

Normal and Abnormal Early Pregnancy Assessed by 3D Sonography

Giovanni Centini, Lucia Rosignoli, Elisa Faldini, Gabriele Tonni¹

Prenatal Diagnostic Unit, University of Siena, Italy

¹ Prenatal Diagnostic Unit, Ospedale Guastalla, Reggio Emilia, Italy, Email: centini@unisi.it

SUMMARY

Ultrasound instruments are now able to provide a good view of the uterus-endometrium and ovaries and normal anatomy can be confirmed with a single scan before conception. Ultrasonographic confirmation of conception is usually only performed after medically assisted reproductive procedures but embryo and fetal development can be followed weekly, from weeks 4, to obtain important physiological information, to check anatomy and to find aneuploidy markers. Three and four dimensional (3 or 4D) scans provide better images than 2D for definition and vision, and facilitate diagnosis of pathology.

MATERIALS AND INSTRUMENT

The material comes from four years of the work (2002 to 2006) at Prenatal Diagnostic Unit of University of Siena (Italy) and Prenatal Diagnostic Unit of Guastalla Hospital, Reggio Emilia (Italy). The people scanned were about three thousand by Voluson 730 Expert (GE).

RESULTS

During the first counseling with a couple who ask about offspring, now it is possible to define with a good sensibility the anatomy of the uterus and ovaries and the status of endometrium by ultrasound. The classic 2D provides a good view, but 3 or 4D scan offers a possibility, by VCI- C plane, to see the coronal plane of the uterus to define a normal anatomy of the cavity of the uterus (Figs 1A and B).

After the conception usually we separate the first trimester in three periods, known as the pre-embryo, embryo and fetal periods.

Pre-embryo Period

Ultrasonography: Weeks 3 and 4

It is only possible to see endometrial decidualisation, the corpus luteum and endometrial vessels (Fig. 2).

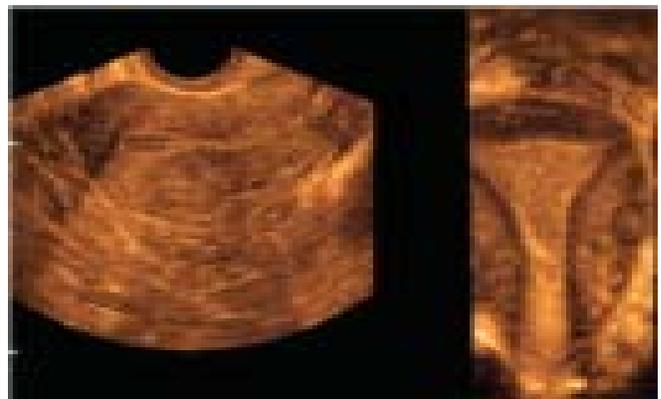


Fig. 1A: By VCI-C plane, in realtime, it is possible to see the longitudinal scan of three lines of endometrium and the coronal scan of the uterus. In this picture the anatomy of uterus is normal (luteal phase)



Fig. 1B: Coronal scan during the luteal phase: It is clear the malformation of the uterus bicornis bicolle. The surface rendering of 3D offers a possibility of diagnosis of uterus malformation similar to hysterosalpingography

Embryo Period

Weeks 5: From 4th weeks + 0 days to 4th weeks + 6 days

From weeks 4 plus 2 or 3 days it is possible to identify the gestational sac (GS) in pregnancies of women who had regular menstrual cycles. The percentage of women in which this is possible increases to almost 100 percent by the end of weeks 5, and the number of GSs can be determined. Spiral circulation around the GC can be detected from weeks 4 and the vitelline sac can be seen by multiplane 3D and surface rendering (Figs 3 to 6). Detection of the GS *in utero* is essential to exclude ectopic pregnancy: Its eccentric position with respect to the

uterine cavity and the presence of chorionic villi and consequent peripheral vascularisation, associated with monitoring of hCG, leave increasingly less room for diagnostic uncertainties. It is also possible to see myometrial and decidual vascularisation and check the homogeneity of vasculogenesis, though their clinical significance is not yet clear. Detection of a GC measuring 2 to 4 mm in weeks 5 makes it possible to date conception with an error of 2 to 3 days.

Visualisation of the yolk sac (YS) the first detectable embryonic structure, may be possible in weeks 5 (Figs 7A and B). Two to four days later the embryo can be seen as a double bubble. From weeks 6, the vitelline sac distances itself from the embryo and the amnion is seen dividing the coelomic and

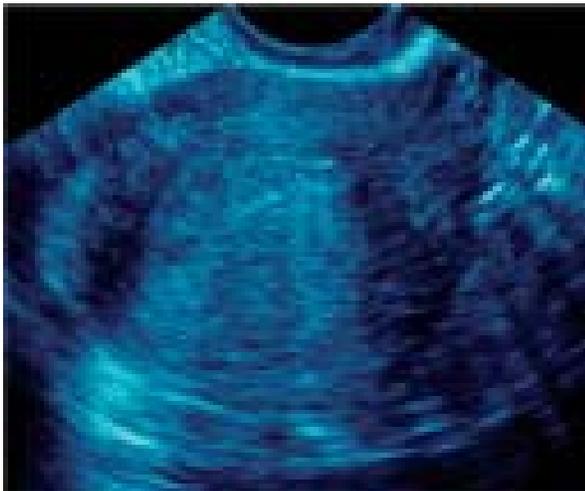


Fig. 2: Weeks 4 + 0: Longitudinal scan 2D of endometrium very large during the early pregnancy

