

3D display mode	4D display mode
Multiplanar mode	Multiplanar mode
Multislice/tomographic ultrasound imaging (TUI)	Multislice/TUI
3D surface mode	3D surface mode
Transparent mode	Transparent mode
Glass body mode	Glass body mode
Inversion mode	Inversion mode
Volume contrast imaging (VCI)	VCI
OmniView	OmniView
3D-animation (cine)	Spatio-temporal image correlation (STIC)
HD*live*	HD*live*
HD*live* Silhouette	HD*live* Silhouette
HD*live* Studio	HD*live* Studio

Merz E, Pashaj S. Advantages of 3D ultrasound in the assessment of fetal abnormalities. J Perinat Med. 2017 Aug 28;45(6):643-650.

Principios básicos

Preparación de la adquisición de volumen

- Optimización de la imagen 2D antes de la adquisición del volumen.

- Elegir el mejor plano de referencia para obtener el resultado esperado.

- Caja de adquisición de volumen.

- Ángulo de adquisición.

- Calidad del volumen y resolución.

Principios básicos
## *Optimización de la imagen 2D*

Fig. 1.1: Left: During the preparation of a 3D acquisition of a head and brain, part of the head will be absent in this case. In the figure to the right, the image is more centered and thus optimal for a 3D acquisition.

Fig. 1.2: Left. The image is not optimized and appears too "bright" with low contrast for a 3D acquisition in surface mode. Right: After image optimization, amniotic fluid appears black and transparent with the surface contours well defined.

Principios básicos
Caja de adquisición
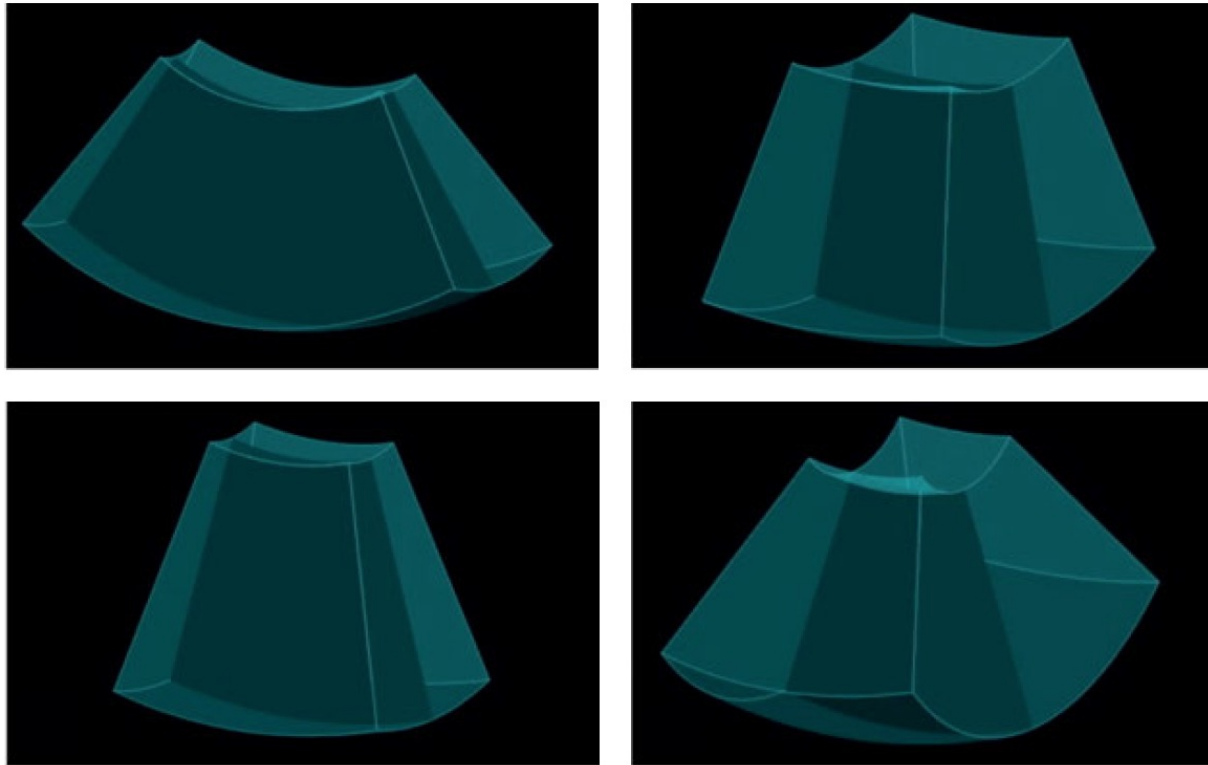
Fig. 1.7: The choice of the volume box shape is often determined by the examined region: Left up: typical volume box of a spine in a longitudinal view. Right up is an example of a box for a fetal face in 3D. The box in the left bottom image has a narrow volume depth in a STIC acquisition and the large box in the right bottom image is for the acquisition of a large body part as the head, or abdomen and thorax or a complete fetus in early gestation.

Principios básicos
Ángulo de adquisición
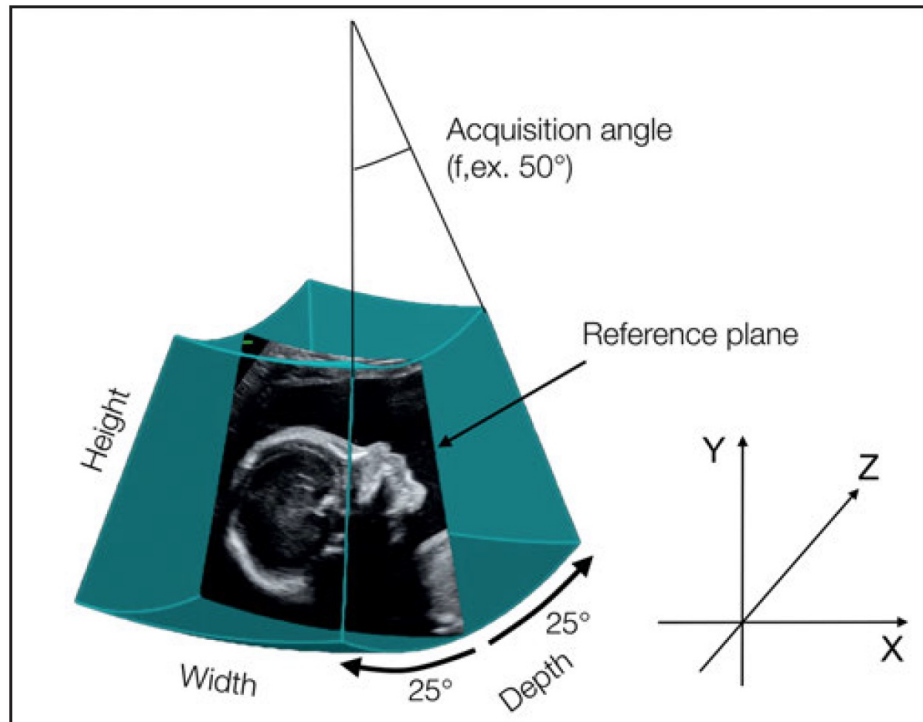
Fig. 1.5: A volume box size consists of height, width and depth. The acquisition angle is the total volume angle, which is during the acquisition half the angle in front and half the angle behind the reference plane. The reference plane is the image the examiner sees on the screen while activating a 3D acquisition.

Principios básicos

Calidad de volumen y resolución

Quality high

Quality low
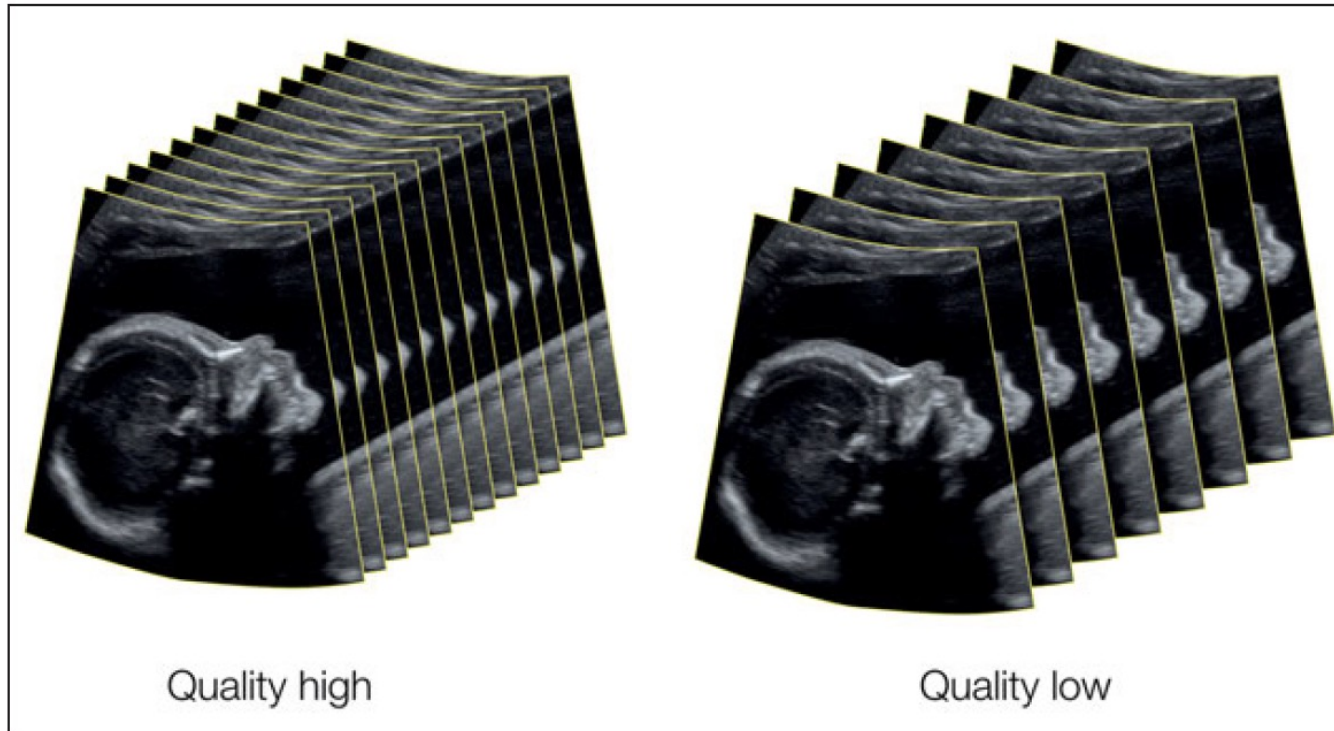
Fig. 1.8: With the same volume angle the choice of "high quality" acquisition (as maximum, high2, high1) leads to the acquisition of many images, with the result of a high resolution image, while the acquisition of few images leads to a low or middle quality volume.

Principios básicos
Calidad de volumen y resolución

Fig. 1.11: Fetal face after a 3D static acquisition in different qualities in "low", "mid2" and "maximum". The middle image appears to be the best and demonstrates that the best result is not always achieved by choosing the highest resolution.

Tipos de adquisición de volumen

- 3D estático

- 4D en tiempo real con transductor mecánico

- STIC (correlación de imagen espacio-temporal)

- 4D en tiempo real con transductor de matriz electrónica

Tipos de adquisición de volumen

3D estático

- Volumen único que contiene un número infinito de planos 2D.

- Permite ajustes post adquisición.

- Su principal limitante es la incapacidad de evaluar movimiento.

Tipos de adquisición de volumen

4D tiempo real con transductor mecánico

- Utiliza el principio de un motor de rotación continua que adquiere una serie de volúmenes representados como un movimiento.

- Su principal ventaja es su capacidad de representar instantáneamente volúmenes en tiempo real.

- Su principal limitante es el desafío de encontrar un balance entre una buena calidad de imagen y la velocidad de rotación del motor para dar una impresión real.

Tipos de adquisición de volumen

STIC

- Es utilizado para la adquisición de imágenes del corazón latiendo o de vasos con pulsatilidad.

- Permite crear un cine-loop de un ciclo cardíaco.

- Permite evaluar el movimiento de la pared miocárdica y la excursión valvular.

- Se puede combinar con otras modalidades de ultrasonido (color Doppler, power Doppler, HD Doppler, B-flow).

- Su principal desventaja es el retraso en la adquisición, que puede ser interferido por movimientos fetales o respiración.

Tipos de adquisición de volumen

4D tiempo real con transductor de matriz electrónica

- Posee un área rectangular de cristales que se activan 2 a 4 veces más rápido que los transductores mecánicos que solo tienen una fila de cristales.

- Mayor velocidad de adquisición de imagen.

- Su principal desventaja es el peso del transductor y el calor que produce.

Orientación y Navegación

- Almacenar volumen.

- Orientación en los 3 planos ortogonales.
  - Plano A: imagen de referencia.
  - Plano B: Rotación 90º.
  - Plano C: Plano horizontal.

- Navegación en los planos ortogonales.
  - Mover el punto de intersección en un plano.
  - Rotar los ejes.
  - Desplazarse a través del volumen para obtener imágenes paralelas.
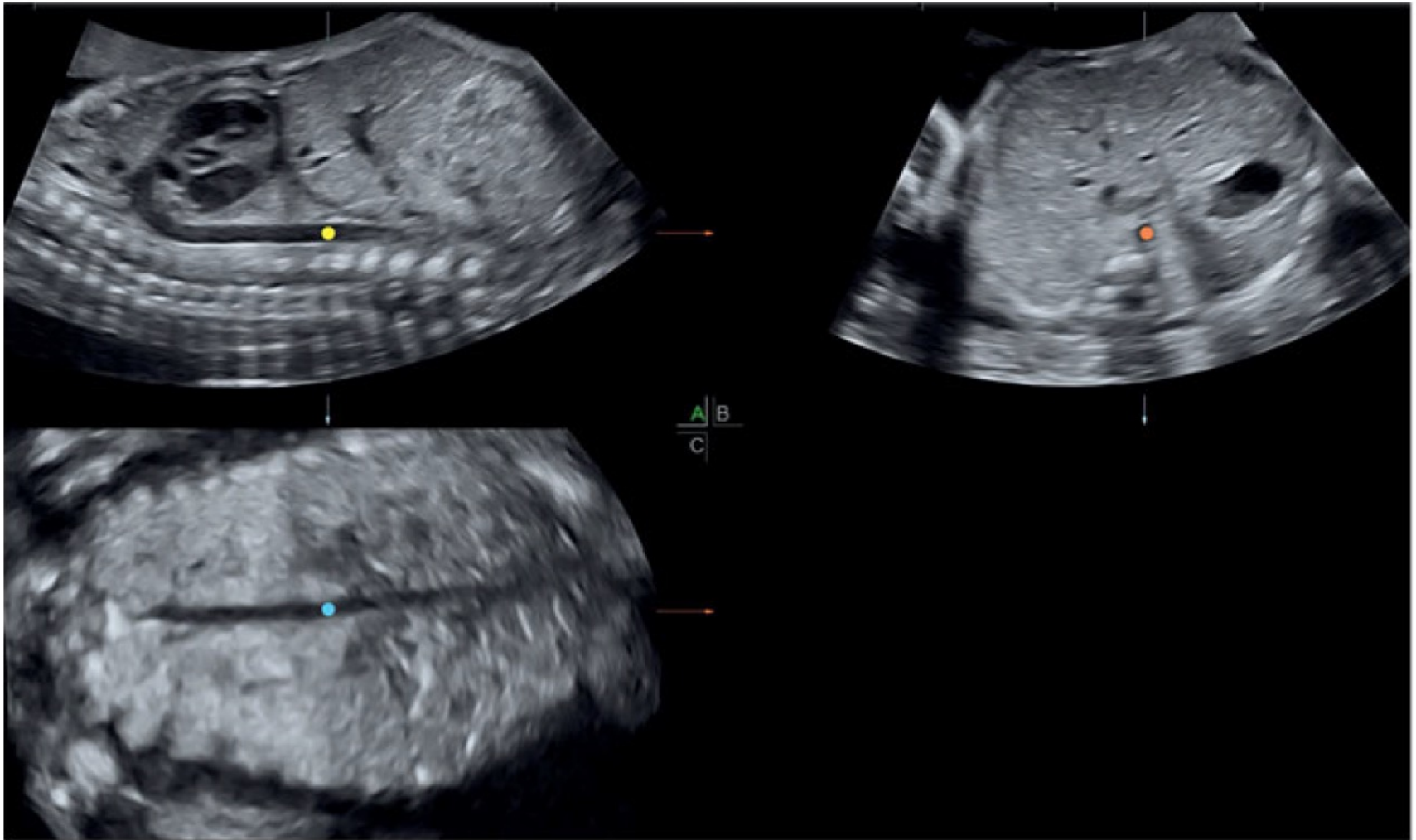
Fig. 2.4: (see also Figs. 2.2 and 2.3). In this figure, the intersection point now lies in the plane B in the aorta, which is also seen in planes A and C. Using this approach, the examiner can continue to navigate within the volume. Often, the resulting image should be adjusted by slightly rotating the volume, which is shown in the next figures.
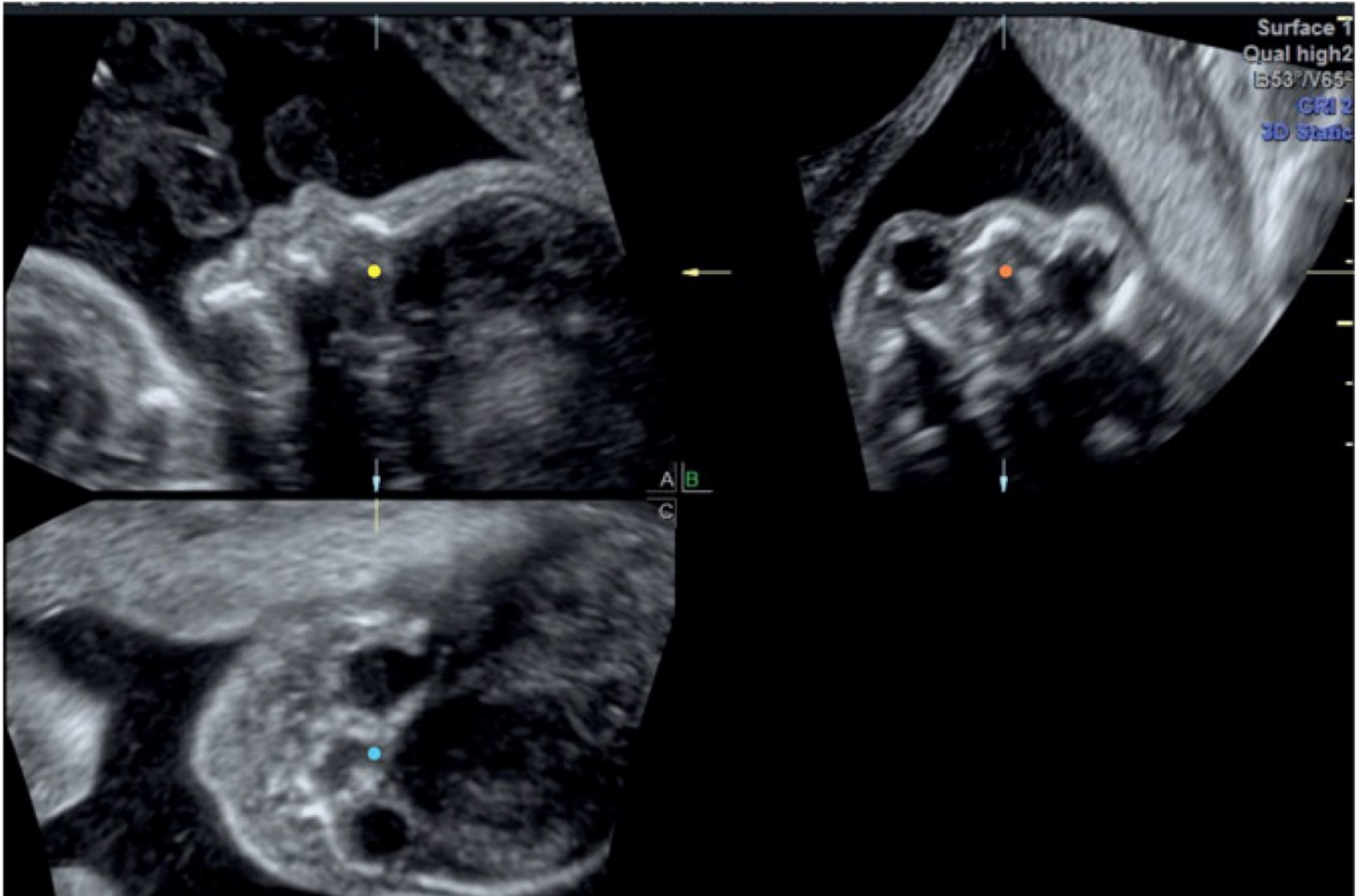
Fig. 2.6: The 3D volume in Fig. 2.5 was adjusted so that both eyes in plane B are positioned horizontally. In next step, plane C was adjusted to align the face axis and get in plane A the profile exactly in the midline.

