Fetal Anatomy by 3-4D Ultrasound

Centini G, Rosignoli L, Faldini E, Centini Ga

Prenatal Diagnostic Unit, University of Siena, Italy

Correspondence: Centini G, Centro Diagnosi Prenatale, Universitá di Siena, Policlinico Le Scottle Viale Bracci 53100 Siena, Italy. e-mail centini@unisi.it

Advanced knowledge and experience of ultrasound technique is necessary to perform a correct two-dimensional (2D) or three- and four-dimensional ultrasound scans (3-4D). Three-dimensional scans are now widely used though their indications and limits have not yet been clearly defined. Scientific societies are therefore working on guidelines for 3-4D in order to optimize its diagnostic possibilities. The western world discourages ludic use of ultrasound, and the French Academy of Medicine has outlawed non medical use, especially in obstetrics.[1-2] Springing from seven years' experience with 3-4D, the following pages are a personal contribution towards the definition of guidelines in this increasingly complex field. The aim is exclusively medical, though the ludic component of the use of 3-4D in obstetrics should always be borne in mind.

The approach to a scan conventionally begins with a scan from the top of the head to the lower extremities. The best time to do the scan is 19-23 weeks of gestation, as for 2D, when the probabilities of detecting fetal pathological processes are good. Clearly, different malformations regarding various anatomical structures have optimum moments in relation to their natural history.[3]

The Head

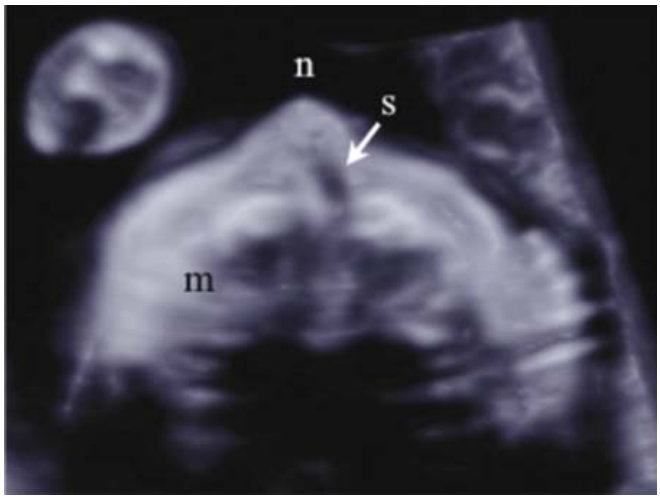
The head is the anatomical region that best lends itself to 3-4D. Scanning from the outside in, the first structure to examine is the fetal face. Images of the fetal face have been the reason for the immediate success of 3-4D, due to the emotional impact they have on those who view them.[4-6] Apart from the aesthetic pleasure of "seeing" one's child in real time in static or cinematic images (4D), 3-4D improves and is sometimes the only way to visualize certain anatomical details.

Face

Correct and perfectly reproducible images can be obtained as early as 7-8 weeks using 3-4D surface rendering minimum mode.[7] The possibility of obtaining images depends on all the usual parameters, predisposing (e.g. lean mother or abundant amniotic fluid) and impedient (e.g. maternal obesity or oligohydramnios), already codified by 2D, and particularly on fetal position. In the second trimester correct images of the fetal face can be obtained in about 90% of cases, sometimes using strategies such as pressing repeatedly on the maternal abdomen, or making the mother lie on one side or the other, or doing the scan in two different moments. This percentage may decline to as little as 30% of cases after week 34, due to the position that the fetus is obliged to take as it grows (Fig. 1). *Gestalt* or impression may

Figs 1A to C: The foetal face at 20th-25th and 34th weeks. The face during the pregnancy takes the final features after 20th week and the baby doesn't change the somatic traits of the face until the birth

have clinical content, since many syndromes are associated with facial dysmorphia. Detailed study of the face enables diagnosis of almost 100% of cases of cleft lip and cleft palate, including (though with a lower success rate) cleft of soft palate which is difficult if not impossible to see by 2D scan (Fig. 2).[8-14] Study of the maxilla and palate is fairly reliable as early as week 11 (Fig. 3). Nasal position and morphology, especially the presence, hypoplasia or absence of the nasal bone in the first and second trimesters, is much more easily and reliably detected by 3D (Fig. 4)[15] and the symmetry of the orbits is easily detected. Study of the ear is also useful, not only ear size in relation to chromosome abnormality (about 70% of Down fetuses have helix-lobe lengths more than two standard deviations from the mean for gestational age), but also ear morphology (after week 22, the ear is no longer circular but becomes elongated) and position (low ears are frequent in many pathological syndromes) or detection of ear appendices, sometimes a marker of kidney malformations (Fig. 5).