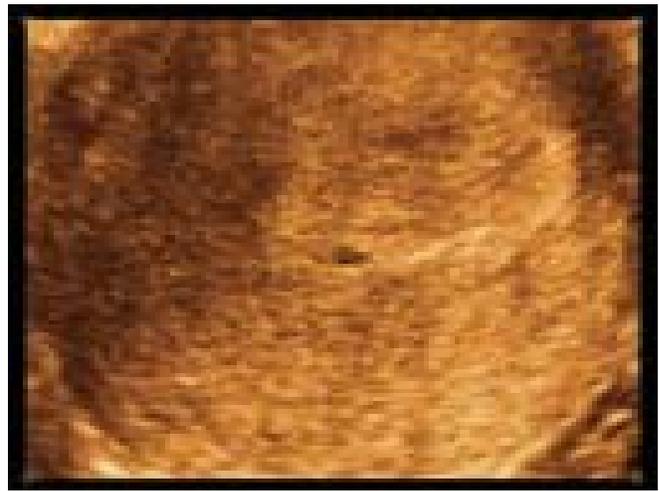
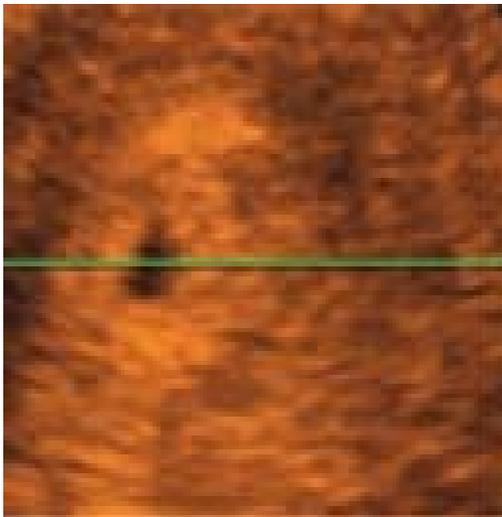
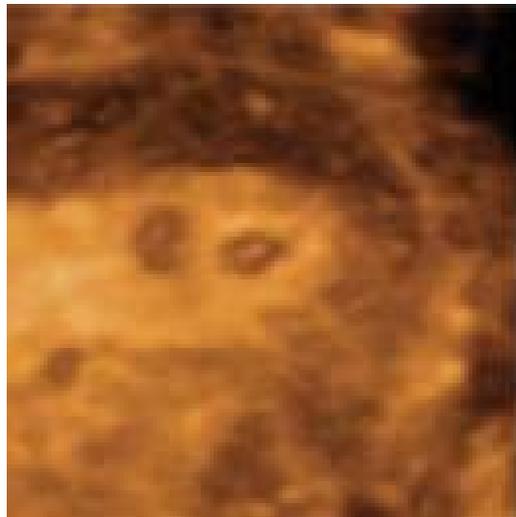


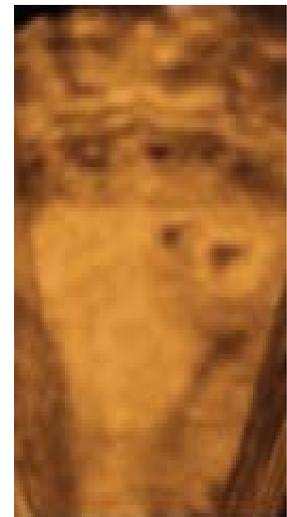
Fig. 3: Weeks 4 + 1: Three dimensional scan of the gestational sac (GS)



A



B

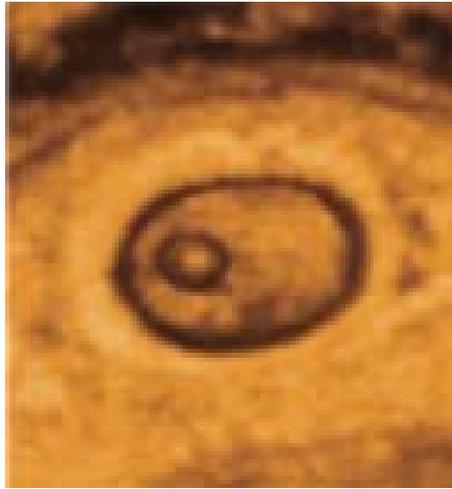


C

Figs 4A to C: (A) Weeks 4 + 2: At this time the GS has a good definition by 3D; the difference from 2D is the possibility to see the external structure, (B): A coronal 3D scan: It is clear the difference between the gestational sac with external structure and the cavity between decidua vera, (C) A coronal scan: the GS is in left cornual position and proximal the cavity between decidua vera



Fig. 5: Weeks 4 + 3: In this picture the 3D shows the corionic villus



A



B

Figs 6A and B: Weeks 4 + 4: The GS grows quickly and now we can see the yolk sac (YS)

amniotic cavities. The vitelline sac appears as a transonic ring above the cephalic pole of the embryo; it grows slowly until weeks 8 to 9 without exceeding 5 mm in diameter, then it gradually reduces, disappearing between weeks 12 and 14.

An absent or much larger, non-spherical, hyperechogenic vitelline sac with echo-rich internal structure indicates a condition implying poor prognosis for the pregnancy. A GS with mean diameter of 20 mm or more and a volume small for gestational age, limited by a peripherally thin trophoblast without embryo indicates a blighted ovum. However, it is always advisable to repeat ultrasound examination a week later, or in weeks 7.