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Rendering

Modos de representación de volúmenes 3D

Modos de representación de volúmenes
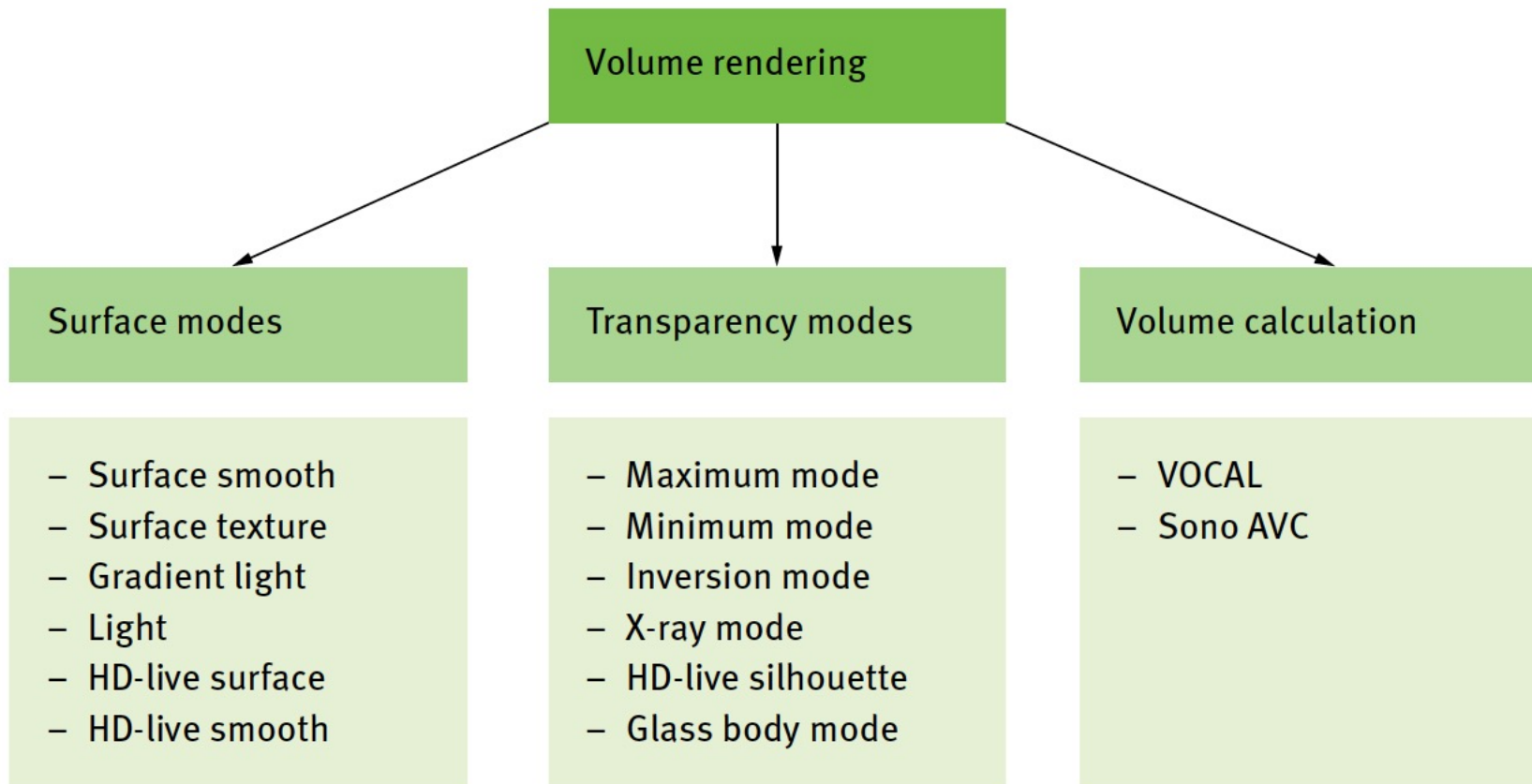
Fig. 3.28: Overview of the different volume rendering modes either in surface mode or in the different transparency modes with the different displays as illustrated in Figs. 3.9–3.12.

Caja de representación
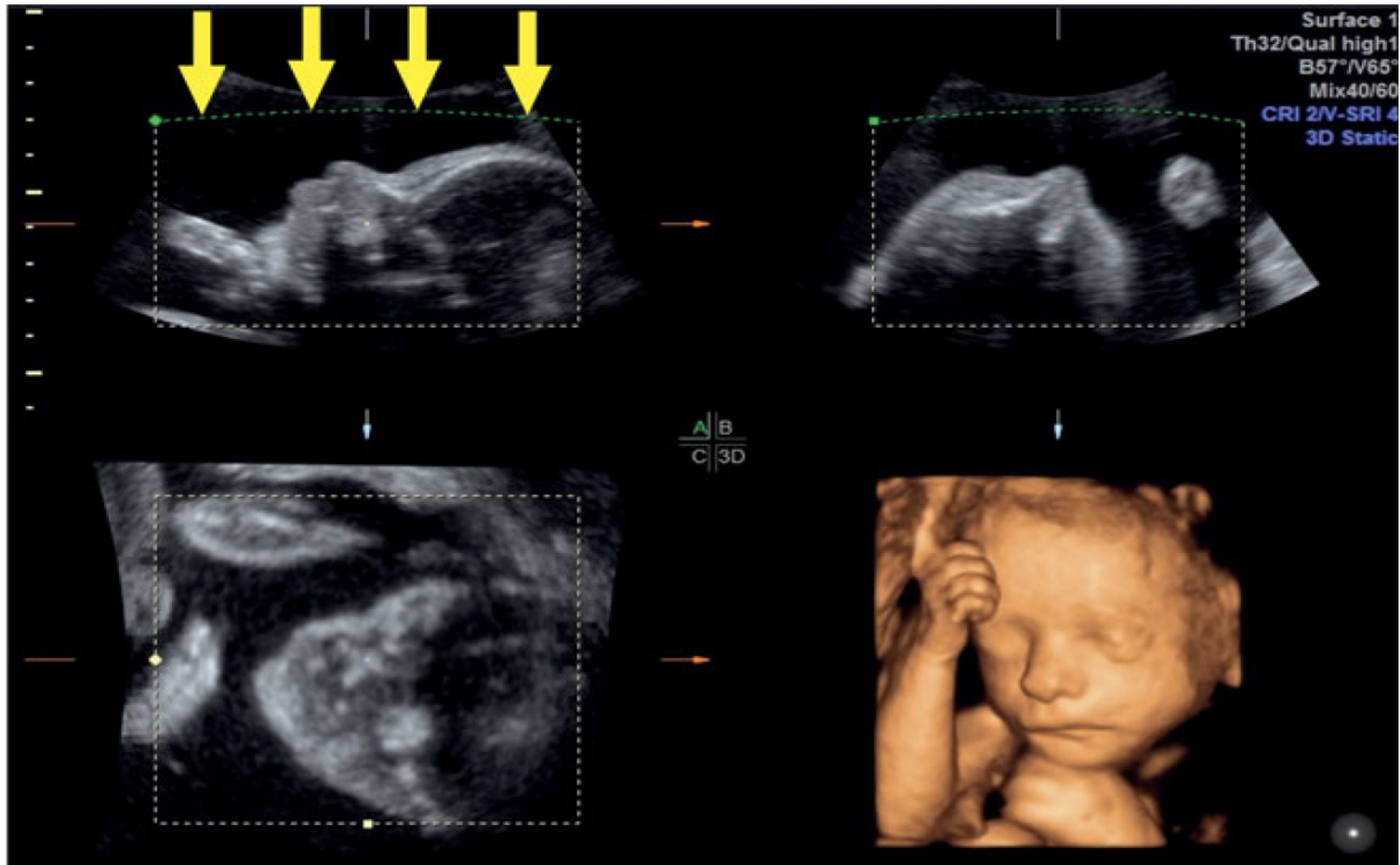
Fig. 3.2: In the 3D rendering mode of a fetal face the "green" projection line is placed on the top in front of the face (arrows).

Caja de representación
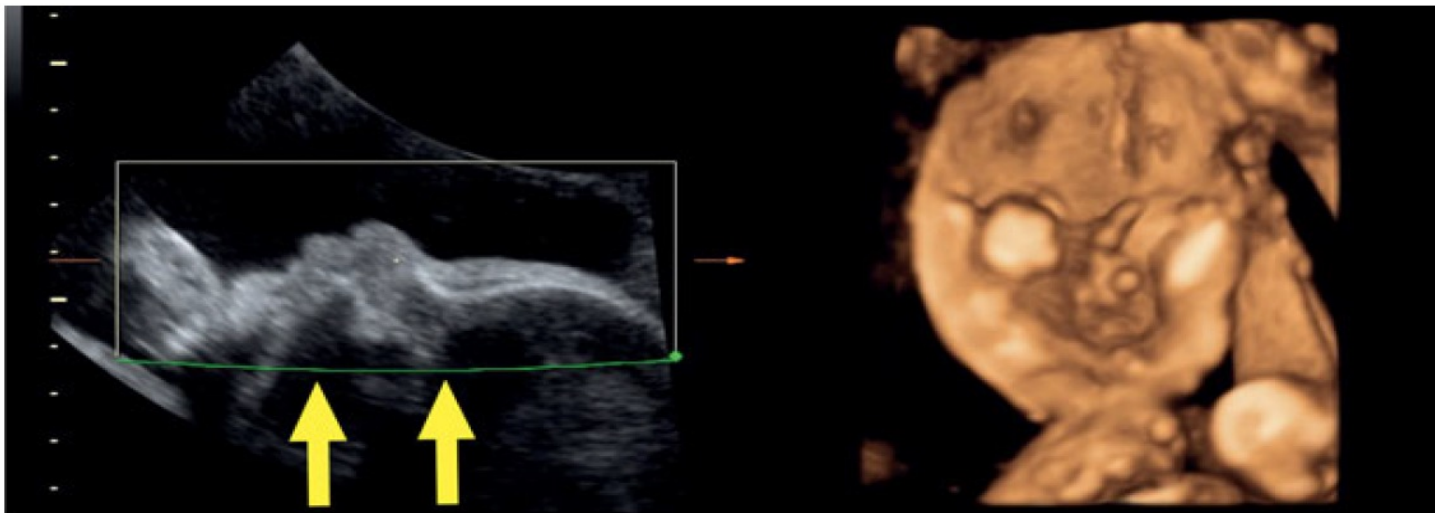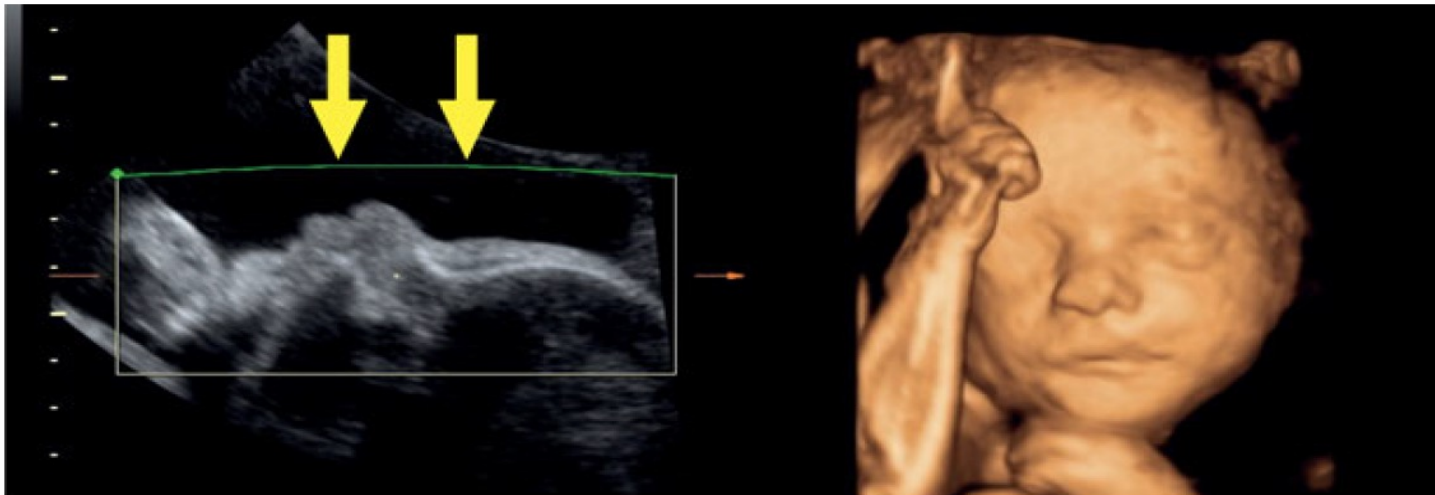
Fig. 3.5: Upper panel: The projection line is placed in the amniotic fluid in front of the face (arrows). In the lower images, the projection line is placed behind the face and the so-called reverse-face view is displayed.

Modos de representación

- Modo superficie
  - Superficie lisa/textura
  - Modo luz
  - Gradiente de luz
  - HD-Live

Surface smooth

Surface texture

Gradient light 100%

Texture 100%

Gradient light 70%
Texture 30%

HD live surface 50%
HD live smooth 50%
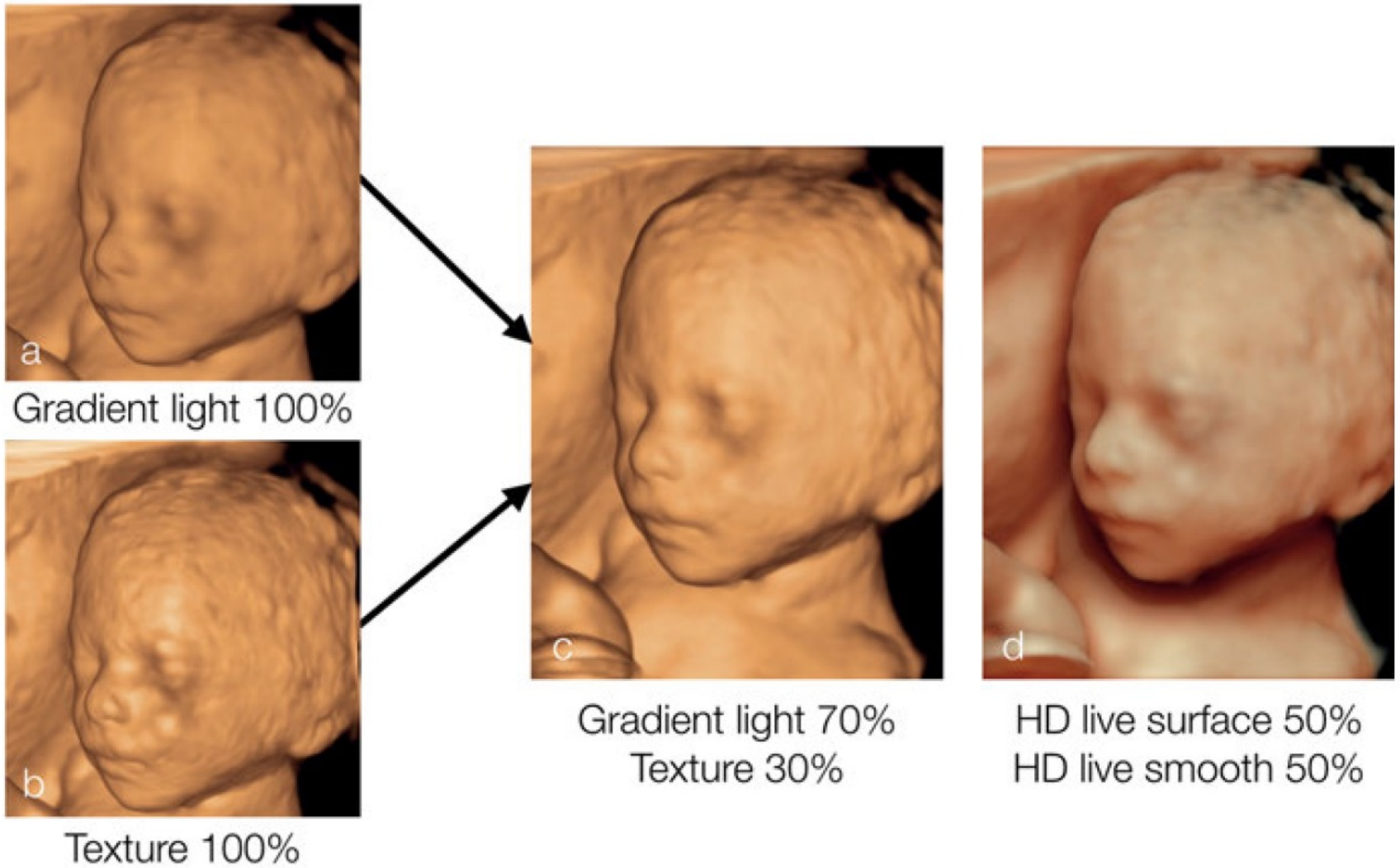
Fig. 3.10: Generally speaking, a mixture of two display modes is applied in a 3D image. The figure shows a fetal face in "gradient light" (a) and "surface texture" (b) and a better result in c) in a mixture of 70/30 %. The figure in d) is a result of a combination of High-definition (HD-) live surface and smooth of 50/50. There is no perfect combination, since each user has his personal preference.
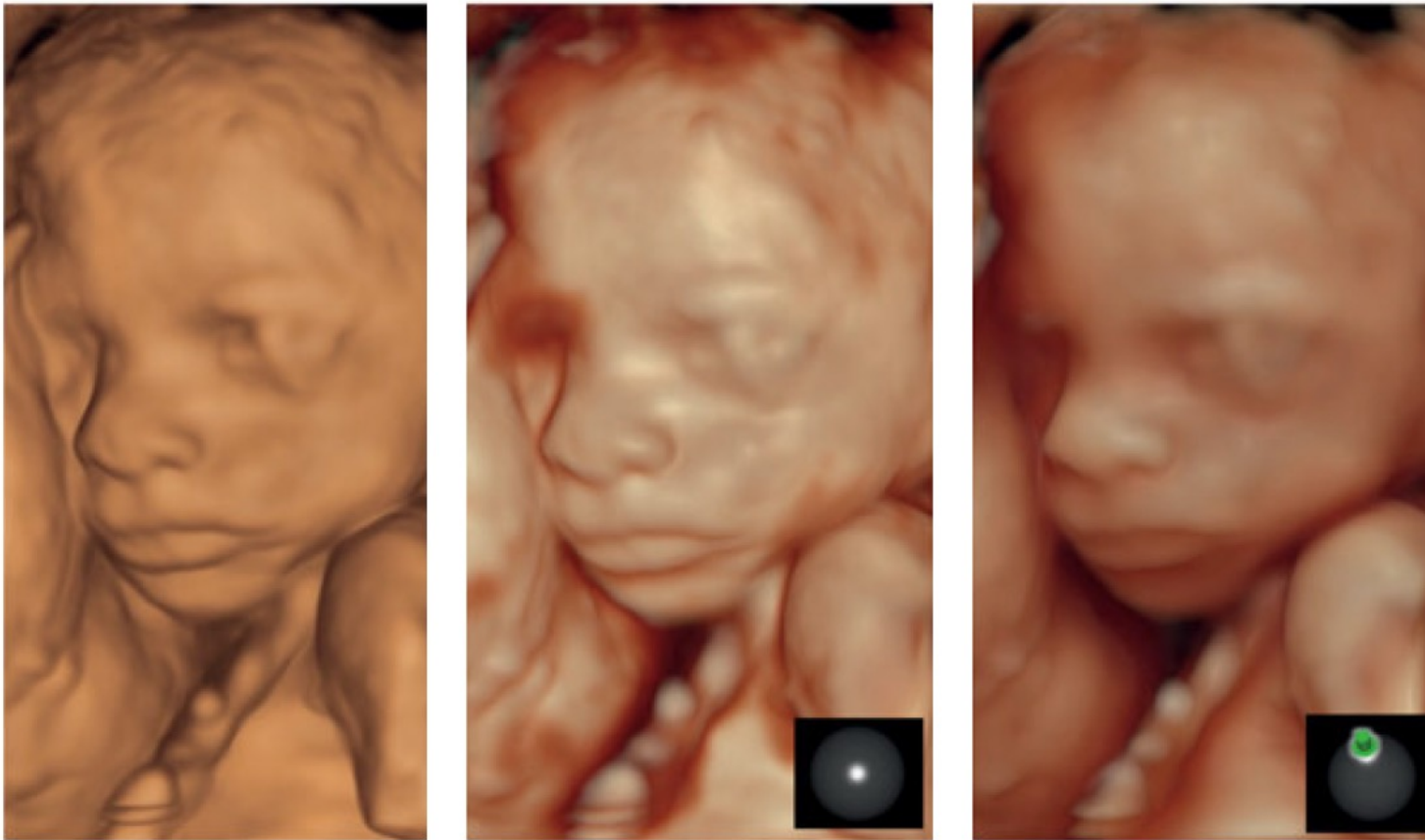
Fig. 3.11: These figures show the step-by-step manipulation of a fetal face volume using HD-Live. The panel at left reveals that surface mode rendering with gradient light has been selected after 3D acquisition. The middle figure presents the result after the switch to HD-live mode with 50/50 ratio of "texture" and "smooth". The final image (right) is the result after increasing HD-live to 100 %, increasing shadowing and transparency and changing the position of light source.