Figs 2A and B: Cleft lip and a maximum axial scan of the maxillary: it is clear the little cleft or schisis of alveolus (n, nasal bone; m, maxillary bone; s, schisis)

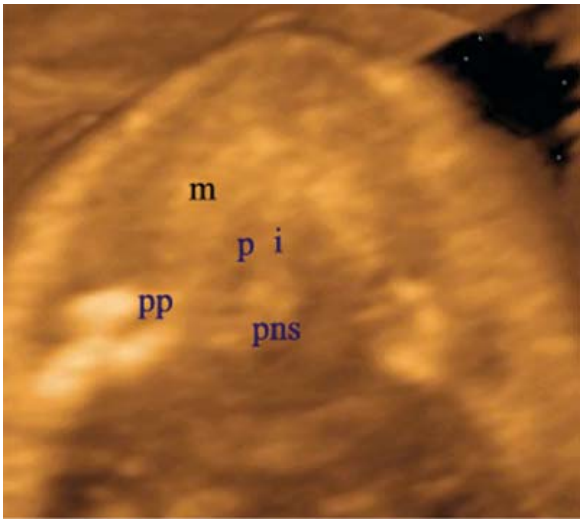
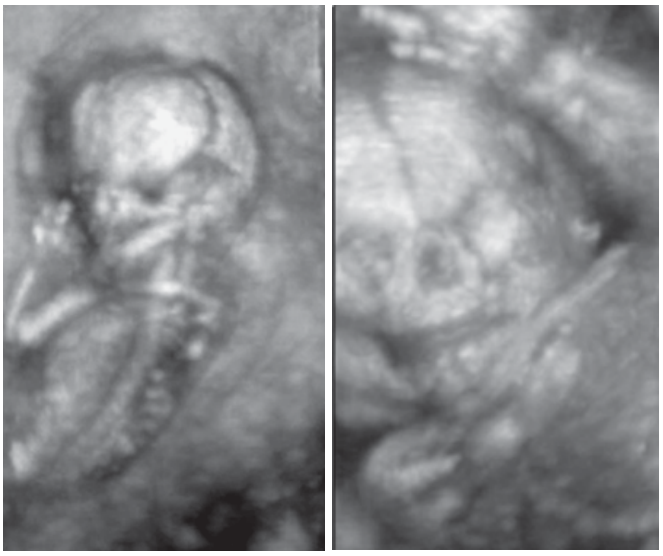