Weeks 6: From 5th weeks + 0 days to 5th weeks + 6 days

The GC should still be visible. If not, hCG assay should be performed and examination repeated a weeks later: the cause may be incorrectly estimated date of conception or ectopic pregnancy. Multiple pregnancy with multiple chorion is easy to detect (Fig. 20). The YS is detected in almost 100 percent of cases towards the end of weeks 6 and the double bubble image is increasingly frequent, with an embryo detection percentage of 20 to 40 percent. CRL measures 1.5 to 4 mm at the end of weeks 6 and embryo heart beat (93 to 106 beats/min) is visible. From weeks 6 until weeks 12, CRL is the most reliable biometric

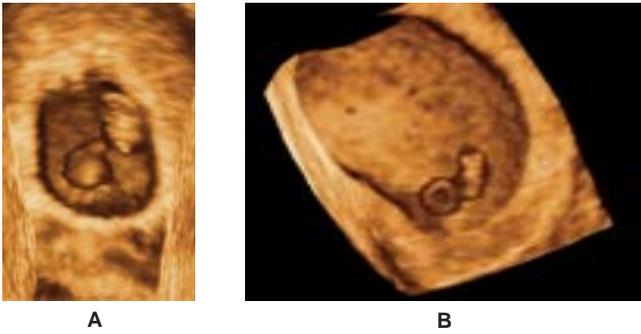


A



B

Figs 7A and B: Weeks 5 + 2-3: The embryo appears on lateral position of YS; the "double bubble" image, where the YS is near the CG's side



Figs 8A and B: Weeks 6 + 4: The separation between YS and embryo

parameter for dating pregnancy. It gives an error of ± 2 to 3 days in expert hands (Fig. 8).

Weeks 7: From 6th weeks + 0 days to 6th weeks + 6 days

The amnion is almost always distinct from the chorion. The vitelline sac is increasingly far from the embryo, sometimes already compressed between the two membranes. Prosencephalon and rhomboencephalon can be detected as well as outlines of the limbs. The first embryo movements can be observed (Figs 9A and B).

Weeks 8: From 7th weeks + 0 days to 7th weeks + 6 days

The amnion is still distinct from the chorion. The two membranes converge on the YS and finally envelop it. The YS disappears when the membranes fuse, which usually happens at weeks 14 to 16. Choroid plexuses are present. The intestine is herniated by the umbilical cord and should return within the abdomen by weeks 12 (differential with omphalocele). Embryo tachycardia > 110 bpm. Evident embryo movements. Visualisation of face, detection of extremities (Figs 10A to C).

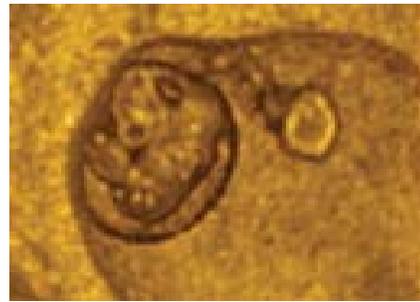
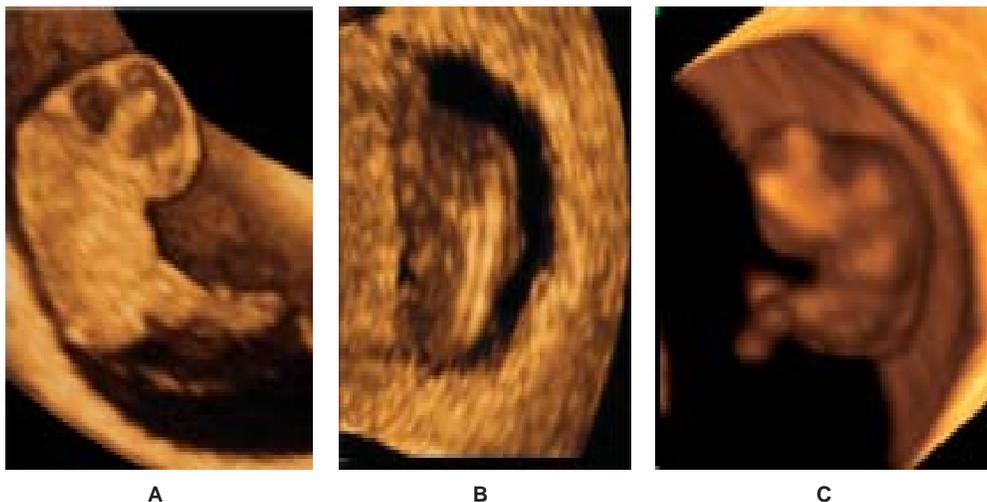


Fig. 9A: (Weeks 7 + 5): A good vision of the embryo: Into the head the prosencephalo, meso and rhomboencephalo are clearly visible; it is possible to distinguish the superior and inferior limbs, the queue and the umbilical cord very large in comparison of the embryo. The amnion is far from the chorion and YS is between the two membranes and in contact to the embryo by pedunculus



Fig. 9B: At this time the face of the embryo is visible



Figs 10A to C: Weeks 8 + 4: (A) Good image of the ventricles, (B) The column, (C) The surface rendering of 3D minimum mode

Weeks 9: From 8th weeks + 0 days to 8th weeks + 6 days

The embryo is clearly visible through vaginal and abdominal acoustic windows and has a human appearance. Its movements are abrupt. More articulated and refined movements do not occur until neopallium development in the 6th or 7th month. The face is clearly visible, especially in 3D volumetric scan. The cerebral hemispheres, ventricles with anterior and posterior (choroid plexus) horns have developed from the two vesicles of the telencephalon. Sometimes the cerebellum can be seen. The rhombencephalon is dividing to form the fourth ventricle (metencephalon) and the medulla (myelencephalon). Spine and ribs are clearly visible. Differentiation of *chorion laeve* and *frondosum* (Figs 11 and 12).