Modos de representación

- Modo transparencia
  - Máximo
  - Mínimo
  - Inversión
  - X-Ray
  - Silhouette
  - Glass-body
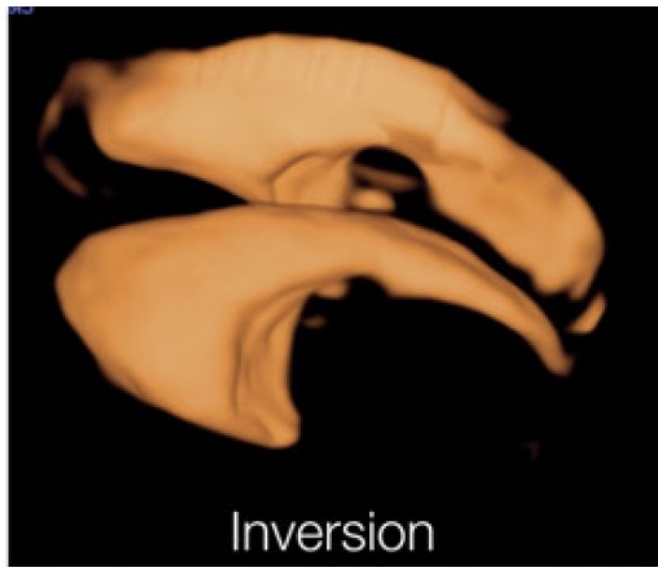
Fig. 3.12: Demonstration of different organs and regions by using different transparent modes as maximum mode, minimum mode, inversion mode and X-Ray contrast mode. Please refer to the text and corresponding chapters regarding different modes.
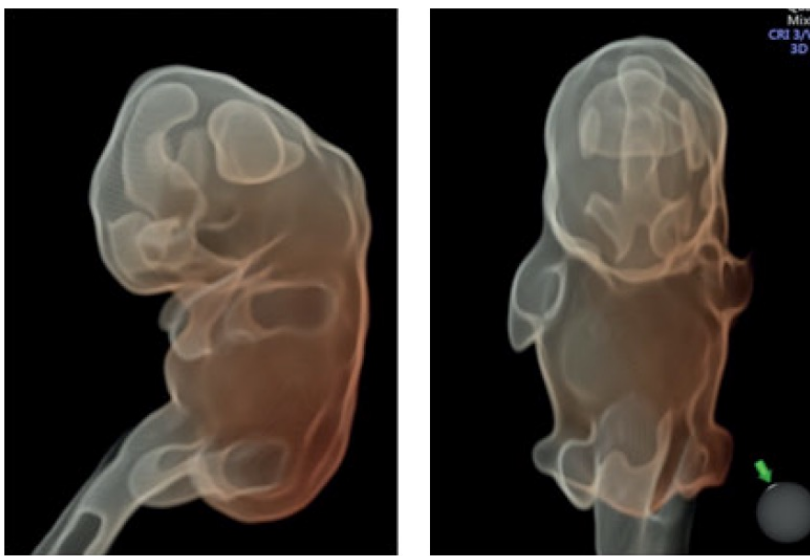
Fet. 11.16: Embryo at 8 weeks' gestation with high level of silhouette effect, with a view from lateral (left) and then a view from ventral (right). Note the clear display of the ventricular walls.
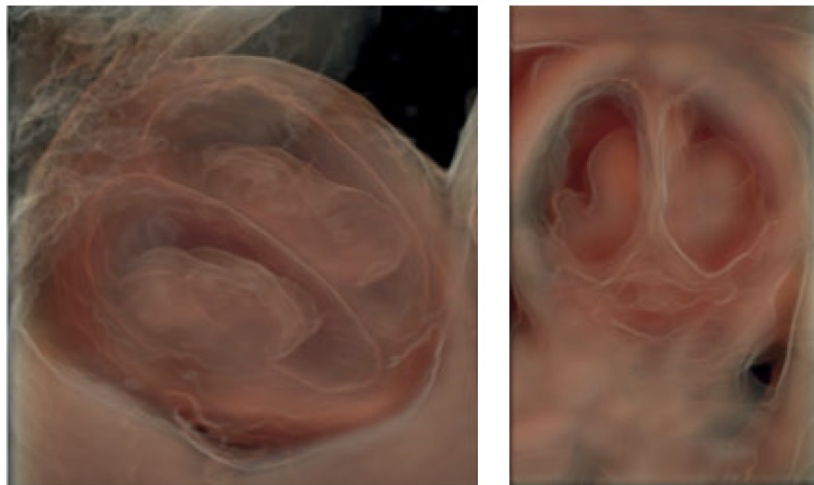
Fig. 11.17: Two fetuses with ventriculomegaly at 14 (left) and at 17 weeks' gestation (right). The view is across the fontanelle and the silhouette effect is activated. Note that the dilated ventricles with large plexus choroidei are recognized with the silhouette effect.
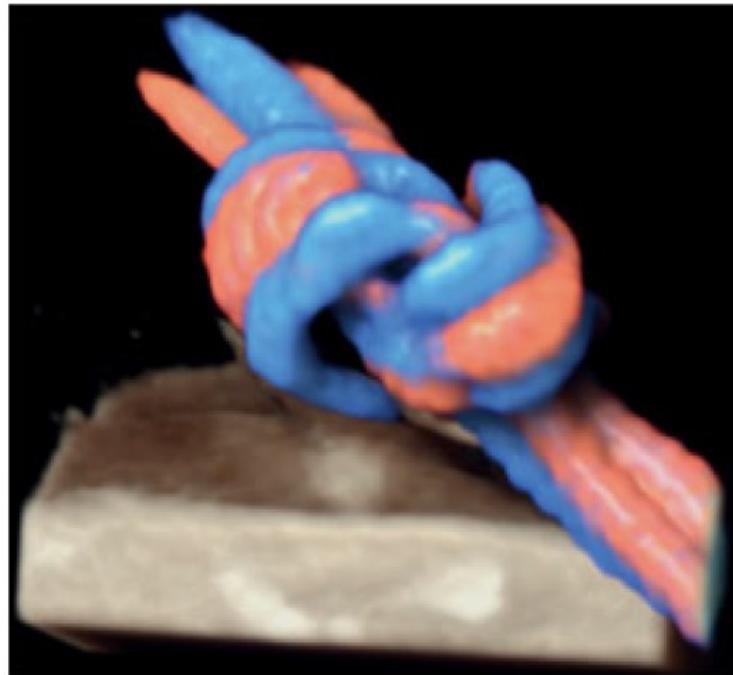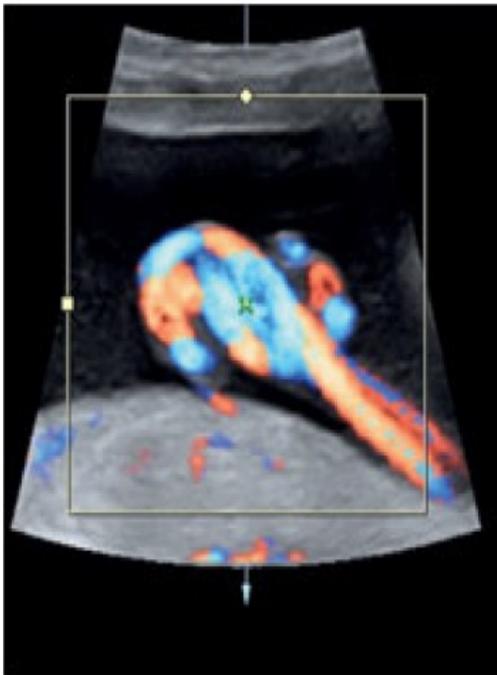
Fig. 12.8: In color Doppler, a true or a false knot in the umbilical cord is suspected (left). In 3D glass-body mode (right), the true knot is recognized due to the spatial display.

Ajustes post adquisición

- Efectos especiales en 3D.
  - Profundidad dinámica y fuente de luz.

- Umbral de grises
- Transparencia/Ganacia
- Brillo/Contraste
- Escala de color/Tintes
- Magicut
- HD-Live estudio

Fig. 3.13: The effect of depth can be improved by using the tool "dynamic depth rendering", which adds a color blue or black to the structures that are deep in the volume, making the amniotic fluid blue in this case. The image to the left is the raw image and the images in the middle and to the right and are the result after adding black and blue respectively. The level of color can be adjusted according to the depth information in the image (see Fig. 3.14).
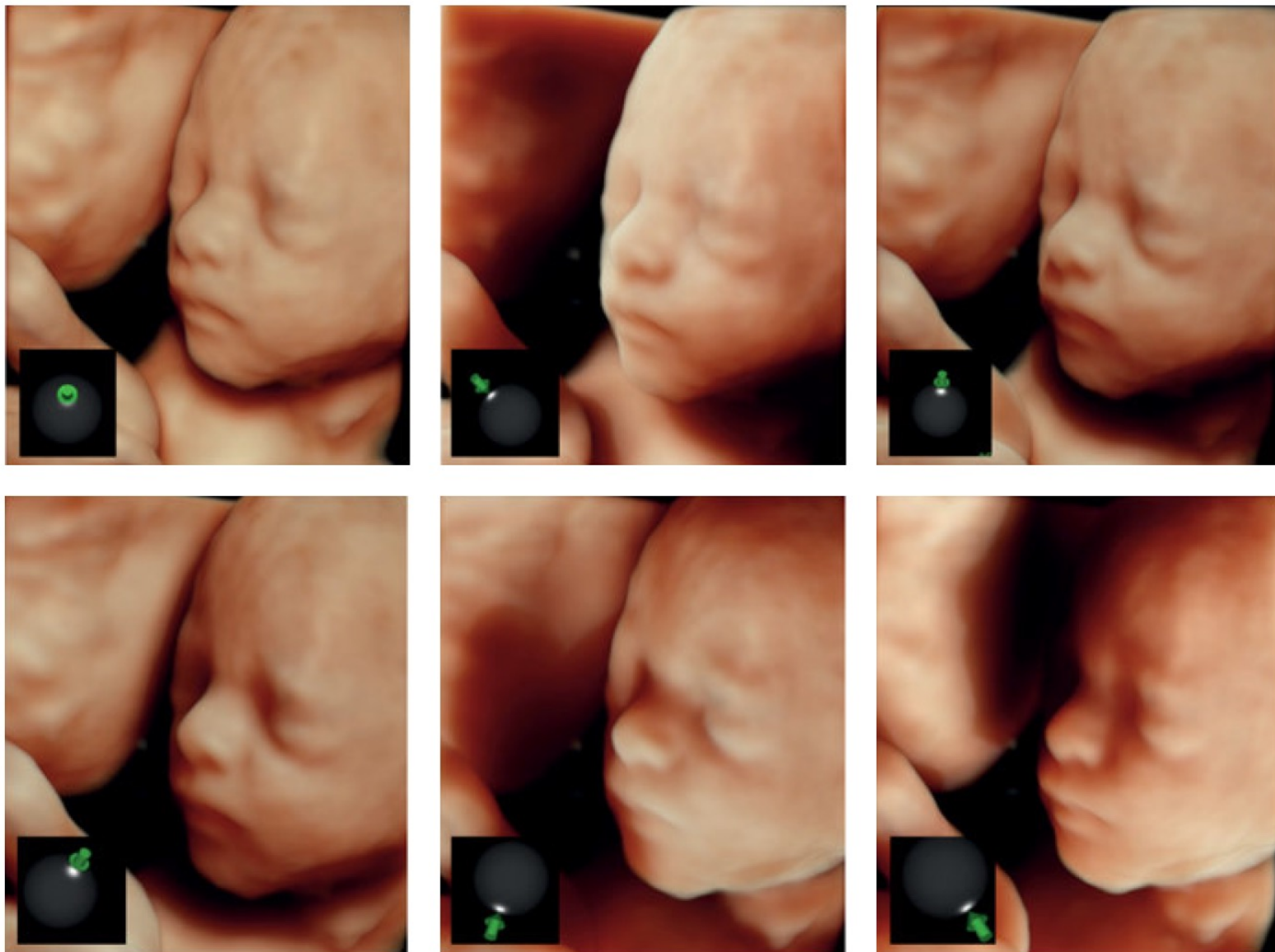
Fig. 3.15: With the recent software the 3D effect can be improved by using a light source. Similar to a torch the lighting can be placed in different positions with a shadow recognized behind the structures. Ideally for a fetal face we prefer to place the light source in the upper part of the image (see also Fig. 3.16).
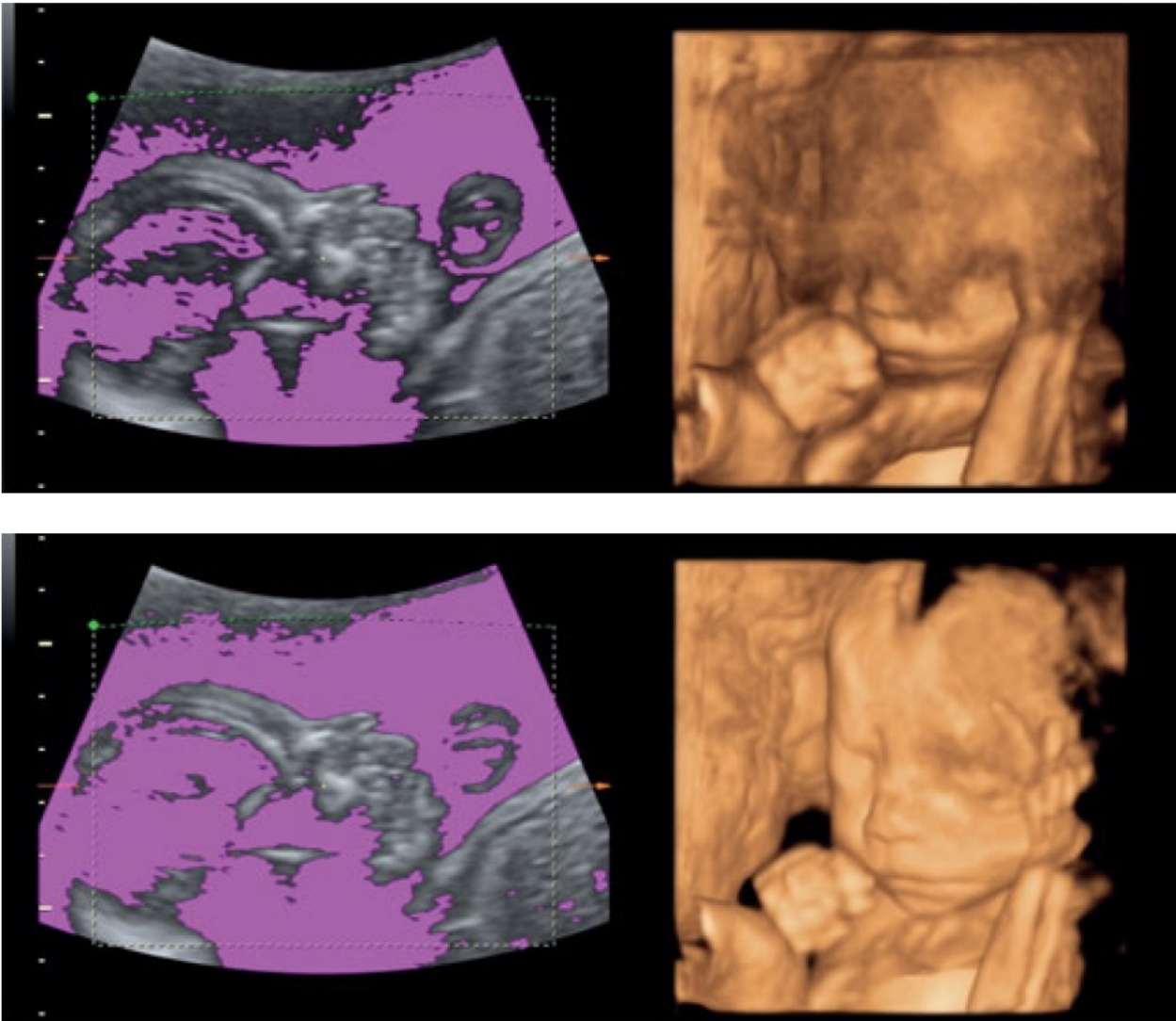
Fig. 3.17: Increasing the level of "threshold" and its impact on the 3D image. The magenta color shadow appears only as long as the knob is used. There is no „ideal" threshold level but the level is selected according to the result seen on the screen.
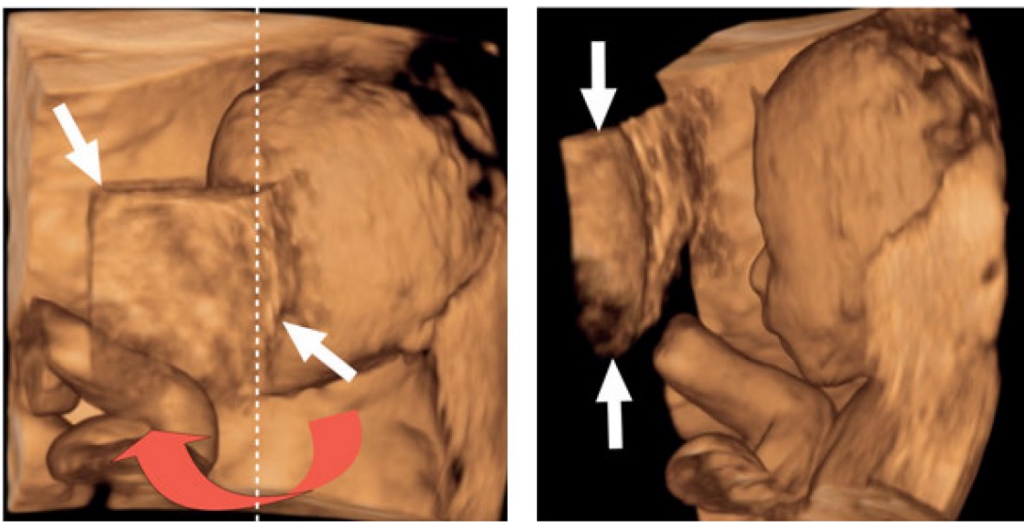
Fig. 3.19: The electronic scalpel is also known by the name "Magicut". After a volume data set is frozen, the volume can be rotated in all directions and undesired information can be removed. On the left this structure (placenta or uterine wall) is obstructing the face and has to be removed (arrows). After a vertical rotation (right) the interfering information can be clearly identified and removed with Magicut (see next figure).