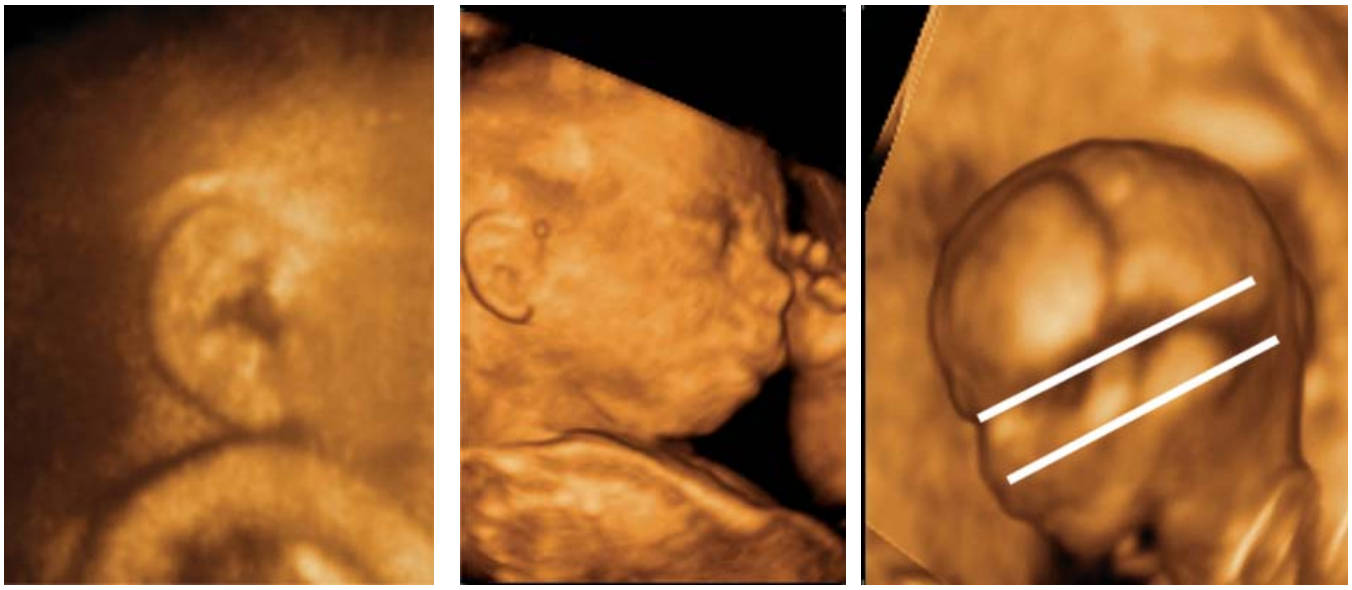
Fig. 3: 3D surface minimum mode of secondary palate (m, maxilla with alveolar ridge; p, palatine process; i, interpalatal suture; pp, pterygoid process; pns, posterior nasal spine; ph, pharynx)



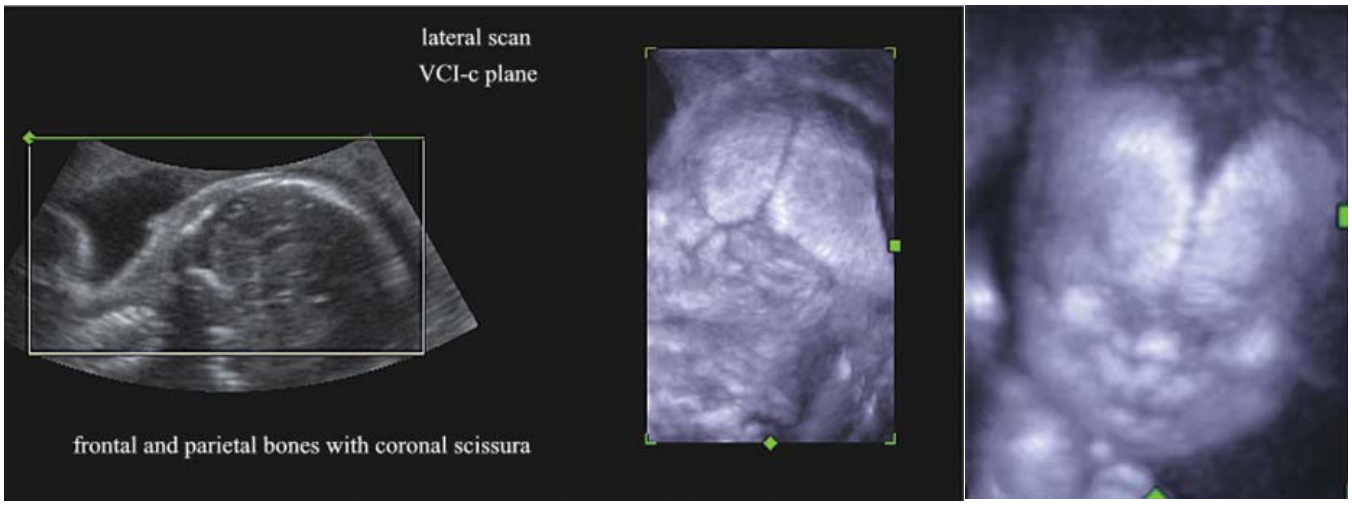
Figs 4A and B: It is easy to find the two nasal bones in the first (12th week) and in the second trimester of pregnancy (20th)

Cranium

Head scan proceeds to the bones of the skull in maximum mode and the fissures and fontanelles. These aspects are useful for early diagnosis of craniostenosis and microcephaly[16] (Fig. 6).