The embryonic period ends and the fetal period begins after weeks 9. The fetal period is characterised by rapid longitudinal (hyperplastic) growth which continues until weeks 20, further differentiation and organisation of organs and tissues formed in the embryonic period and acquisition of specific functions.

Fetal Period

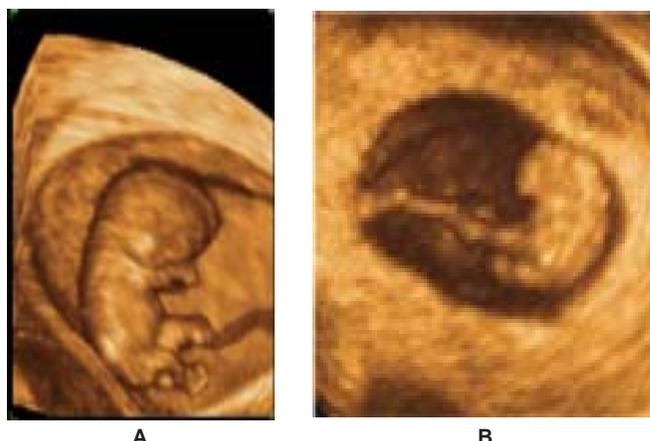
Weeks 10-14

Until the end of weeks 10, the transvaginal route is universally recognised as the best acoustic window for study of the embryo. After weeks 10, transabdominal US can also be done with good ultrasound equipment in women who are not overweight. By weeks 10, CRL is no longer accurate for dating pregnancy, its error increasing to ± 5 days (due to flexion and extension of the fetus). From weeks 11, biparietal diameter (BPD) is preferred, though CRL is still important when measuring nuchal translucency (NT).

From weeks 10, the fetus has anatomical characteristics that do not change, except in size and function. Umbilical hernia disappears around weeks 12. By weeks 14, the vitelline sac can hardly be seen and the two membranes fuse. The choroid plexuses in the brain no longer fill the cranial cavity but are relegated to the posterior horns. The cerebellum is increasingly evident and the posterior cranial fossa is detectable. Although the corpus callosum is not complete until much later and can be detected by weeks 20 to 22, the cavity of the septum pellucidum can be seen. The heart and its four chambers are visible by transvaginal US from weeks 12, though not in all cases; the detection percentage increases sharply in weeks 14. The fetal face becomes increasingly human and impressive images are possible by 3 or 4D. From weeks 12, BPD is the most reliable biometric parameter for dating pregnancy, with a mean error of ± 7 days (Figs 13 to 15).

Weeks 15-22

The 11 to 14th weeks is the best period to find a majority of foetal malformations except the heart; it is necessary a very important experience to study the hearth and the great vessels



Figs 11A and B: Weeks 9 + 2: Amazing images of umbilical cord with physiological hernia



Fig. 12: Weeks 10 + 2: The fetal's face not beautiful



Fig. 13: Weeks 11 + 3: The multiplanar scan offers the possibility to find all the fetal limbs and to study the encephalus; the fetus appears by surface rendering minimum mode under a total vision

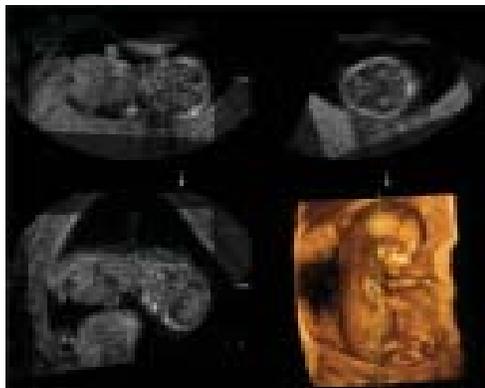
at this period by 3 to 4D (14th weeks). In fact many countries offer a second scan (19 to 22 weeks) like best period to detecting foetal anomalies, but today several countries (Israel for instance) offer a detailed heart scan by vaginal probe at 16 weeks. During the 19 to 22th weeks period the foetal anatomy is easy to study and 3 to 4D offers a beautiful images and more possibility to define the foetal malformations and normal pathological embryo-foetal behaviour (Fig. 21). It is possible to study better than by 2D the face by several aspects: morphology and all the part of the face (nose,lips,ears,fontanel,appendix of the ear,chin, bones); and the scan is very easy, suggesting, rapid also for the column, for the long bones, for extremities and for the position of the cord.

CONCLUSION

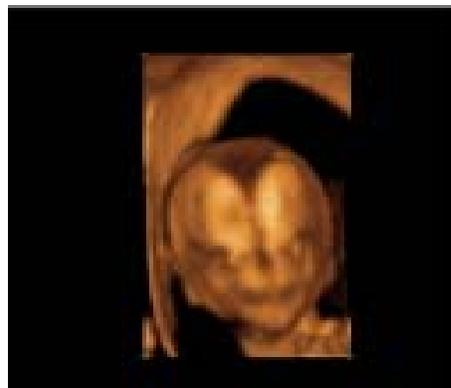
The study of embryo-fetal anatomy by 3D ultrasound provides sufficiently precise and detailed information for a clear picture of embryo-fetal physiology and pathology. Moreover, three-dimensional US with the time dimension, known as 4D, can show the physiological development of embryo-fetal



Fig. 14: (Weeks 12 + 2) By the 3D scan surface rendering maximum mode we can study the bones