Fig. 3.20: Left: With Magicut the structure in front of the face is removed after rotating the volume. The face then appears clearer on the right side, but there still are structures besides and behind the head, which can be removed.
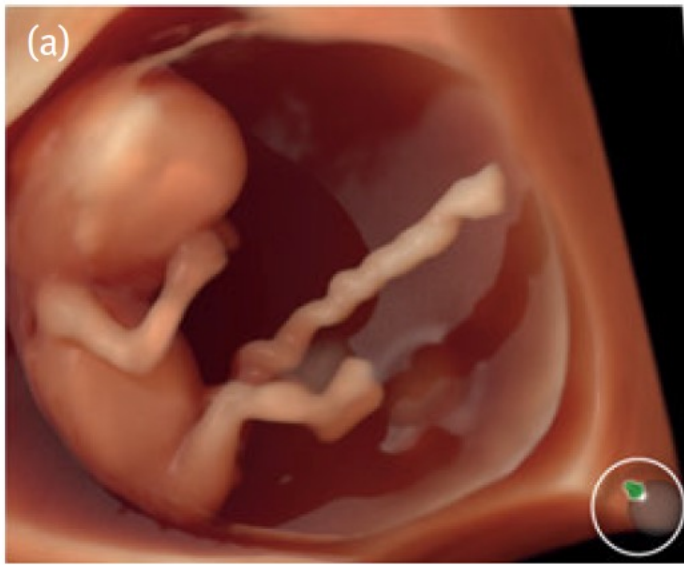
Fig. 3.24: The fetus at 12 weeks is displayed in 3D HD-live smooth with one light source. The examples in (b), (c) and (d) illustrate the same volume but applying the new HD-live studio with three light sources and special light effects. The circles indicate the light sources used.
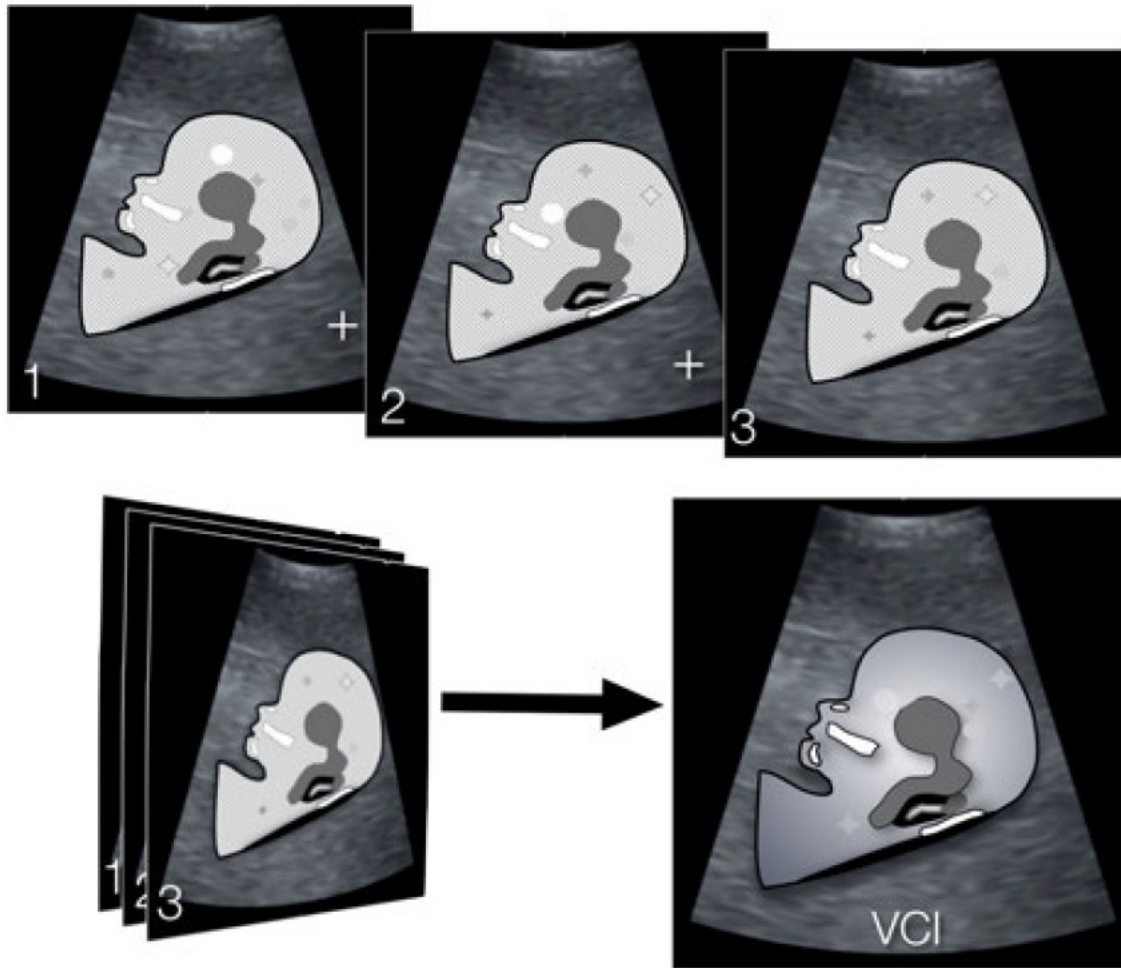
Volume Contrast Imaging (VCI)

Imágenes de contraste de volumen

VCI

- Reconstrucción de una imagen 2D a partir de un volumen 3D para reducir los artefactos y aumentar la calidad, contraste y resolución de la imagen.

- VCI estático
  - X-Ray
  - Máximo
  - Mínimo
  - Inversión
- 4D con VCI-Omniview
- 4D con VCI-A

Fig. 4.3: Series of schemes illustrating the VCI effect. In this fetal face from a 13 weeks fetus the true information present in adjacent images is from nasal bone, maxilla, chin, and brain tissue. However, artifacts are found in the different parts of the images, as illustrated with stars and circles. Adding three images leads to an increase in the true information and an almost disappearance of the artifacts around (compare with clinical example in the following figures).
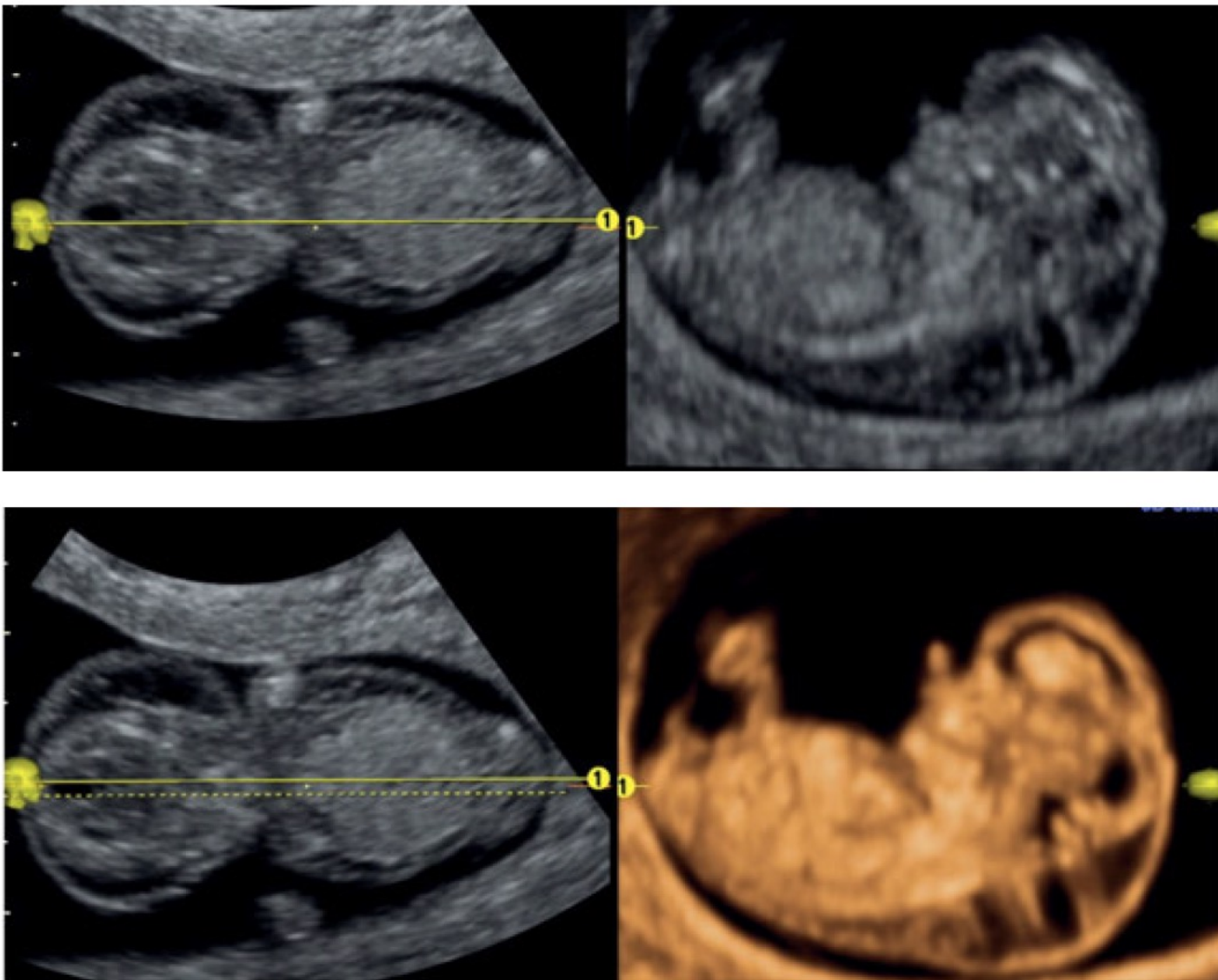
Fig. 4.5: Omniview display of the midsagittal view of an embryo. In the upper panel, native reconstruction of the plane of interest has a reduced resolution (upper right image), while in the lower panel VCI tool was activated and provides better contrast and resolution of the reconstructed image (lower right image).
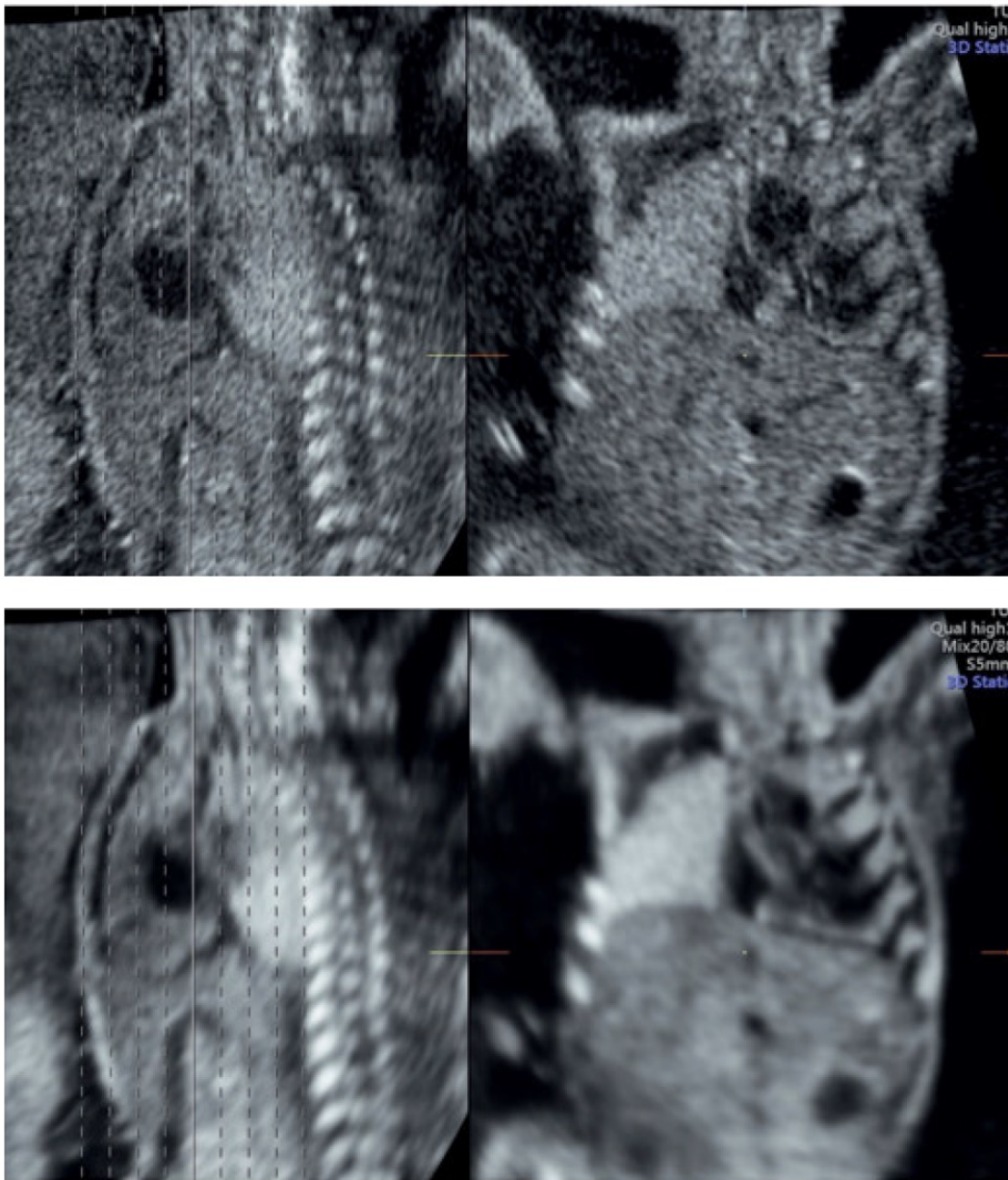
Fig. 4.6: 3D volume with a coronal visualization of lung, heart, diaphragm and liver. The upper images present a native image with tomography mode. The lower images show the result after activating VCI and increasing contrast and details recognition.
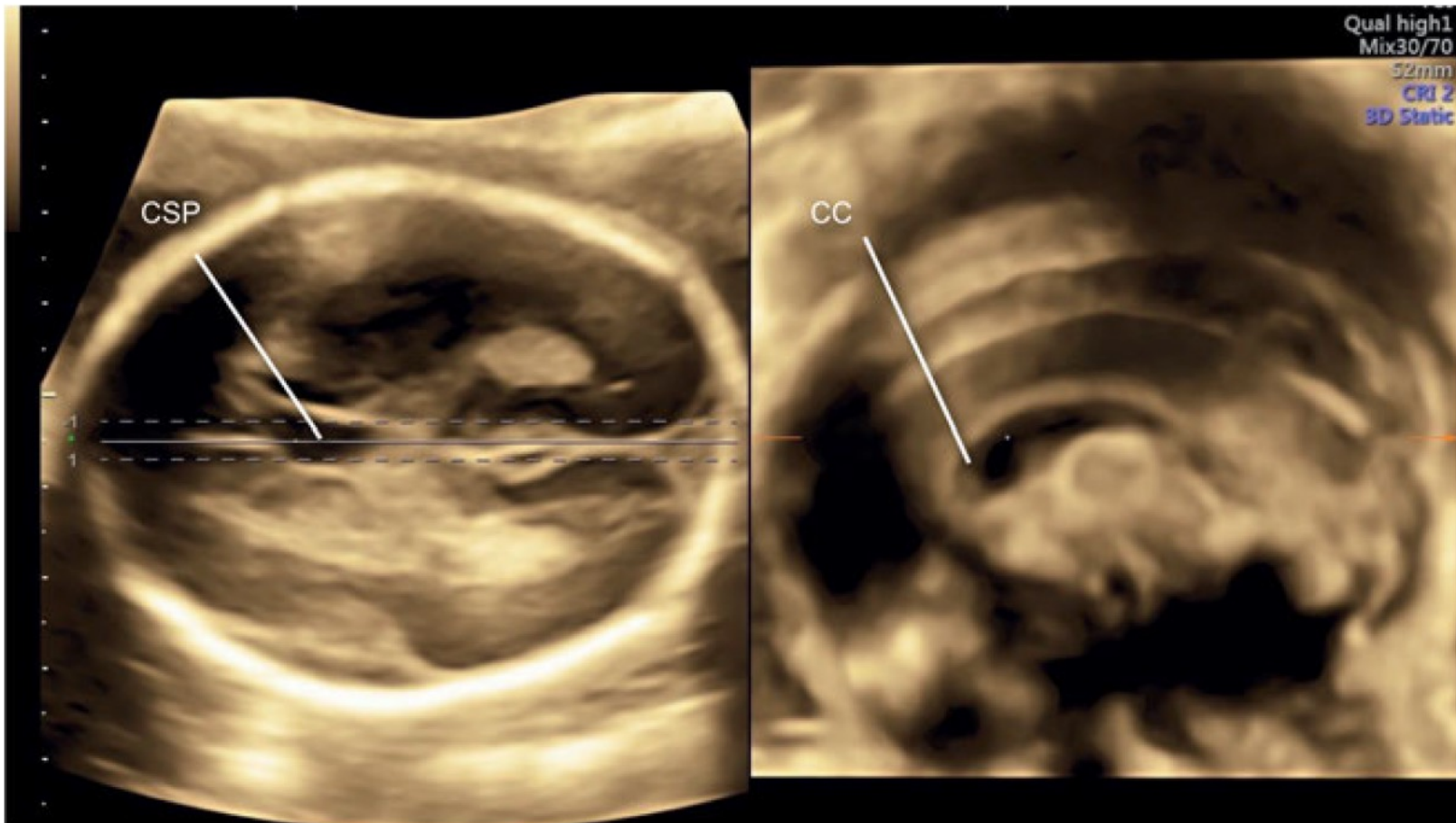
Fig. 4.8: In this fetus lying in vertex presentation, the corpus callosum cannot be visualized. After an axial 3D volume acquisition of the head and placing the reconstructed plane along the falx cerebri and cavum septi pellucidi (CSP) in the left image, the corpus callosum (CC) can be reconstructed (right). The image quality is improved by adding VCI with 2 mm thickness.
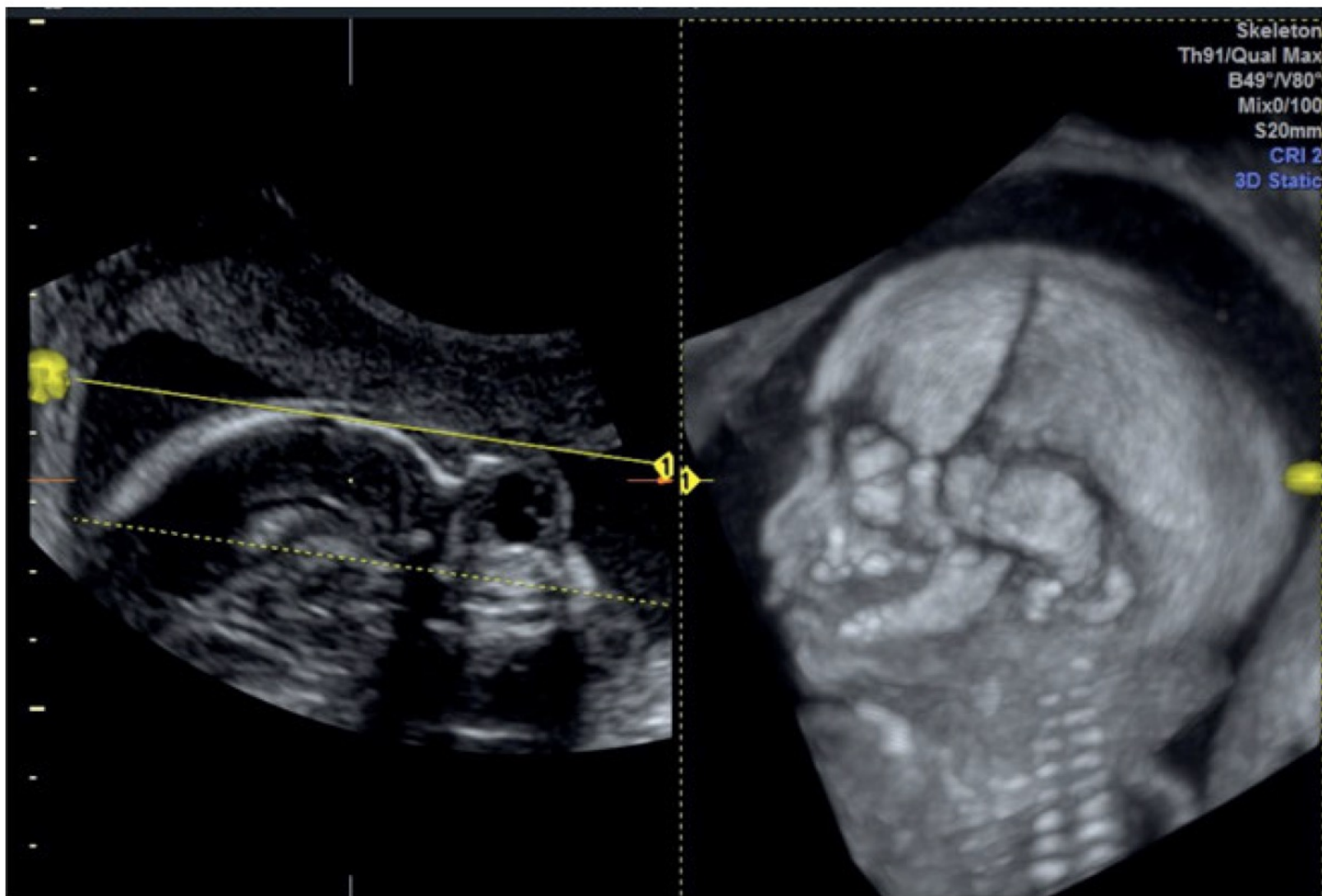
Fig. 4.9: Lateral acquisition of a 3D static volume of the fetal head with a VCI of 20 mm and maximum mode display revealing the skull bones with the corresponding sutures.