Figs 5A to C: The normal shape of the ear and the little appendix at 20th week. The normal position of the ear at 12th week



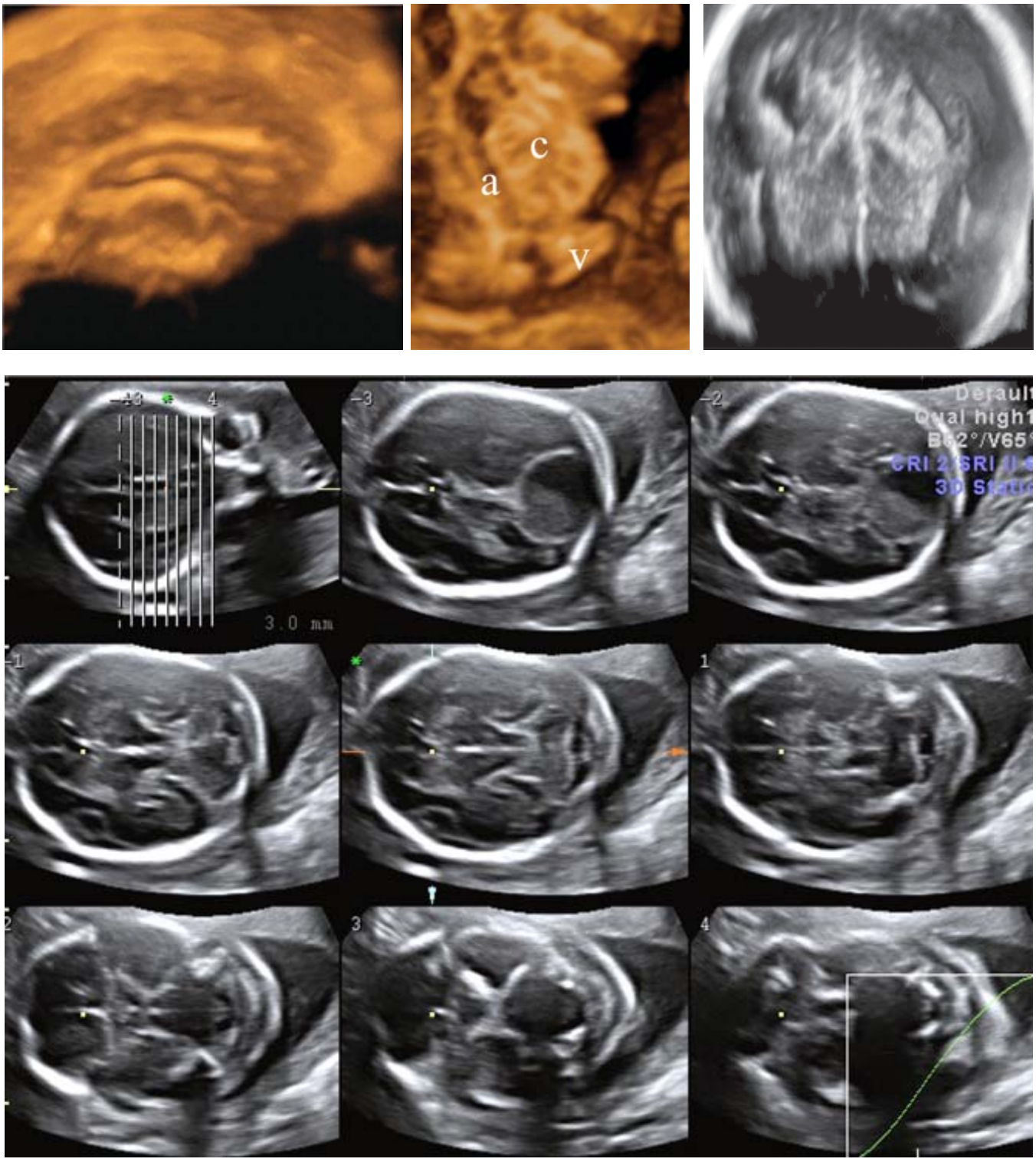
Figs 6A and B: Maximum mode 3D in the second trimester (20th): sagittal and coronal view of the bones of the skull (it is possible to see the scissures and fontanels)