A



B

Figs 15A and B: (A) Weeks 13 + 3: Now we have a total vision of the fetus, (B) Weeks 14 + 0: The face of the fetus take a human features



A



B

Figs 16A and B: Weeks 12 + 2: Holoprosencephaly with anencephaly and abdominal wall schisis



Fig. 17: Weeks 12 + 1: Trisomy 18: We can see the omphalocele and the arm malformation



Fig. 19A: Weeks 12 + 2: A 3D scan surface rendering maximum mode to find the nasal bone



Fig. 18A: Weeks 12 + 3: Simple hygroma: The typical anechoic areas at the basis of the neck



Fig. 18B: Weeks 14 + 0: Septated cystic hygroma



Fig. 19B: The maximum mode offers a good vision of the two nasal bones

movements, starting from the tonic-clonic movements of weeks 7, through to contact reaction with contraction of the lower limb muscles at weeks 12.

Sonoembryology, the detailed anatomical and functional study of the embryo, is based on these possibilities and can be extended to weeks 14, bringing forward the period of acoustic observation currently performed in weeks 19 to 22. Indeed, there have already been many reports that most malformations (Figs 16

to 17) and chromosome defects can be detected in the first trimester and transient markers (nuchal translucency, cystic hygroma (Fig. 18) certainly apply to this period or other markers of aneuploidy like nasal bone (Fig. 19) and maxillary length. Those that develop between the second and third trimester are of course excluded. The economic and psychosocial advantages of early diagnosis made possible by these techniques are enormous.

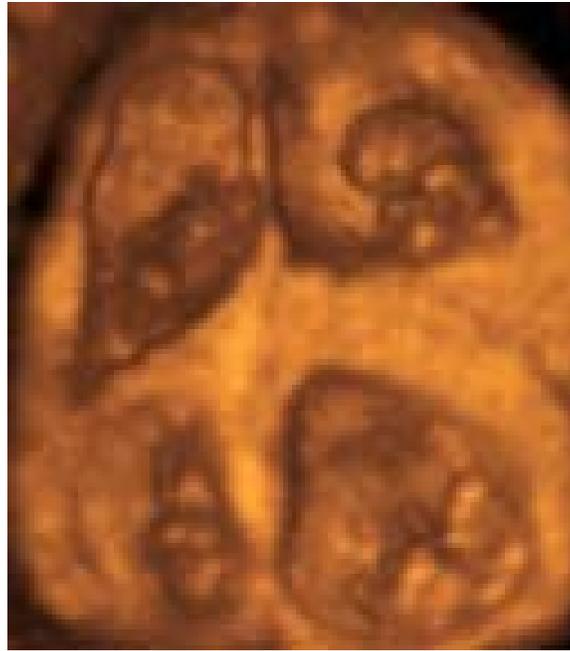


Fig. 20: Weeks 7 + 2: An amazing image of teratogenic pregnancy



A



B

Figs 21A and B



Figs 21A to K: weeks 7, 10, 14, 20, 21, 23,25, 26, 31, 33 and 36 respectively. This series of images of embryo and fetal face show an increasingly “human” appearance and increasing possibility of facial expression. After about weeks 21, facial traits are so precise as to almost enable recognition at birth



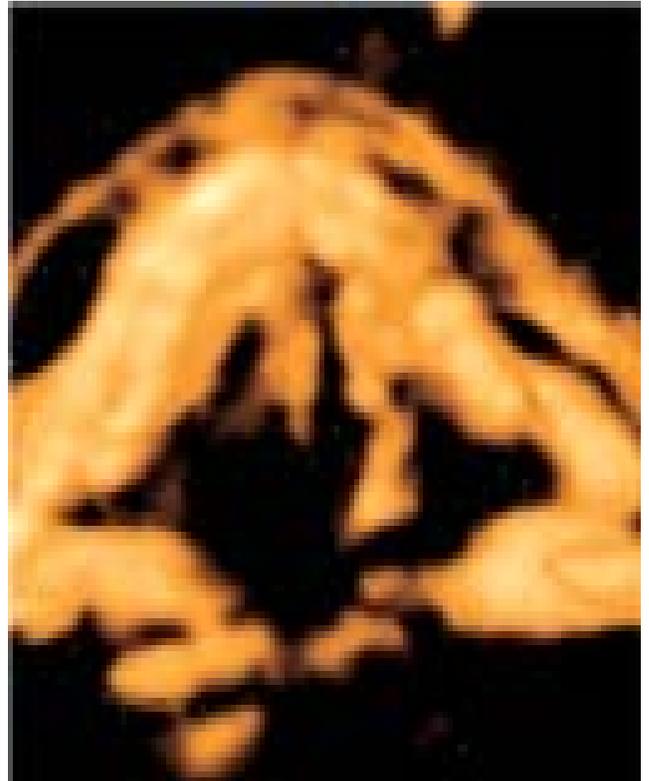
Fig. 21L: Weeks 19, day 3: Maximum mode even shows bones of the head



Fig. 21M: Weeks 25, day 0: Image showing ear appendages (by kind permission of Dr. Mariangela Rustico)



N



O

Figs 21N and O: Weeks 23, day 0. The jaw can be studied by minimum (o) or maximum (p) mode



Fig. 22: Weeks 14, day 3: Transverse scan showing cerebellum, choroid plexuses and median line