# Multiplanar

Ortogonal y Omniview

- Reconstrucción multiplanar

    - Imágenes únicas o multiples en modo multiplanar ortogonal.

    - Imágenes únicas o múltiples en modo tomográfico.

    - Imágenes únicas obtenidas por corte selectivo usando Omniview.
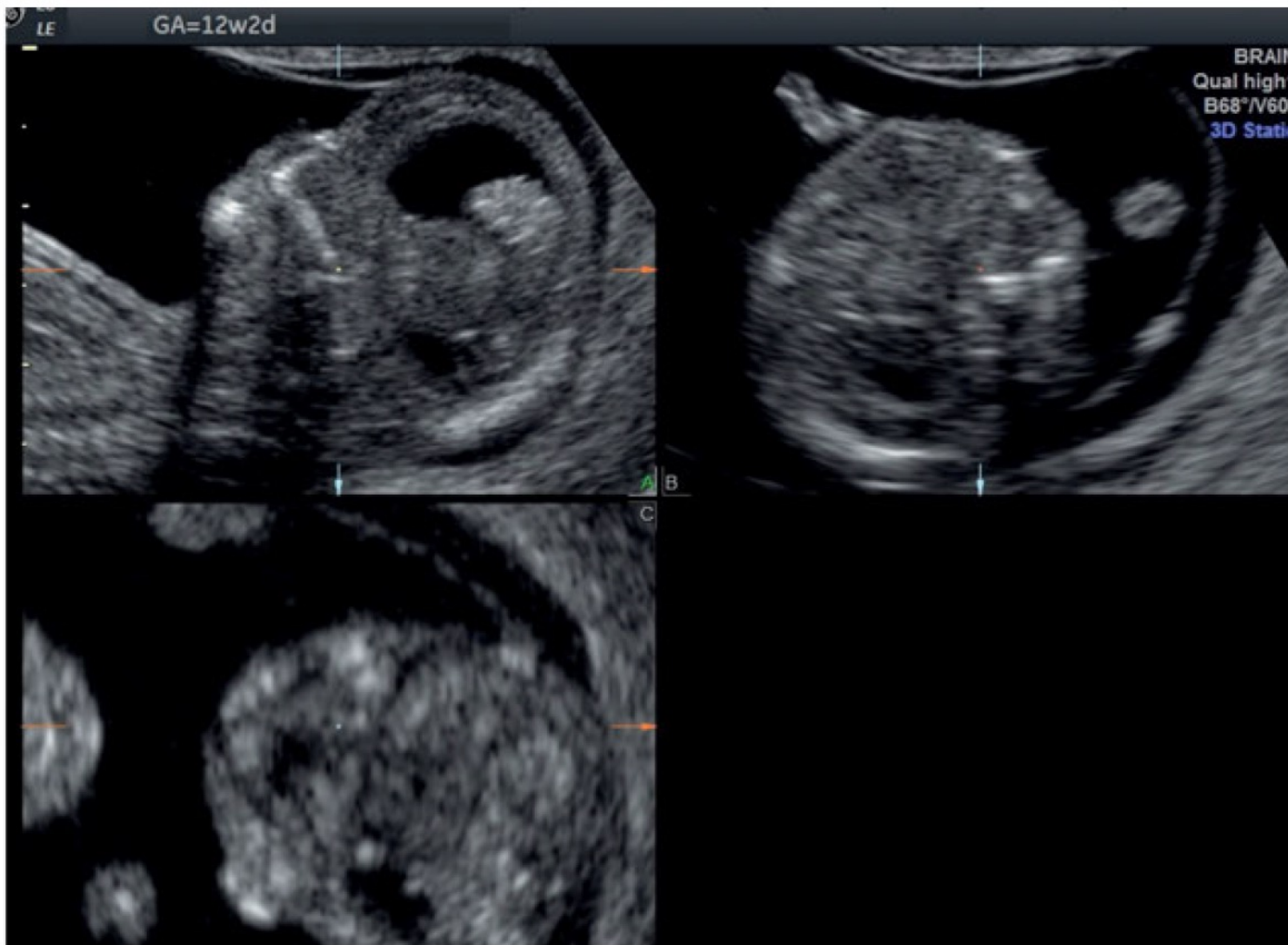
Fig. 5.1: Step-by-step reconstruction of a plane out of a volume data set. During a transvaginal examination, it is often difficult to manipulate the transducer to obtain the ideal view of the structure of interest. In this case the examiner tried to obtain a view of the profile and decided to do it by reconstruction. The acquisition of the fetal face is performed from the side, as close as possible to the final plane of interest (see next images).
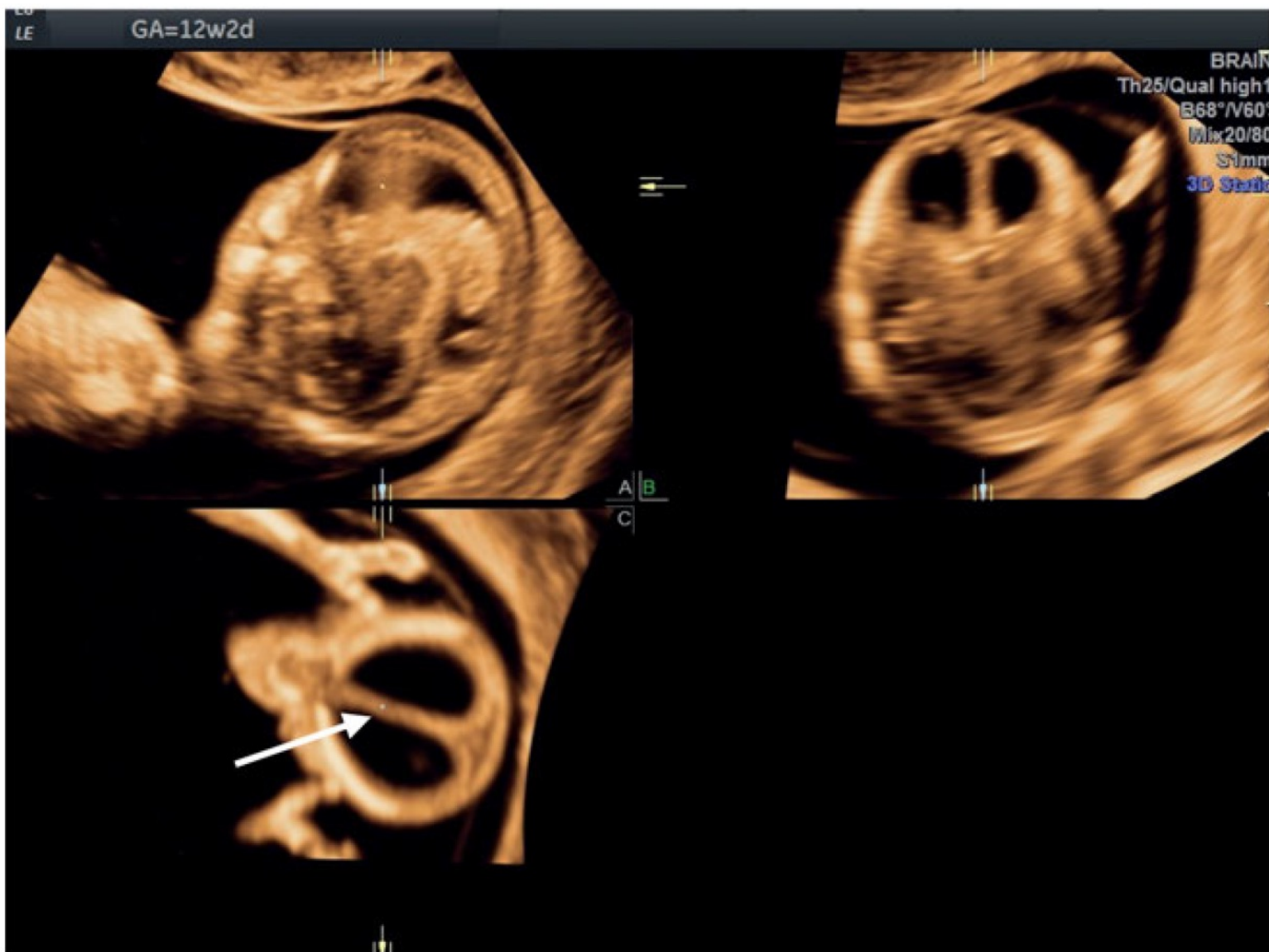
Fig. 5.2: Taking the volume of Fig. 5.1 the VCI tool is activated to enhance contrast and the intersection dot is placed on a well identifiable structure as the falx cerebri (arrow). In the bottom the falx is oblique in plane C. Therefore, the lower image is turned until the falx aligns with the X-axis and the plane in B is aligned as well. The result is seen in Fig. 5.3.
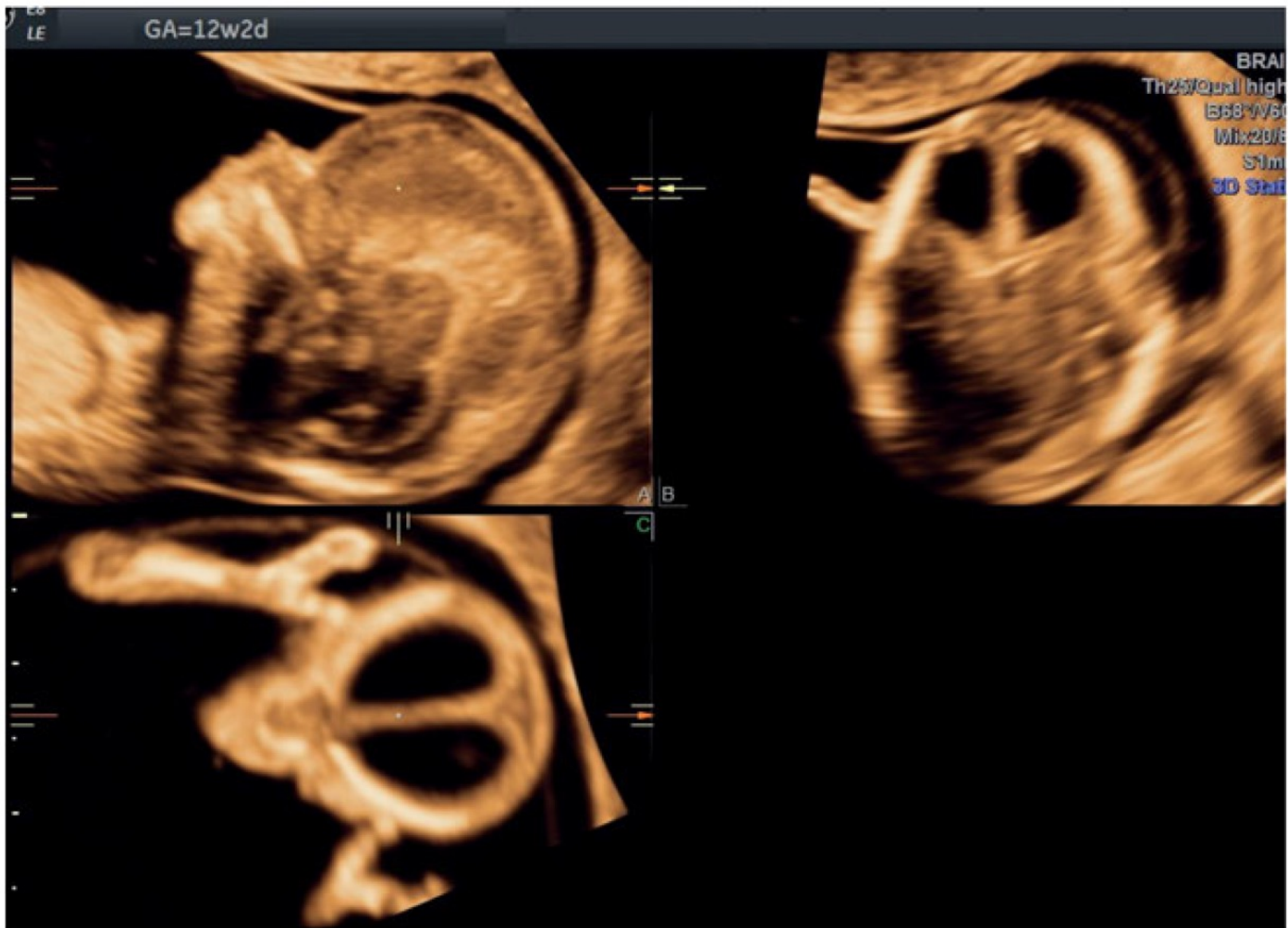
Fig. 5.3: Continuing Fig. 5.2. Now the falx lies in the X-axis and the intersection dot is on the falx cerebri and in the plane A the profile is well recognized. Fig. 5.4 reveals the final result.

Fig. 5.4: Result of a fetal profile reconstructed from the volume data set of an oblique view of the fetal face (see Figs. 5.1–5.3). Now nasal bone and nuchal translucency are well seen and the nuchal translucency is measured.
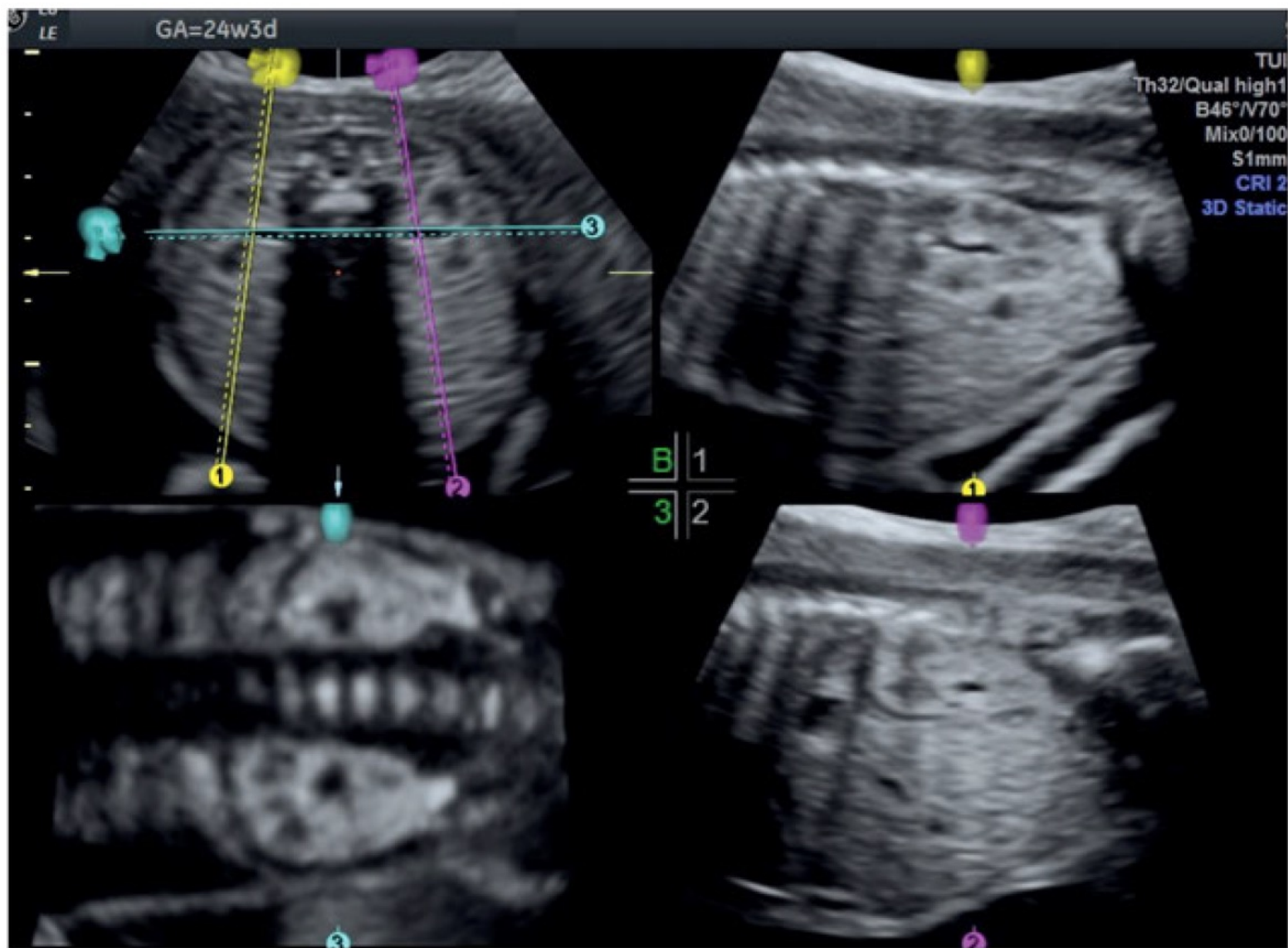
Fig. 5.8: Use of Omniview in the visualization of kidneys. The 3D volume was acquired in a fetal dorsoanterior position and kidneys are found left and right to the spine. Two Omniview lines are drawn parasagittal (1, yellow line, 2, magenta line) and one frontal (3, cyan line) highlighting the kidneys from different perspectives.