Fetal Brain

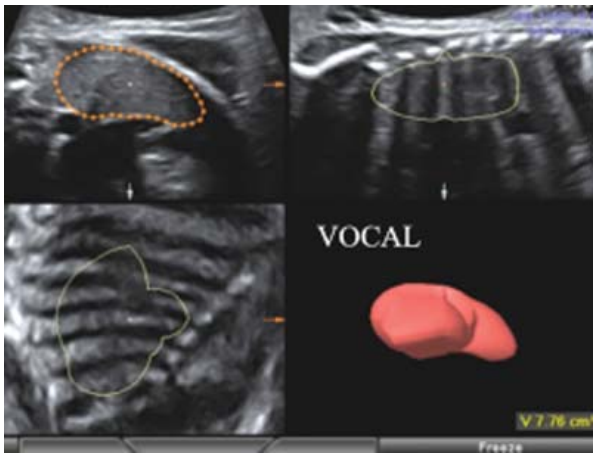
For the study of the brain 3-4D can be useful, especially in multiplanar mode, volume contrast imaging in coronal plane (VCI-cplane) and tomographic ultrasound imaging (TUI). The corpus callosum, vermis and optic chiasma can be easily detected by 3D.[17] TUI enables the brain to be visualized in almost as much detail and by TAC or NMR imaging for the study of expansive brain masses (Fig. 7).

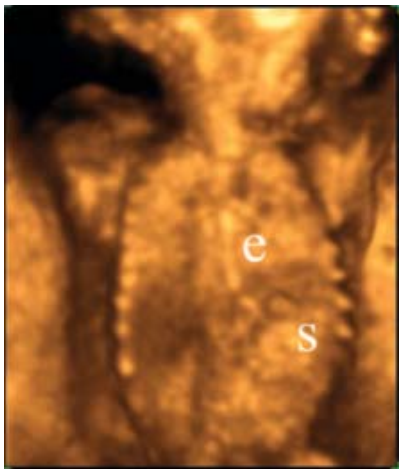
Chest

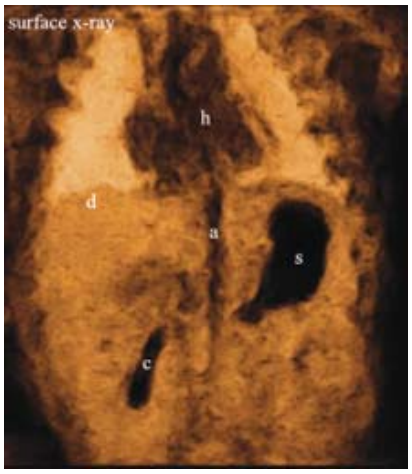
The possibility of easily measuring volumes afforded by VOCAL, makes multiplanar 3-4D particularly useful for assessing fetal lung volume, for example in cases of diaphragm hernia.[18] Visualization of thymus volume (difficult with 2D) and esophageal morphology are readily achieved with 3-4D. The spatial relationships between lungs, heart, esophagus and diaphragm become particularly evident[19] (Fig. 8).