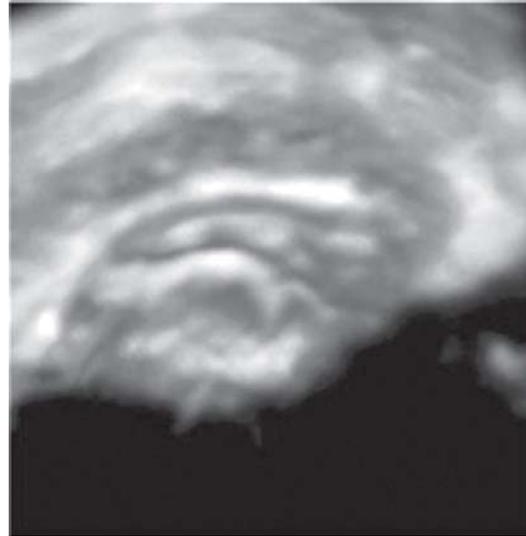


Fig. 23: Weeks 23, day 0: Longitudinal scan clearly showing corpus callosum and fossa of pellucid septum



Fig. 24: Weeks 21, day 2: VCI-C plane method shows corpus callosum and fossa of pellucid septum in realtime



Fig. 25: Weeks 22, days 3: Glass-body power angiography showing pericallosal and marginal arteries



Fig. 26A: Weeks 21, days 4: Section of fetal head showing oro-nasal cavity



Fig. 26B: Top view of bregmatic fontanelle

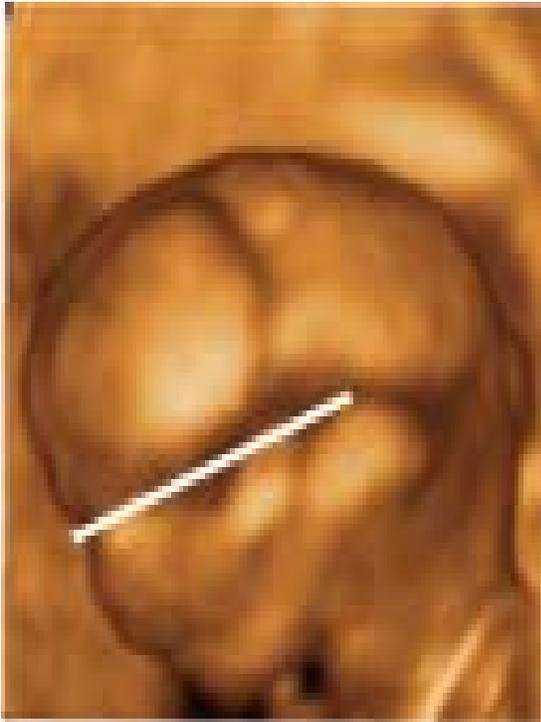
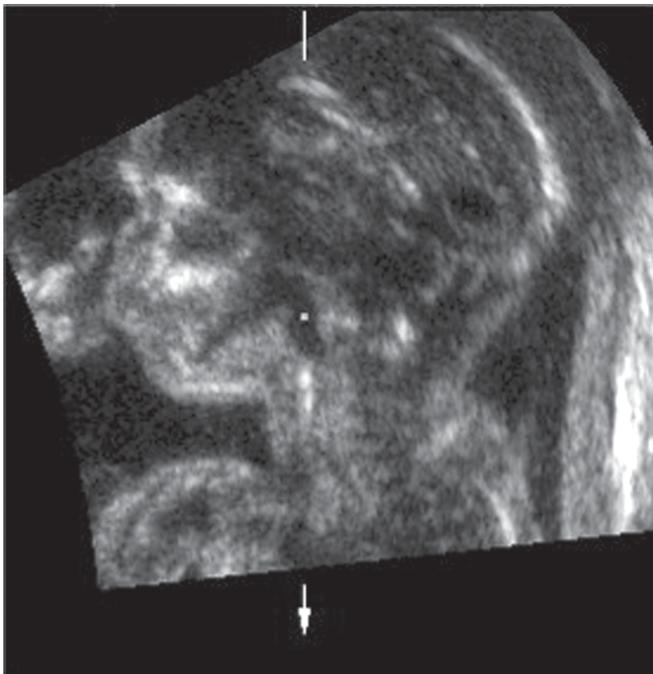


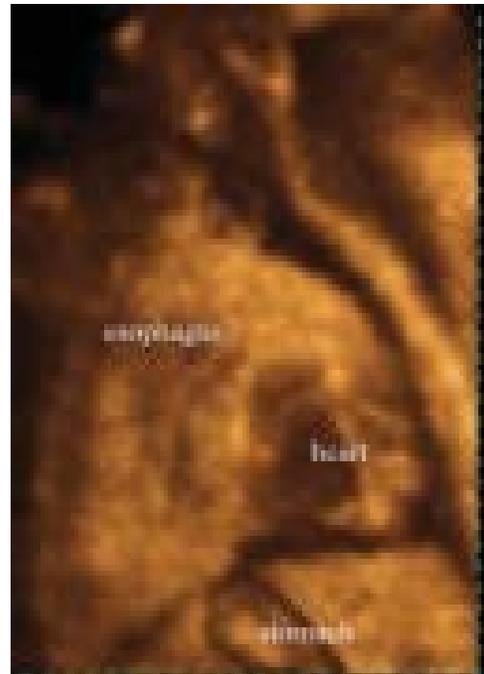
Fig. 27: Weeks 14, day 0: 3D study of ear position since first trimester. The elice should be at eyebrow height



Fig. 28: Weeks 22, days 3: Sagittal scan showing chest and heart area anterior to thymus and posterior to lung, diaphragm, liver, intestine and bones of spine and sternum