Multiplanar

Modo tomográfico (TUI)

- Modo de representación de volumen como planos paralelos similar a lo obtenido en TC o RM.

- Después de elegir la región de interés se puede controlar el numero de planos y la distancia entre éstos.

- Se pueden utilizar las mismas herramientas de navegación del modo ortogonal.
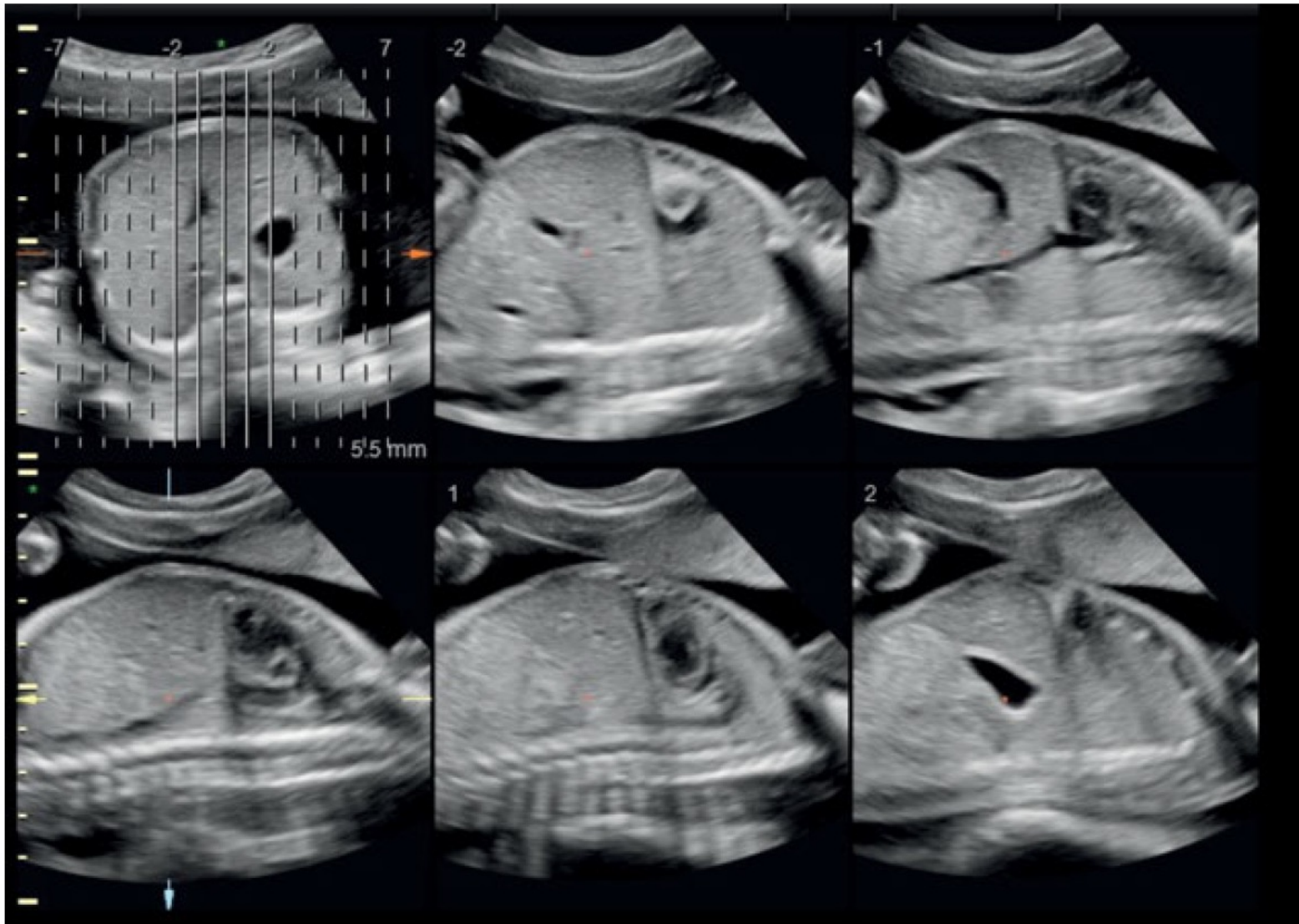
Fig. 6.3: The same display as in Fig. 6.2, but plane B was activated. The orientation plane is in the upper left panel, with the demonstration of parasagittal planes from left to right.
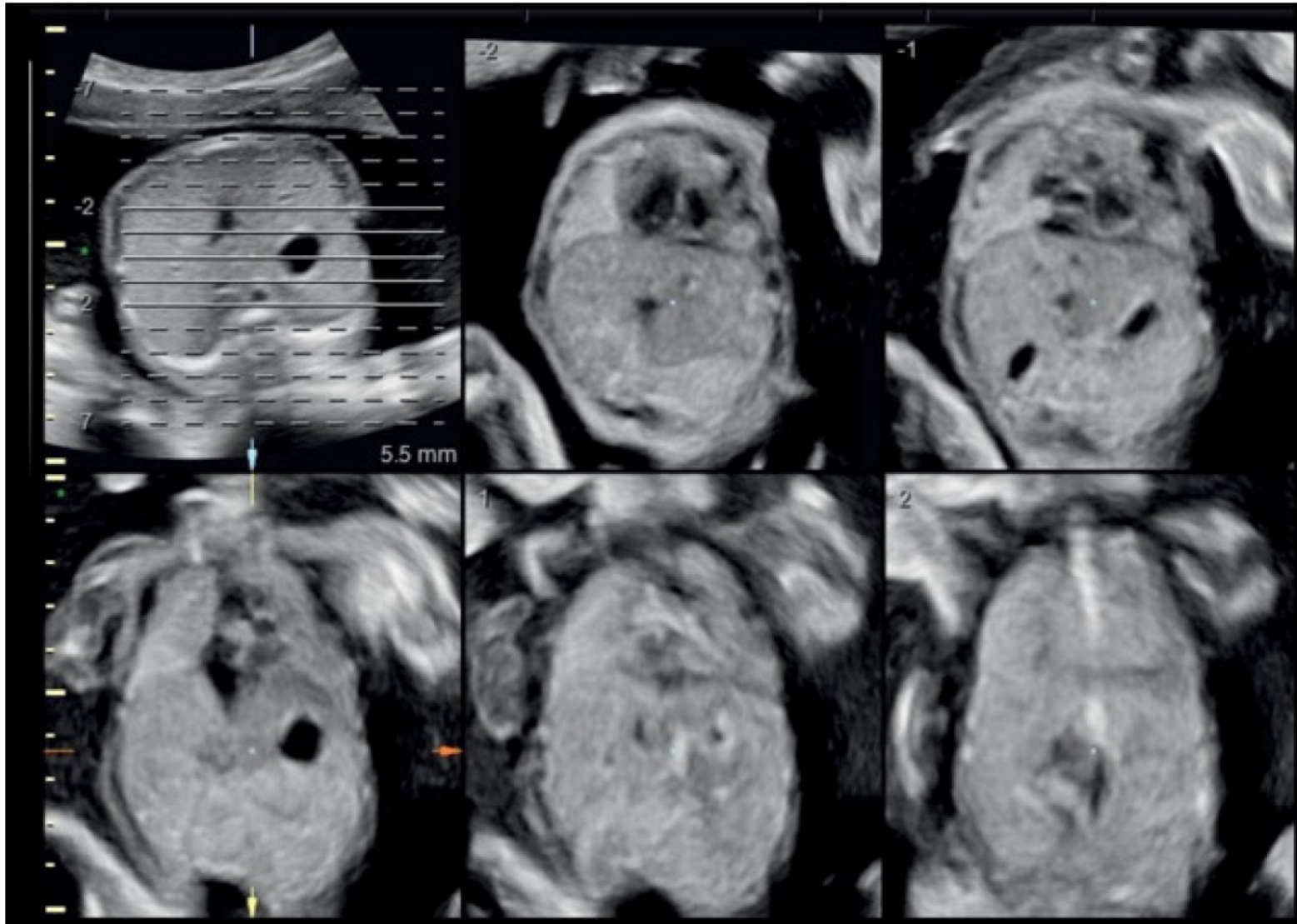
Fig. 6.4: The same display as in Fig. 6.1 and 6.2, but in this case, plane C is activated with the demonstration of coronal planes from anterior to posterior.
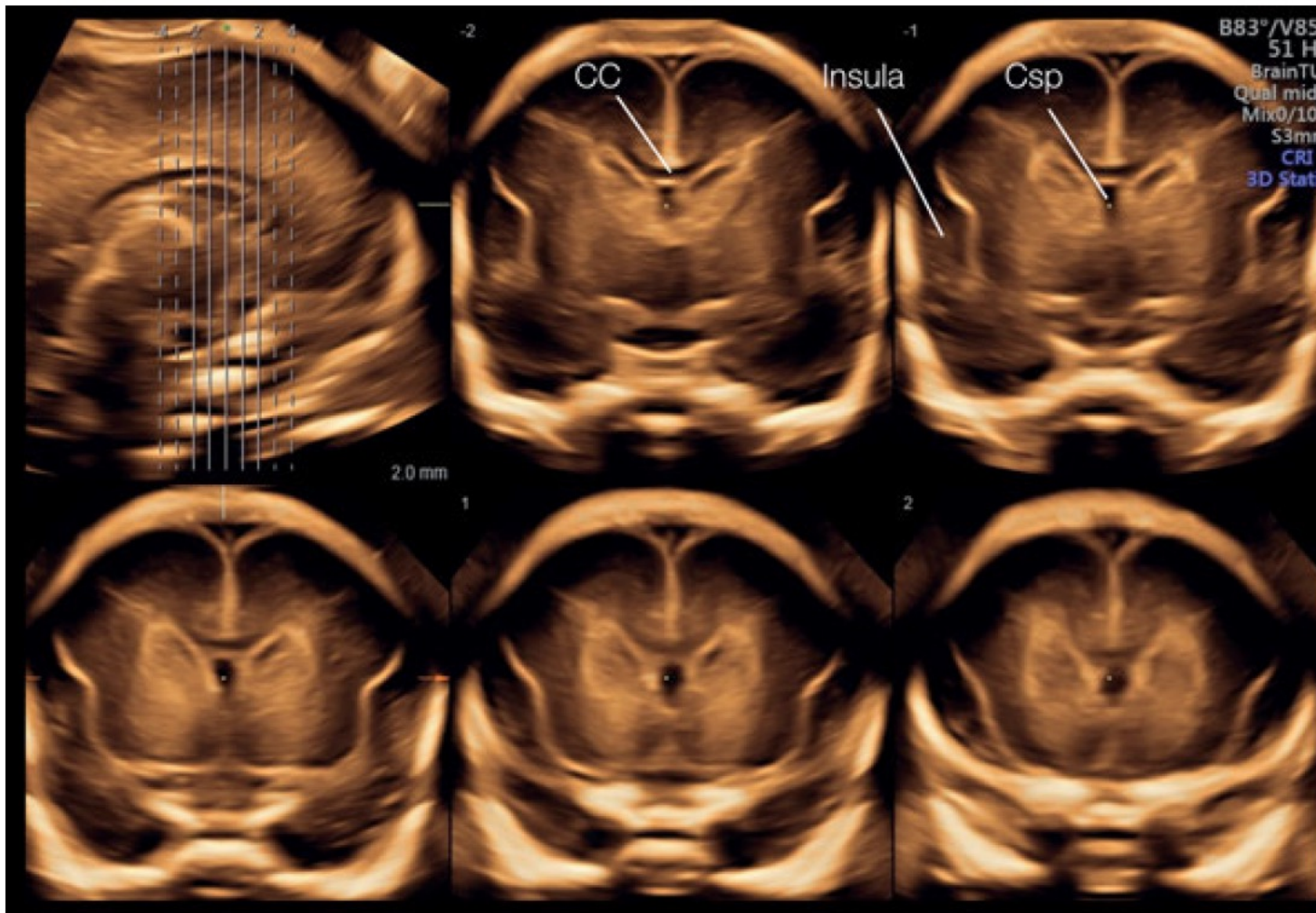
Fig. 6.13: Transvaginal neurosonography in tomography mode with coronal planes. Typical structures such as the corpus callosum (CC), the cavum septi pellucidi (CSP) and insula are clearly observed and identified.

Aproximación práctica

Modo Superficie / HD Live

Modo Superficie / HD Live

- Representa la capa mas superficial cercano a la línea verde.

- Requiere ajuste previo de la imagen 2D de referencia.
  - Liquido amniótico oscuro (ajuste de ganancia).
  - Insonación perpendicular a la superficie.
  - Idealmente el objeto de interés debe estar paralelo a la línea de representación.
 - Caja de volumen de adquisición amplia.
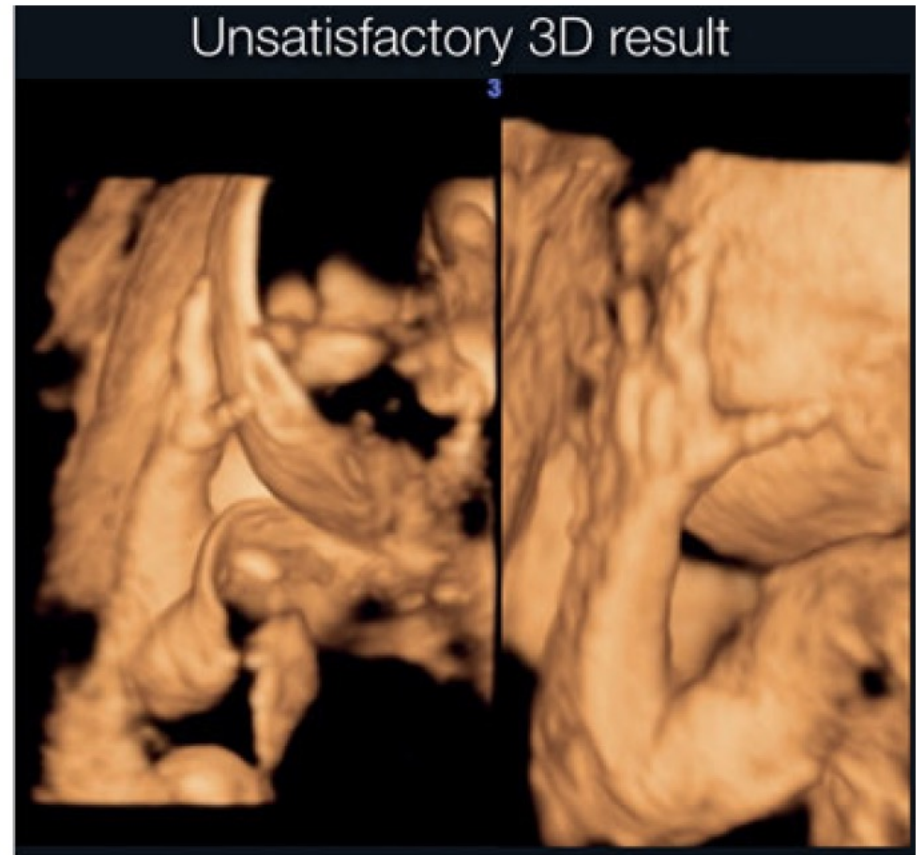
Fig. 7.4: For a good 3D image, not only the contrast but also the insonation angle is important during volume acquisition. In the panel to the left, the hand is clearly visible in 2D but for a 3D volume acquisition the fingers are parallel to the ultrasound waves and are not well displayed on the 3D surface image as seen in the middle panel. The right image is the result after rotating the volume.
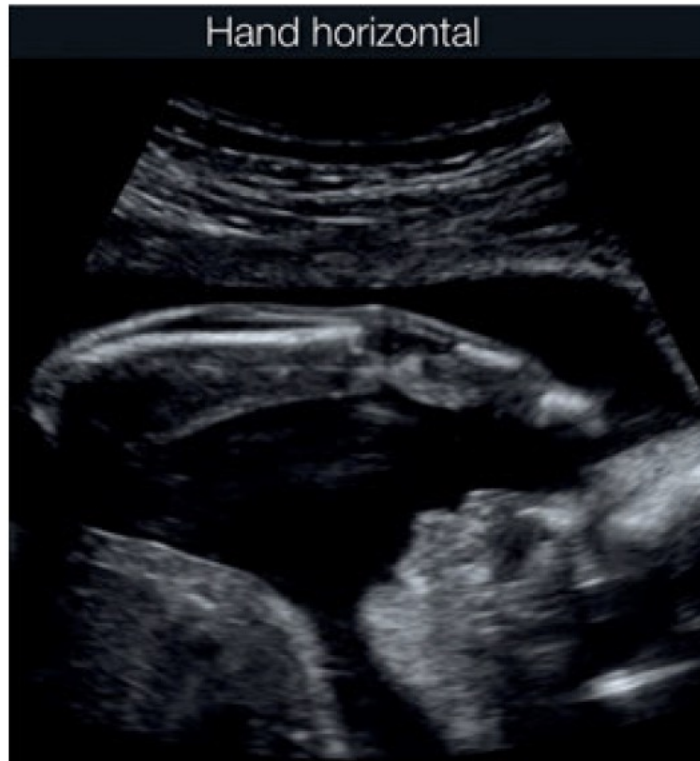
Fig. 7.5: In comparison to Fig. 7.4 the insonation of hand and fingers (left panel) is now perpendicular and ideal for a 3D acquisition. The result is better than in Fig. 7.4.
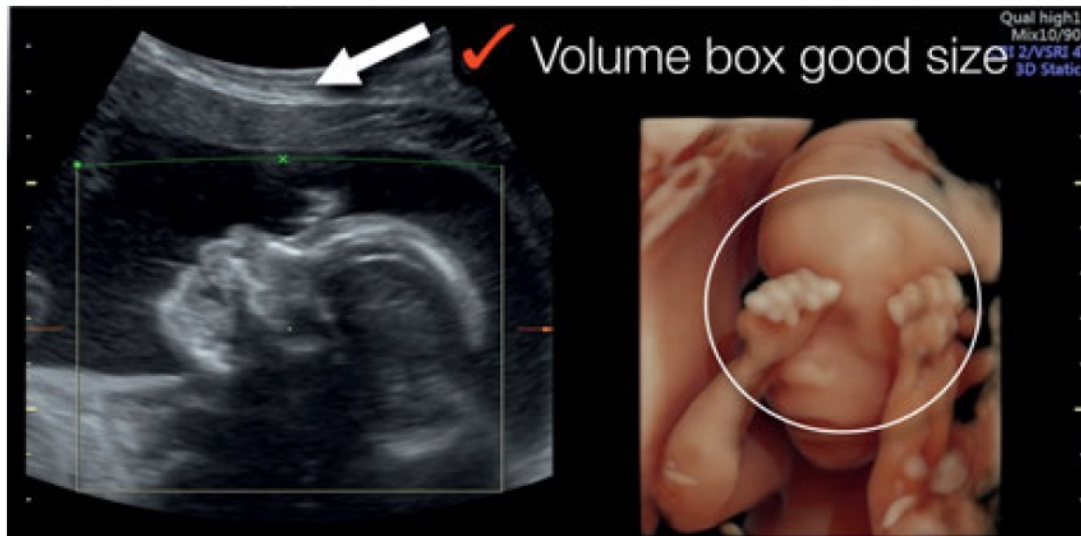
Fig. 7.7: 3D volume acquisition with a small volume box (upper panel). The face is seen, however, a part of the hand is missing due to the small volume box. Choosing a larger box (lower panel) in static 3D acquisition also makes it possible to include structures in the area of the region of interest. The hands can now be seen in the lower panel.