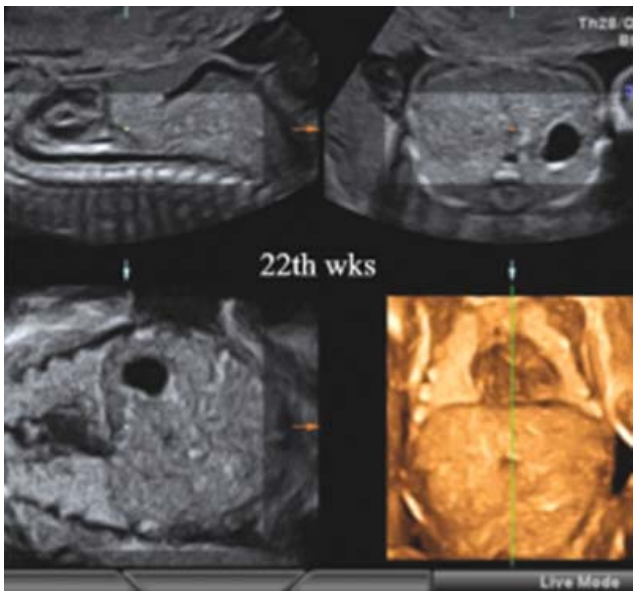


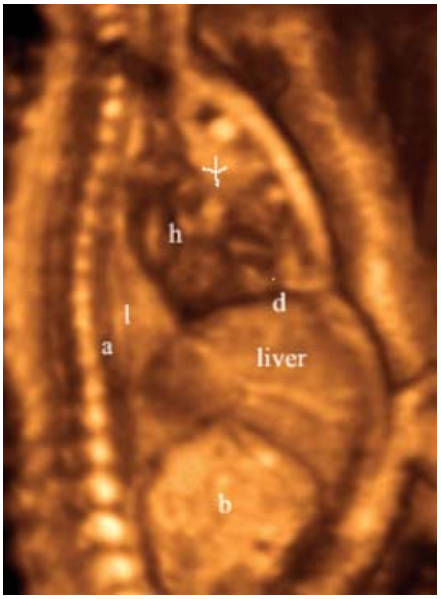
Figs 7A to D: A good vision of corpus callosum by 3D sagittal scan (A), vermis (B) v, vermis; c, cerebellum; a, acquenductus Silvianus), optic chiasma by transversal scan and 3D TUI scan of fossa cranica posterior



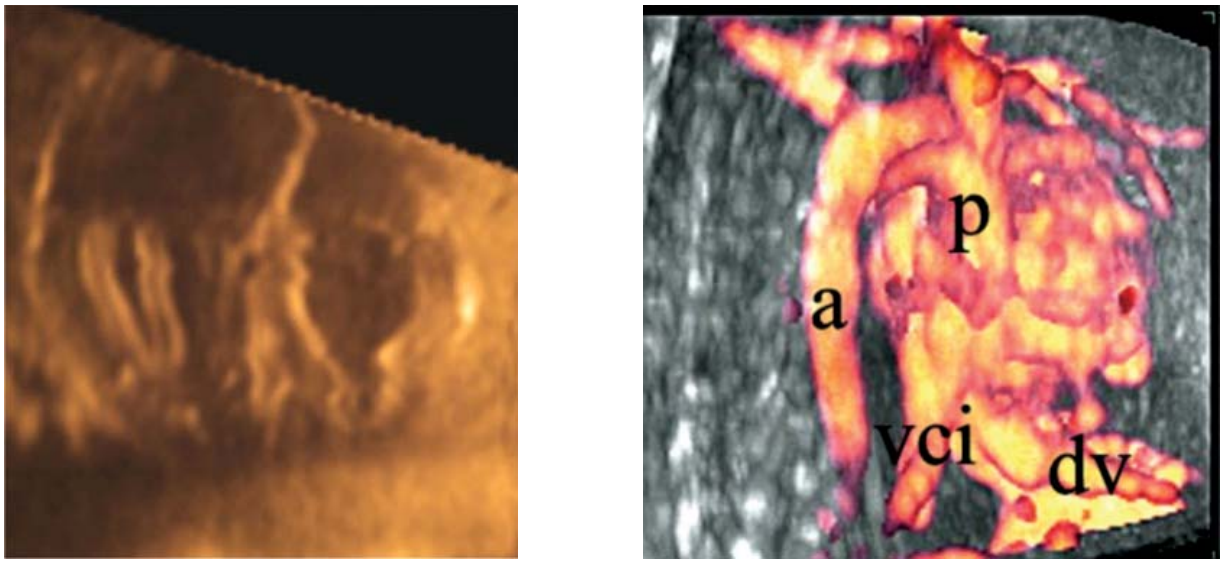








Figs 8A to F: Lung's volume by 3D vocal (A) a strange scan to detect the thymus (B) t, thymus; e, esophago), by coronal 3D scan it is possible to see the esophagus and the stomach (C) e, esophagus; s, stomach), the anatomic 3D surface X-ray scan of the thorax and abdomen (D) h, heart; d, diaphragm; a, aorta; s, stomach; c, cholecyst); coronal and sagittal 3D scan surface minimum mode of the thorax and the upper part of abdomen (E-F) h, heart; a, aorta; l, lung; d, diaphragm; l, liver; b, bowel; t, thymus)