A



B

Figs 29A and B: Weeks 22, day 3: 2D and 3D images of esophagus



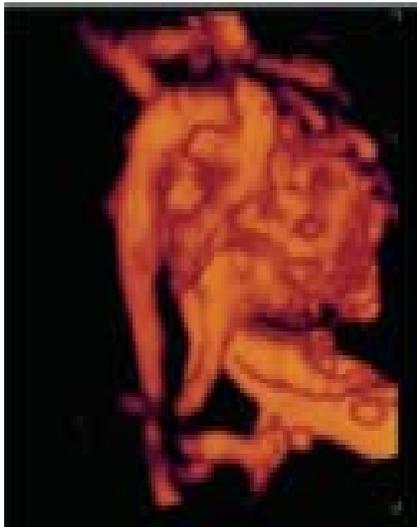
Fig. 30: Weeks 22, days 3 detail of thymus



Fig. 31A: Weeks 22, days 2: 3D image of heart showing four chambers and interventricular septum



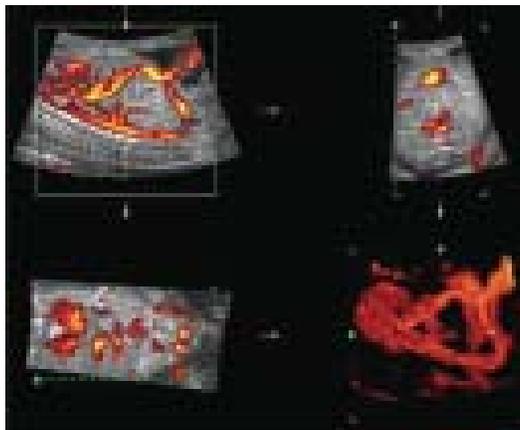
B



C

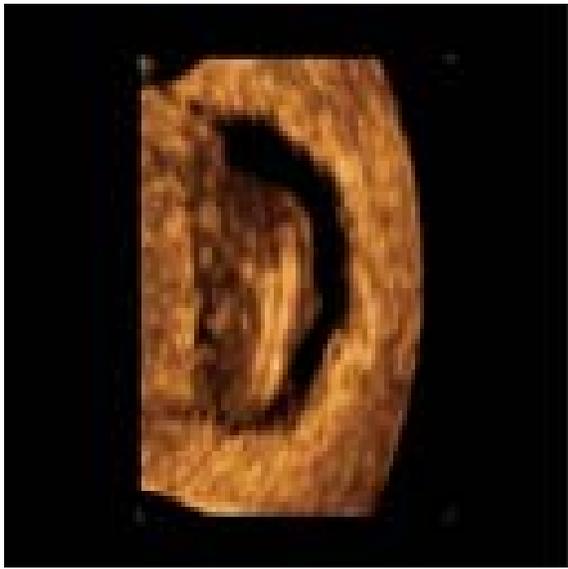


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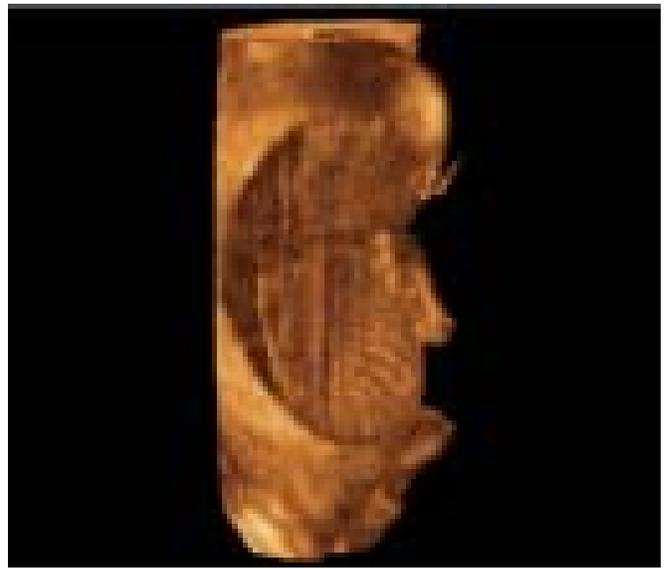


E

Figs 31B to E: 3D power colour angiography showing details of aorta, aortic arch, inferior vena cava, ductus venosus and pulmonary artery



A



B



C

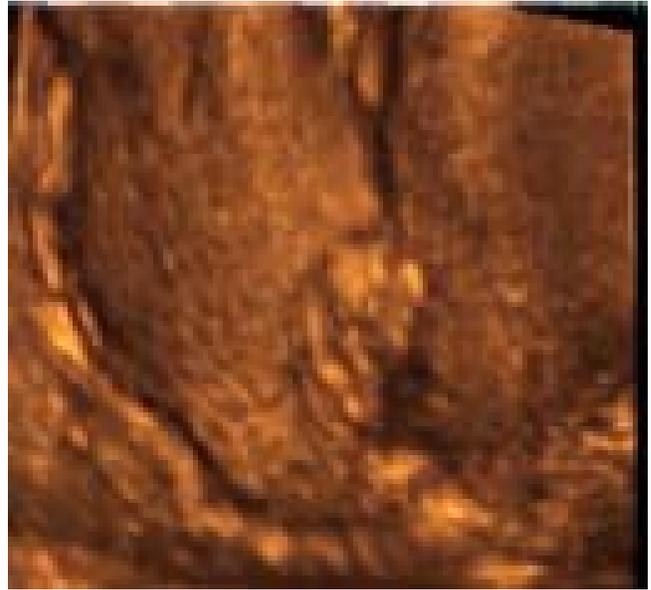


D

Figs 32A to D: Weeks 7, 13, 19 and 24 respectively: 3D multiplanar maximum mode images of spine provide accurate examination of vertebral column from first trimester