Aproximación práctica

Glass-Body / HD-Live Flow
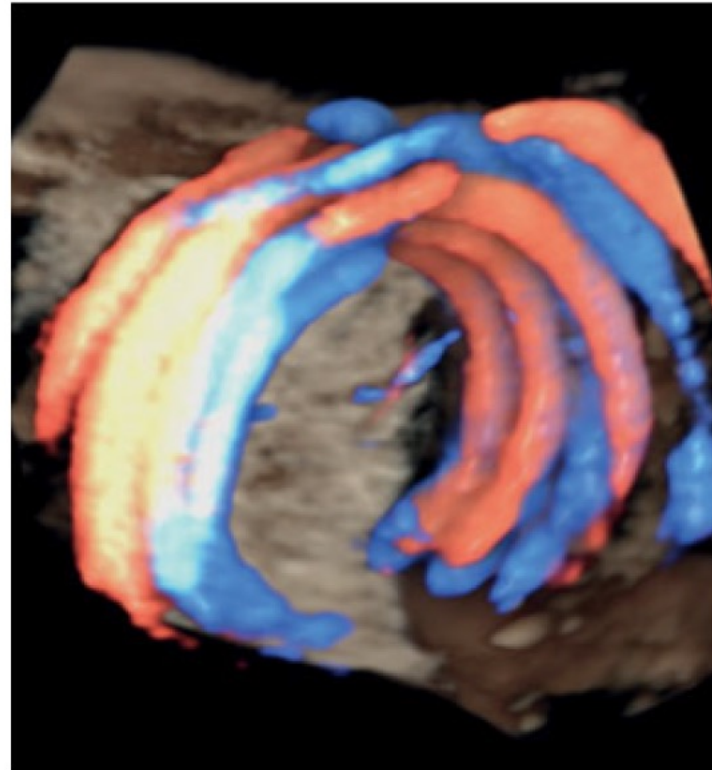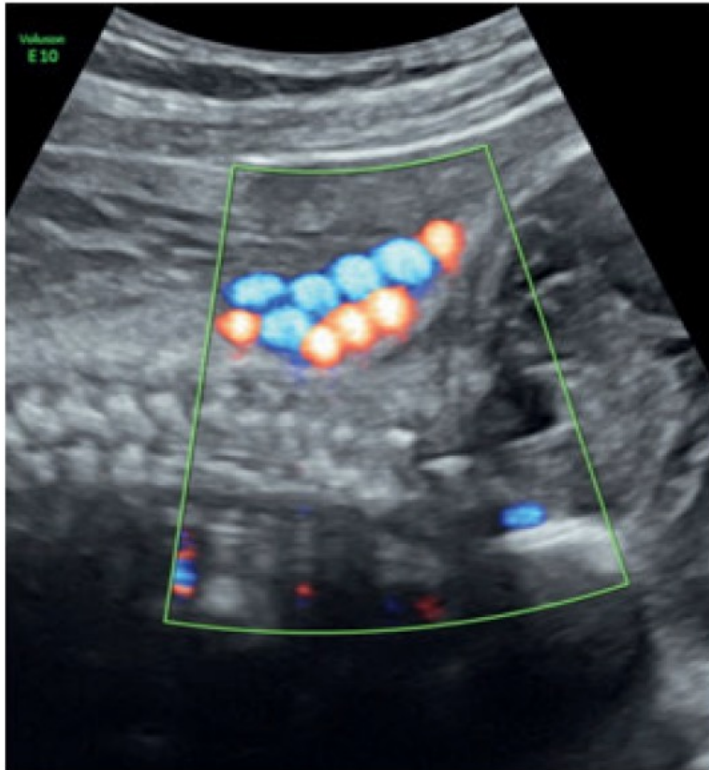
Glass-Body / HD-Live Flow

- Previo a la adquisición de volumen se debe optimizar la configuración de color.
  - Aumentar cuadros por segundo y persistencia.
  - Resolución media.
  - Grado de transparencia (mejor efecto 10/90% y Doppler color en modo superficie)
  - Uso de Magicut

- Se puede representar como B-mode, Color Doppler o en combinación.
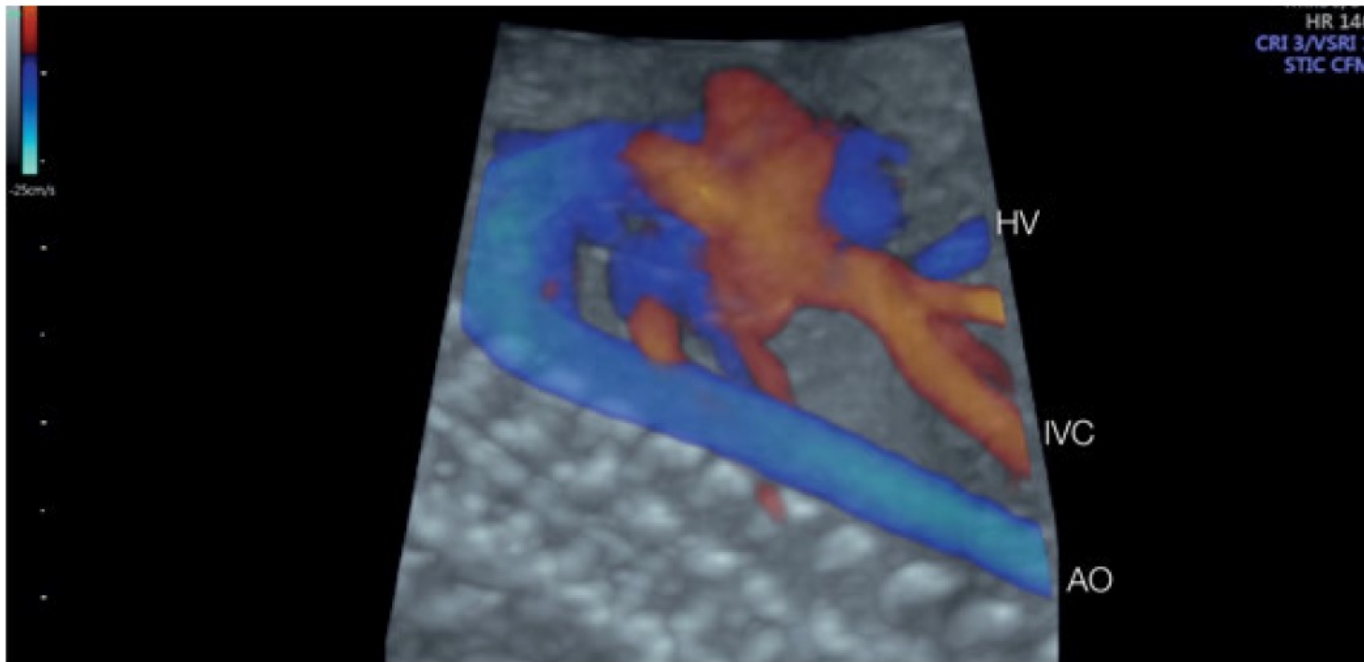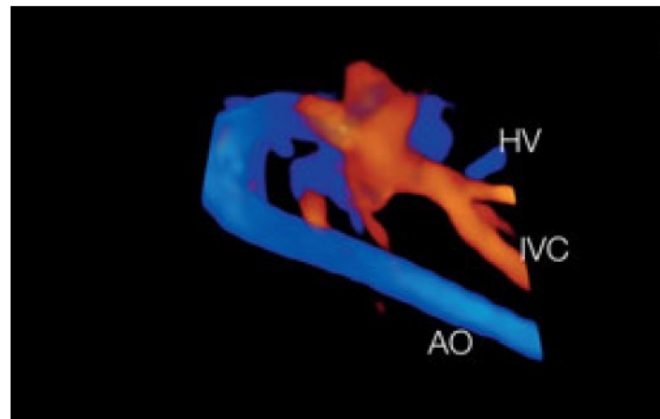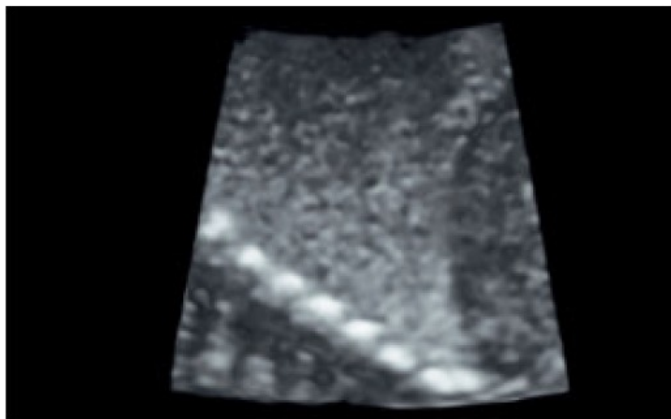
Fig. 12.1: Volume acquisition of the thoraco-abdominal vessels with STIC or static 3D in combination with color Doppler. In 3D rendering mode, the user can choose between different displays, either only grayscale (upper left), only color Doppler information (upper right) or a mixture of both as glass-body mode (lower panel); hepatic vein (HV), umbilical vein (UV), inferior vena cava (IVC), aorta (AO).
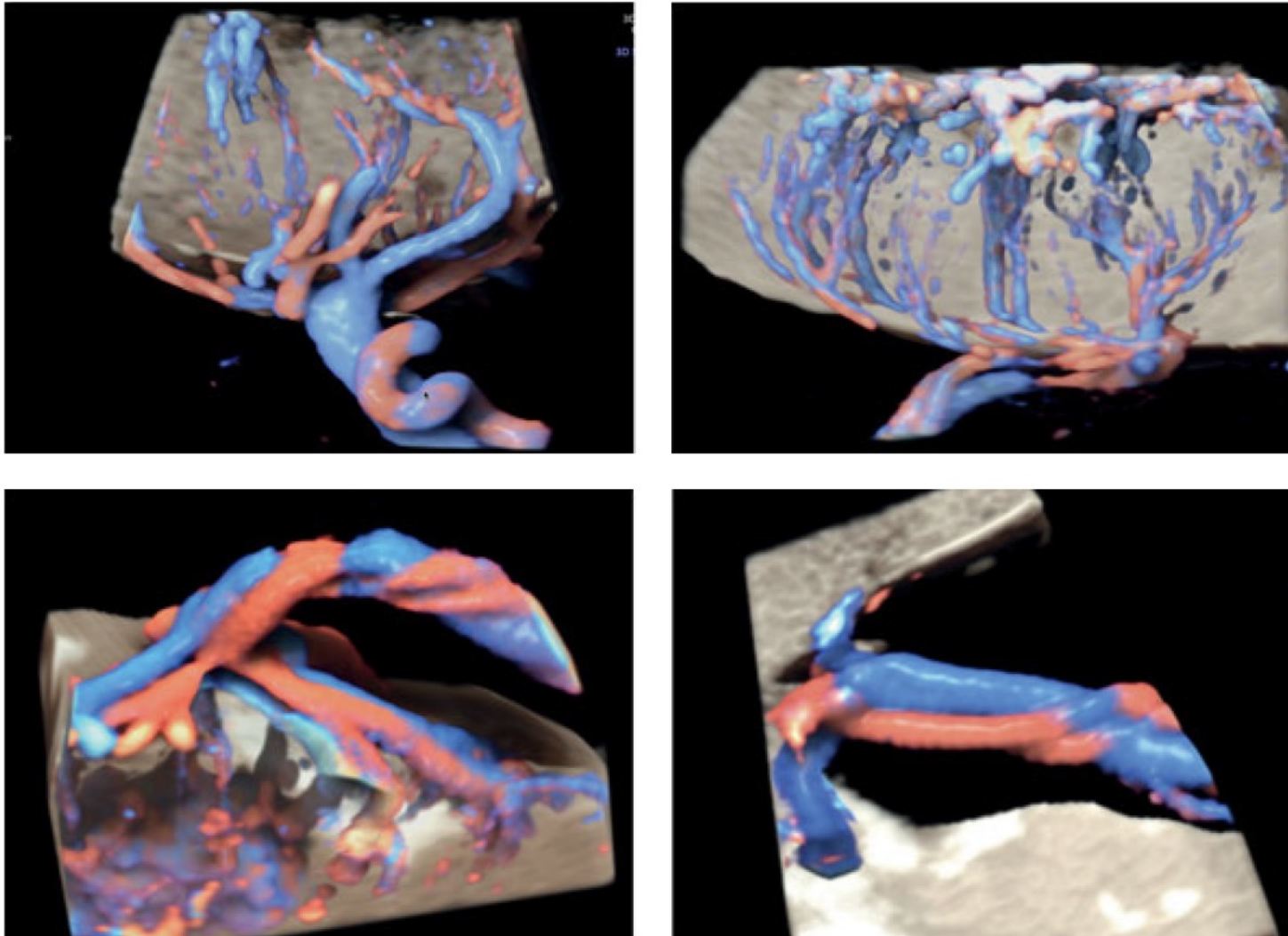
Fig. 12.5: 3D glass-body mode of the umbilical cord insertion on the placenta in an anterior placenta (upper images), a posterior placenta (lower left) and as velamentous insertion in placenta bipartita (lower right).

Fig. 12.10: Fetus with a single umbilical artery and fivefold umbilical cord around the neck in HD-flow (left) and in 3D glass-body mode and HD-live-flow display (right).

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VOCAL / Sono AVC

Cálculo de volúmenes 3D

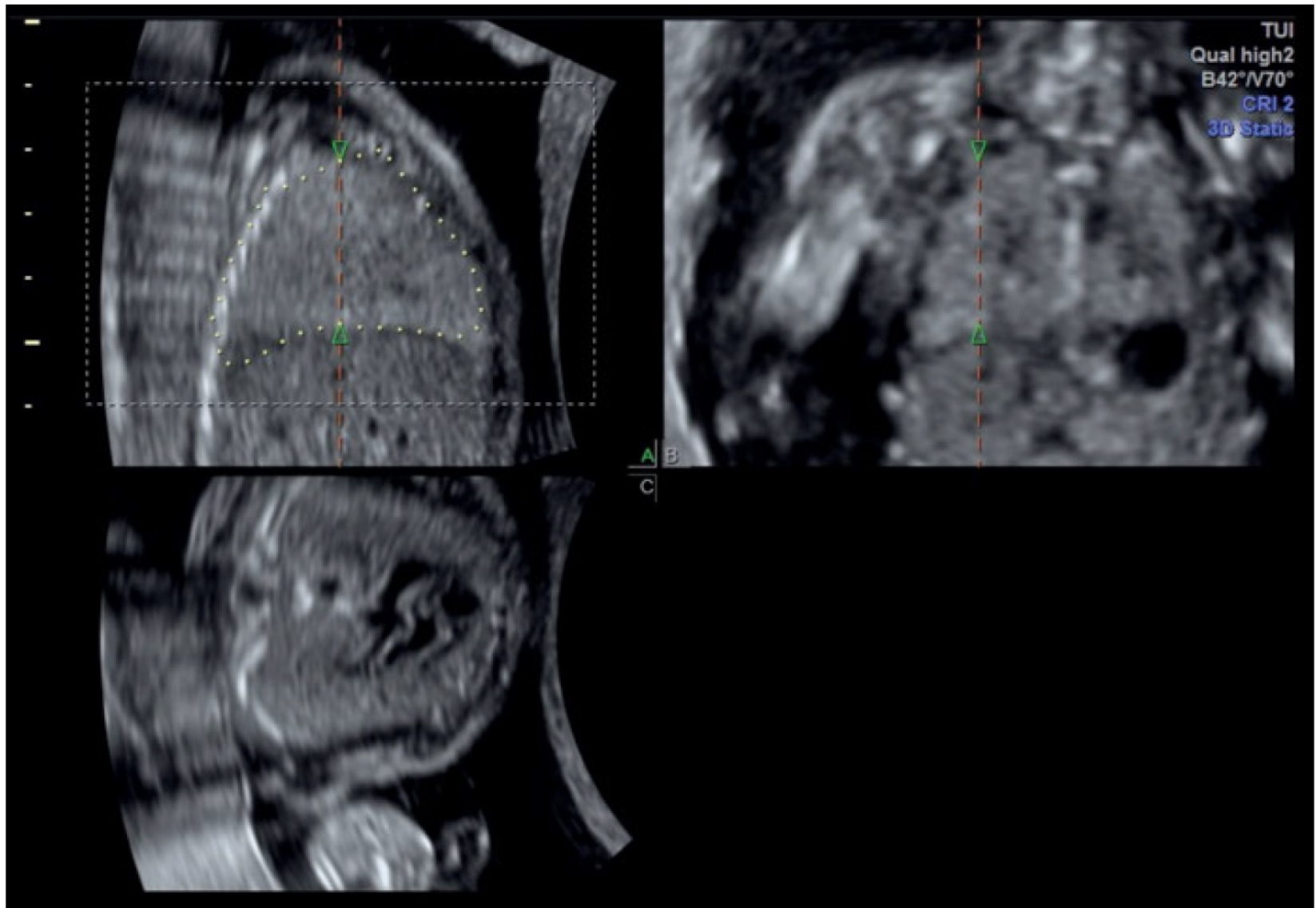# VOCAL

Virtual Organ Computer-aided Analysis

- Adquisición de volumen 3D.

- La estructura de interés es presentada en el modo ortogonal y en el centro de la imagen.

- Se posicionan los triángulos en cada polo del área a medir.

- Selección del contorno manualmente, semiautomático o automático.

- Se ajustan los pasos anteriores en cada plano.
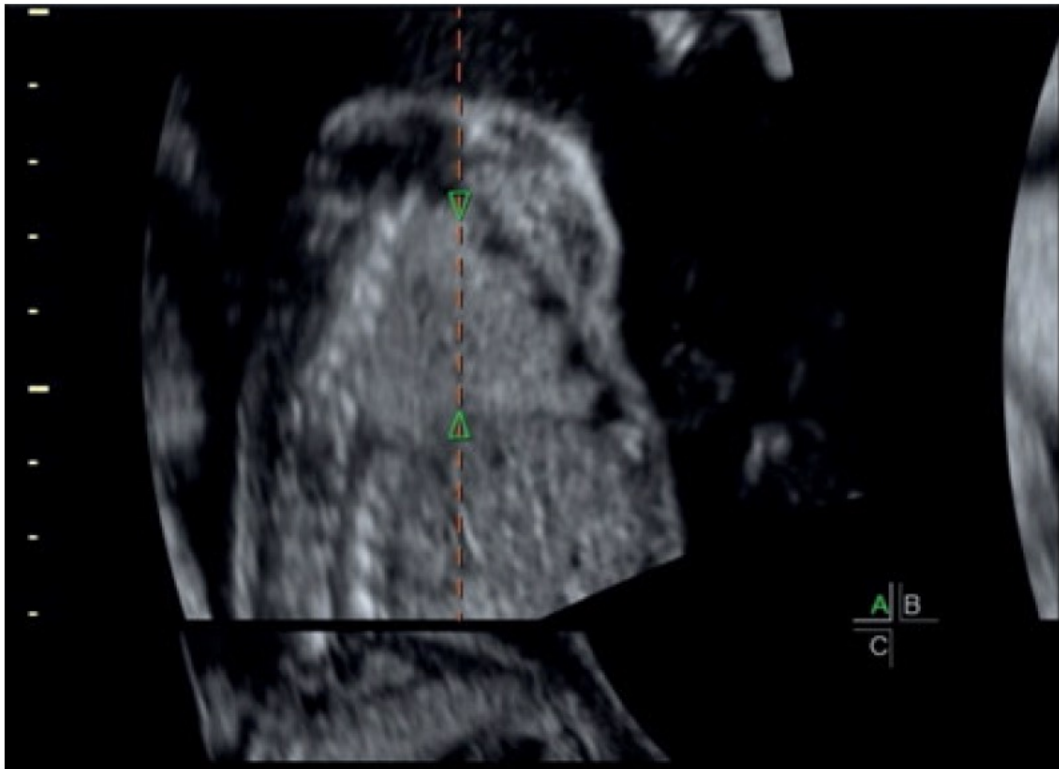
Fig. 15.1: Step-by-step 3D volume calculation using VOCAL: Once the region of interest is displayed in orthogonal mode, the VOCAL function is then selected. A vertical line appears with two triangles. These are placed manually at the two poles of the selected area, in this case the lung.