Figs 9A and B: A 3D scan of the heart: the two ventricles and the septum is clear and it is easy to find the great vessels (a, aorta; p, pulmonary artery; vci, vena cava inferior, dc, ductus venosus)

Study of the heart and large vessels by STIC is a new chapter. STIC consists in recording a number of heart beats and multiplanar viewing as a movie with or without color or power Doppler.[20-22] About the heart pathology, 3D has enormously increased the potential of ultrasound and diagnosis *in utero*, and has not only stimulated research but also development of volumetric and matrix probes that were unthinkable a few years ago (Fig. 9).

Abdomen

For abdominal examination, 3-4D does not improve visual quality, though VOCAL makes evaluation of expanding masses easier and INVERT improves investigation of the exact morphology of those containing liquid by showing liquids as solids (Fig. 10).

Spine and Long Bones

Maximum mode in 3D or 4D provides images of the spine that greatly increase the capacity to diagnose processes of malformation.[23] Multiplanar mode makes it possible to study the spine vertebra by vertebra in three spatial projections. Detection of all the long bones is easier, more reliable and faster (Fig. 11).

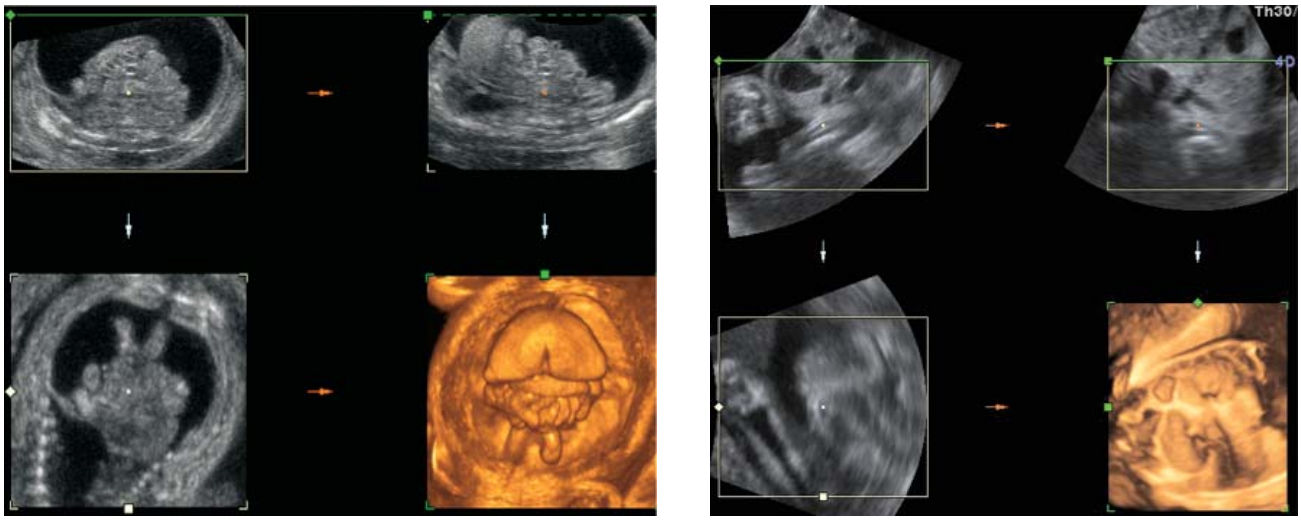
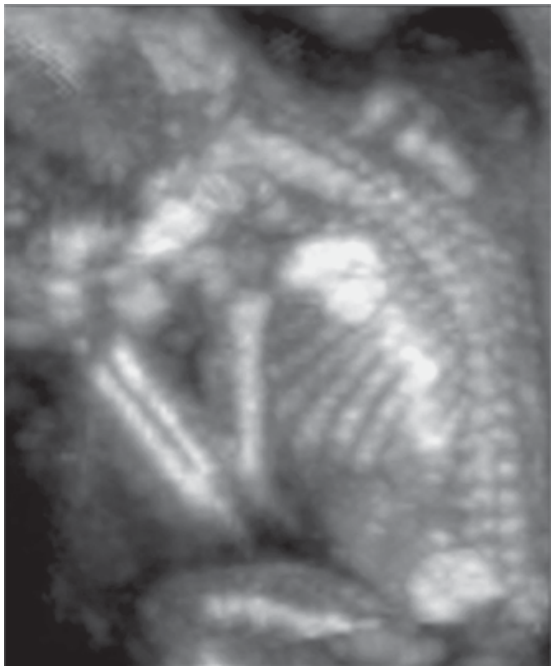