Fig. 15.2: The next step in VOCAL volume calculation (see Fig. 15.1): After the region of interest has been magnified and the triangles placed on the poles, the type of outline drawing is selected, either as manual or semiautomatic. Once the outline is drawn well, the measurement is then confirmed and an automatic rotation of the volume to the next image occurs.
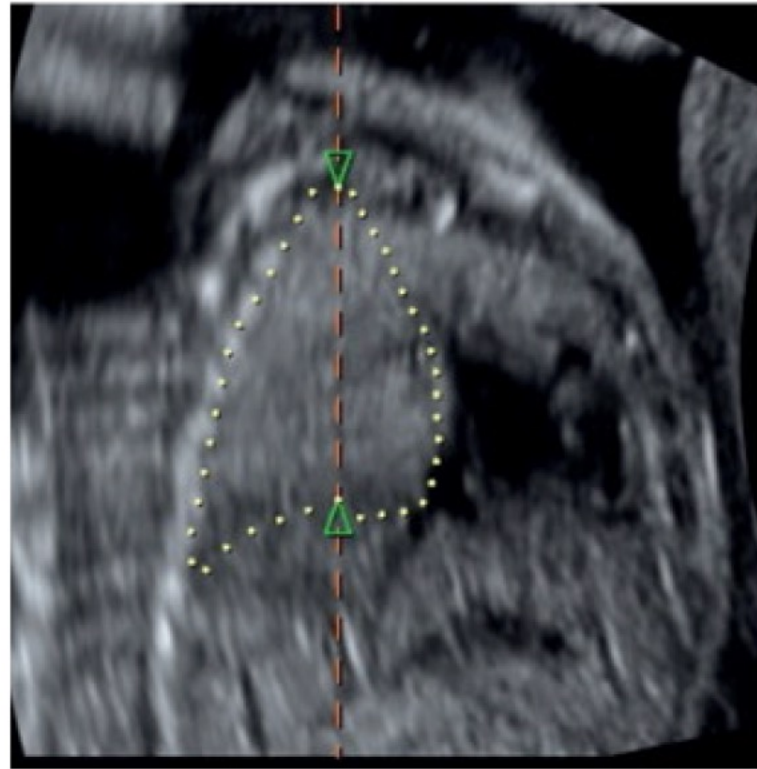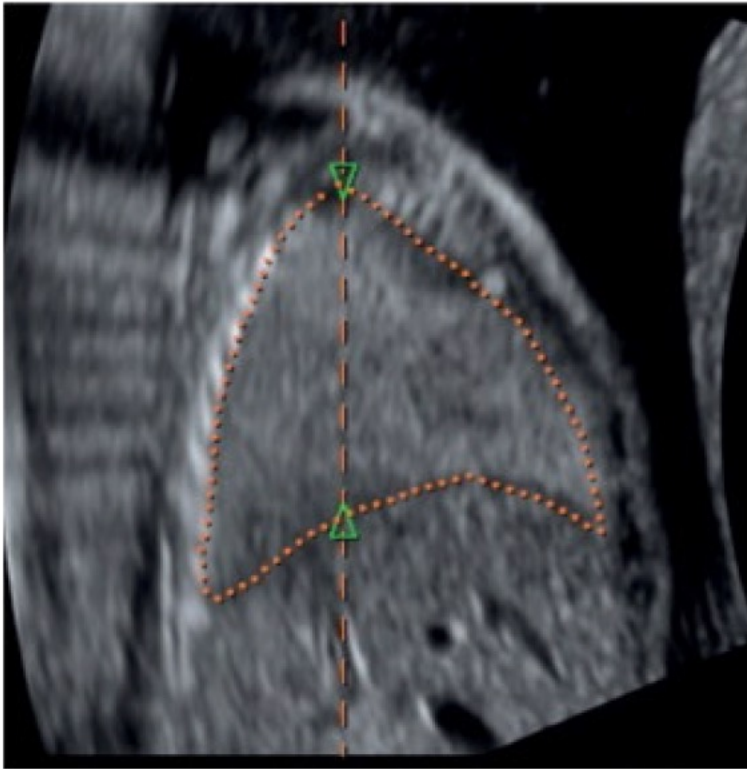
Fig. 15.3: The next step in VOCAL volume calculation (see Figs. 15.1, 15.2): The user now proceeds in a similar fashion to Fig. 15.2, moving from image to image and drawing the outline and confirming the result until all steps have been completed. The number of rotations can be selected by the operator prior to volume calculation.
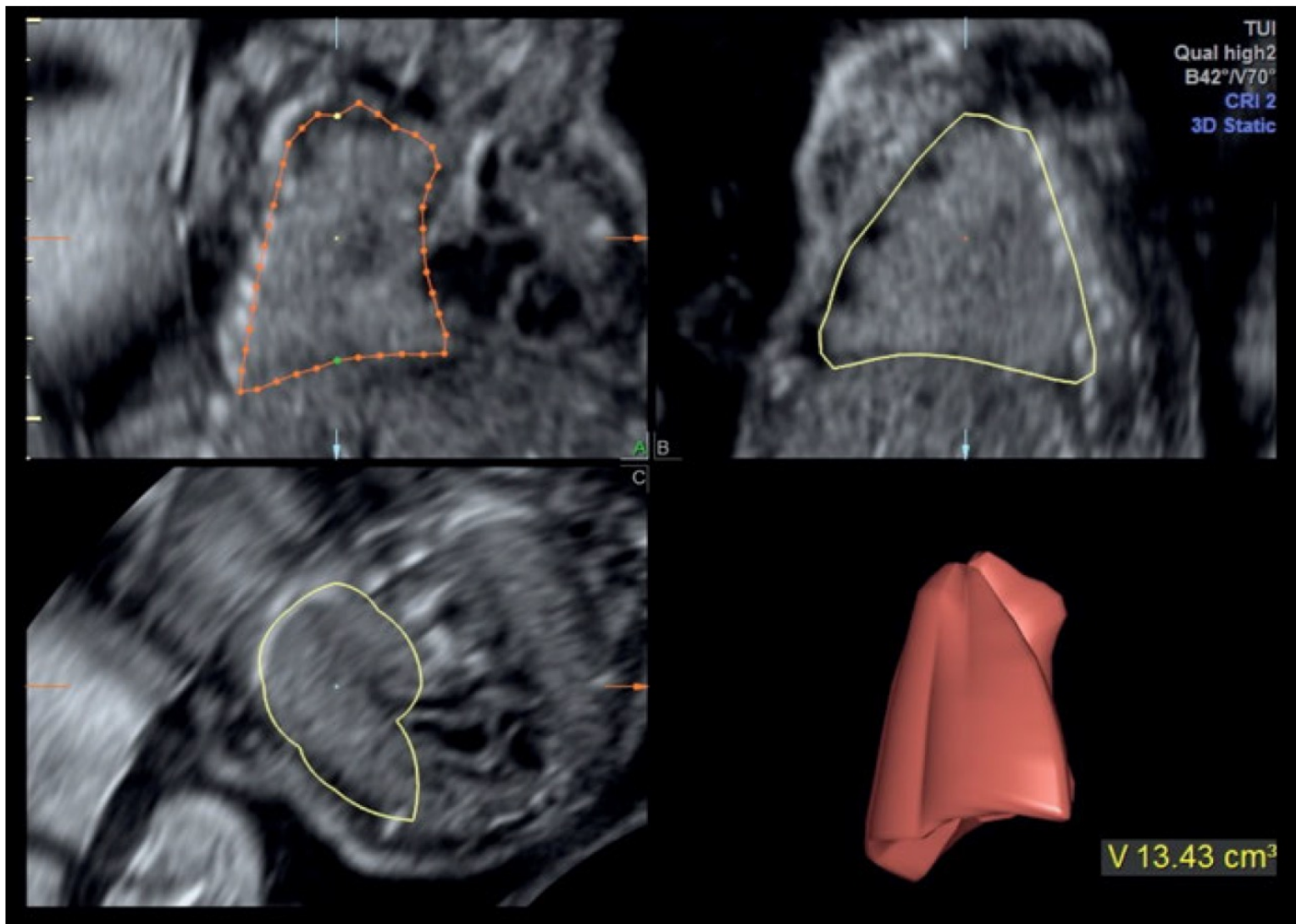
Fig. 15.4: The next step in VOCAL volume calculation (see Figs. 15.1–15.3): At the conclusion of the previous steps of drawing the lines and rotating the volume the result is displayed on the screen highlighting the measured region of interest to the lower right, in this instance the lung, after calculation. At this stage, some corrections can be made by reviewing one or other of the planes to adjust contour drawings.
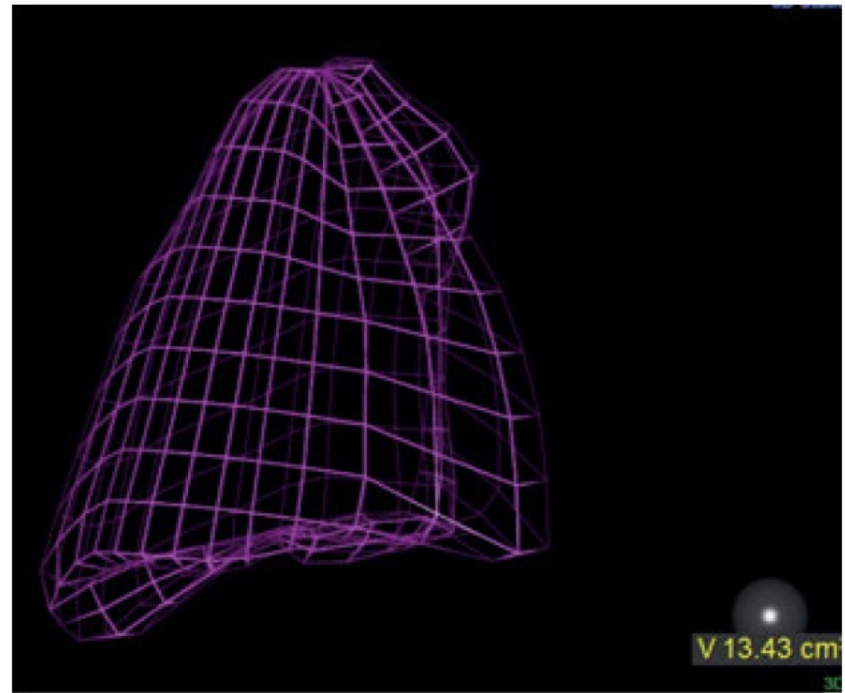
Fig. 15.5: The 3D VOCAL result for the previously assessed lung. The result can be displayed in different colors as a solid area (left) or as a mesh (right).
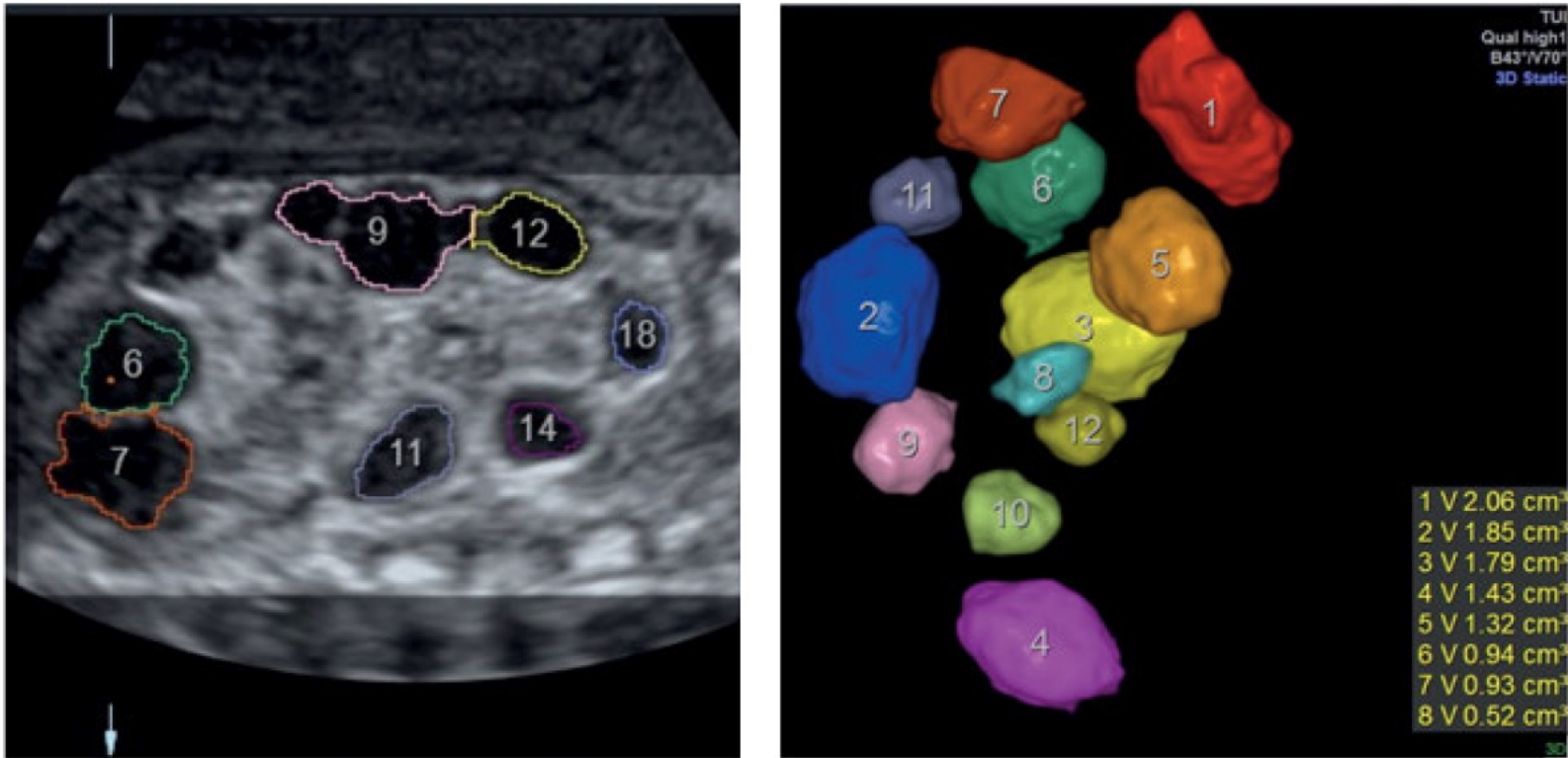
Sono AVC

- Este software reconoce automáticamente áreas ecolucidas únicas o multiples y calcula los volúmenes correspondientes.

- Se selecciona un área con los volúmenes de interés.

- Se puede agregar o remover estructuras a medir.
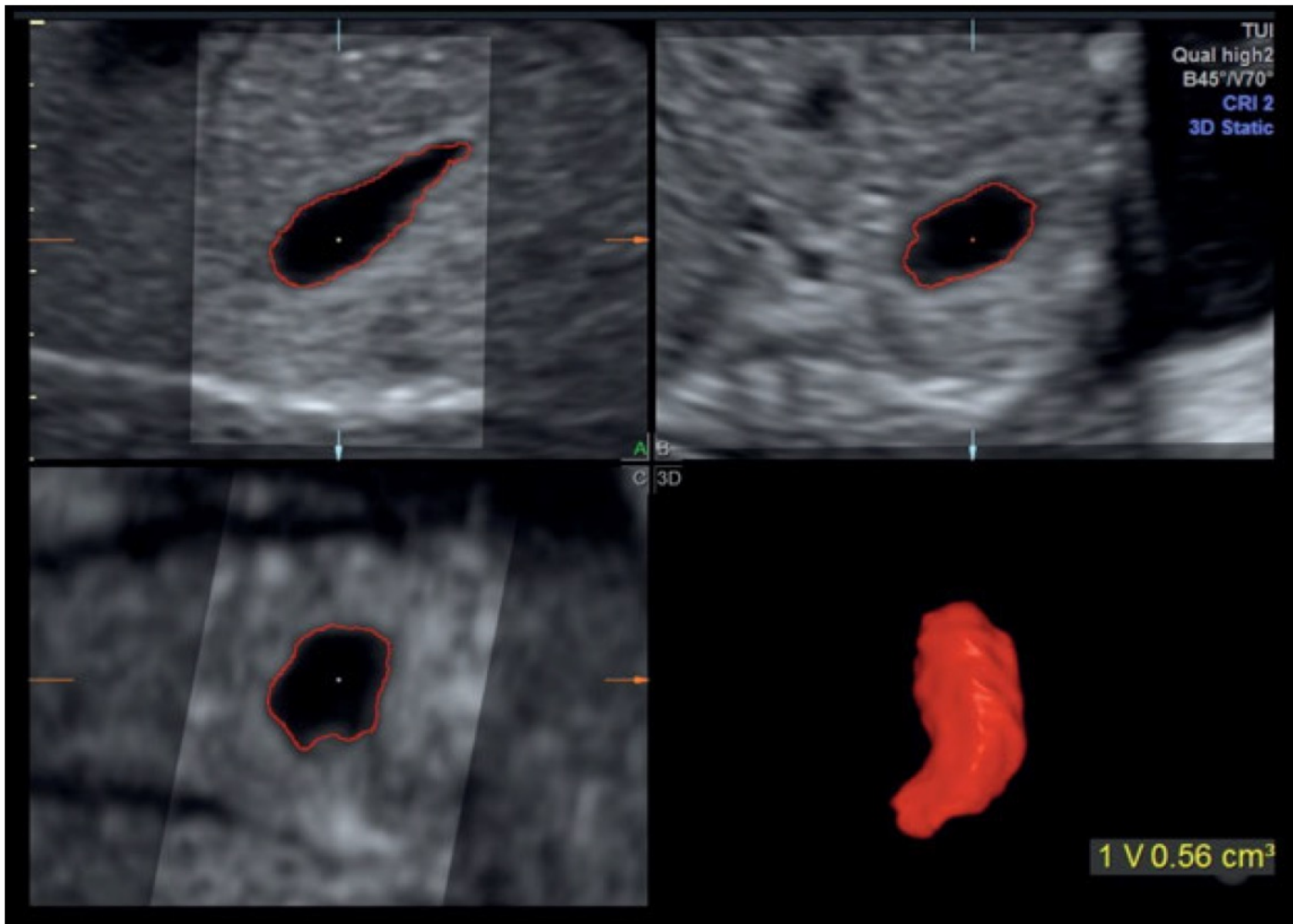
Fig. 15.7: 3D volume calculation with Sono-AVC: Following the mouse click, the liquid is identified and the volume displayed. The 3D shape of the stomach is displayed and the volume calculated.

Fig. 15.10: 3D volume calculation with Sono-AVC in a fetus with multicystic renal dysplasia. The volumes for different individual cysts can be separately calculated and displayed. Measurements are illustrated for the different cysts in different colors, and the numbers refer to the region measured.

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Ecografía 3D-4D

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