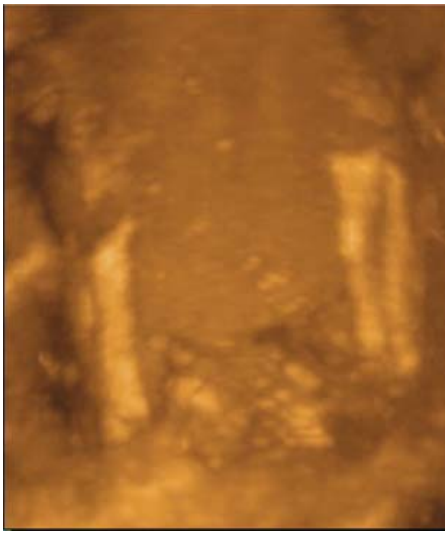
Fig. 10A and B: Ascites at 23th week by 3D multiplanar and INVERT mode; the liquid is transformed in solid and ileal stenosis by 3D multiplanar and surface minimum mode



Figs 11A and B: 3D maximum mode scan of the rachis and the skeletal at 18th to 20th weeks

Extremities

If the scan is performed in the second trimester, 3-4D enables detailed examination of fingers and toes in nearly all cases and about 100% certainty of detecting agenesis and extra digits (Fig. 12).



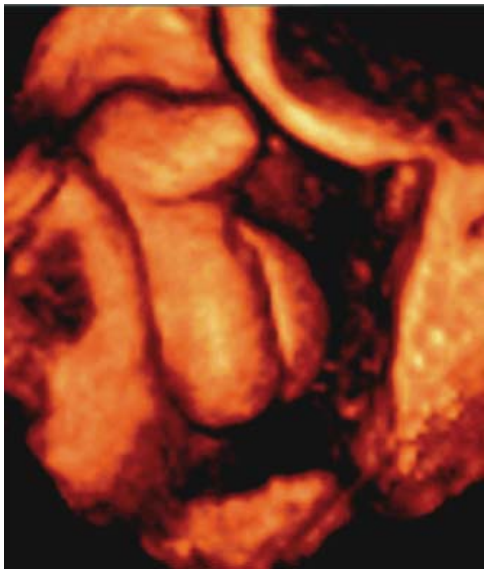
Figs 12A and B: A minimum mode and maximum mode scan of talipes equinovarus

Genitals

Images of genitals are strikingly clear, increasing diagnostic capacity in cases of hypospadia (tulip sign) in the third trimester and in cases of clitoral hypertrophy[24,25] (Fig. 13).

CONCLUSIONS

Since transmission of the first images of the fetal face at the start of the second millennium, in only a few years 3-4D has progressed in a manner that few could have imagined. However, the full potential of 3D is yet to be completely developed. The great novelty of this technique is the possibility of saving a



Figs 13A and B: A normal penis at 26th week and penile hypospadias at 27th week

volume and studying predefined sections of it later or referring them to different specialists. Three-dimensional ultrasound has the quality of TAC and NMR imaging, while costing less, being less invasive and being much less troublesome for mothers. It is also a source of emotional bonding, or in the case of malformations, of tangible evidence. In very few years, applications of 3-4D have been tested over the whole range of ultrasound for anatomical examination and identification of malformations and pathological processes.[26]

Although a 2D scan performed by an expert ultrasonographer with a good instrument will meet all the requirements of ultrasound protocols of the various scientific societies, 3-4D comes into its own for examination of the head (where certain projections can only be obtained by this method), spine, long bones and heart field.[27,28] Scanning time takes longer at first but after 6-12 months of training, the pleasure of better work combines with faster examination and greater accuracy. We personally think that today, no prenatal diagnosis center can be without a 3-4D instrument.

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