A

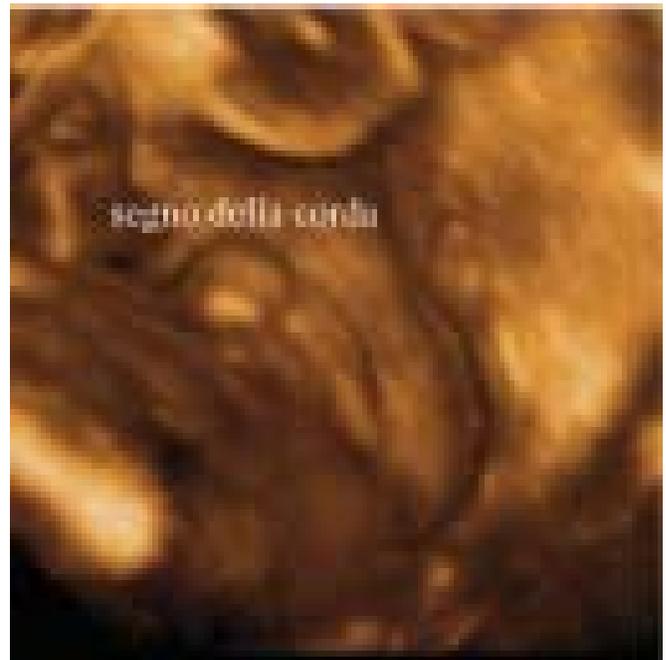


B

Figs 33A and B: Weeks 23, day 0: Comparison of normal female genitalia and clitoral hypertrophy

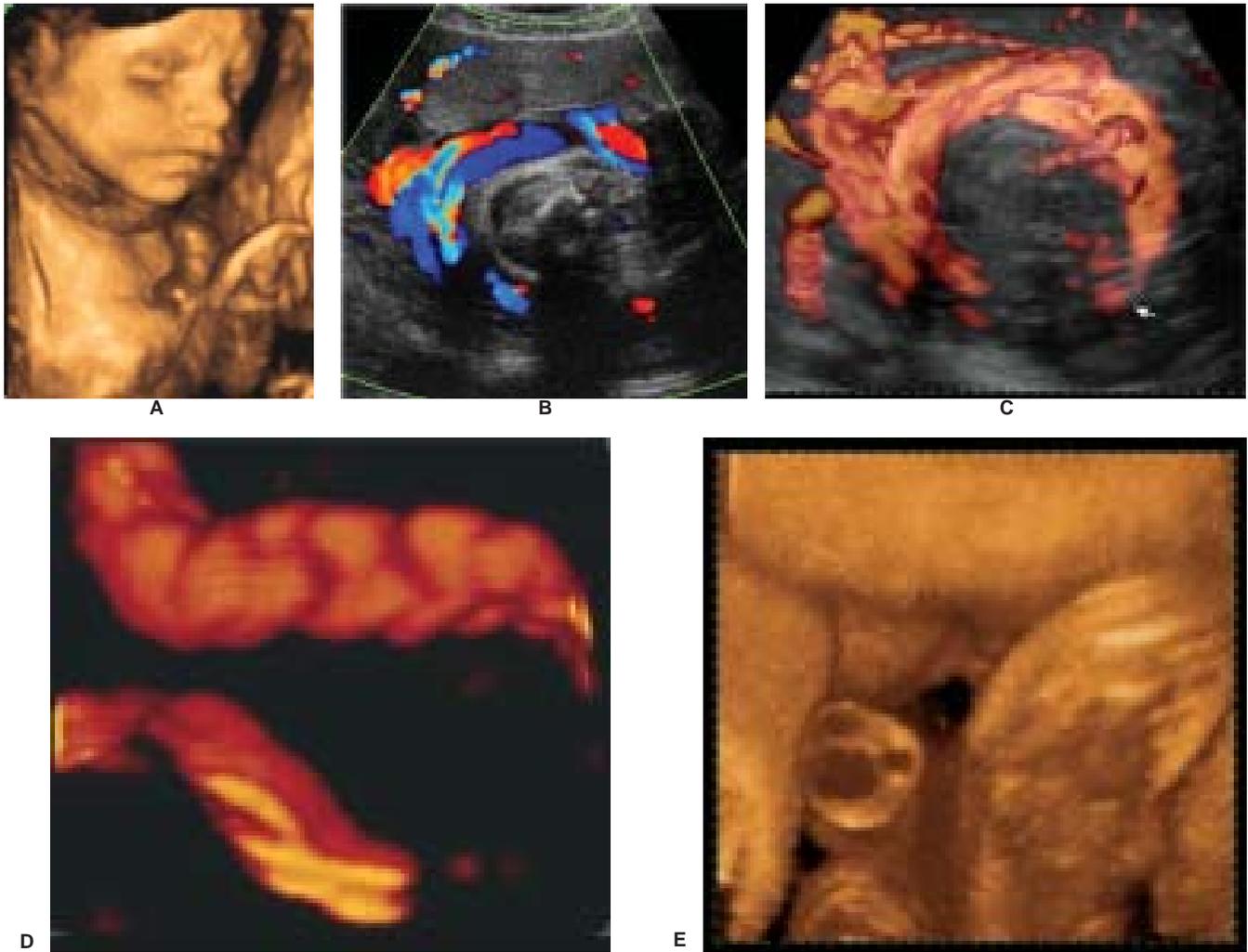


A

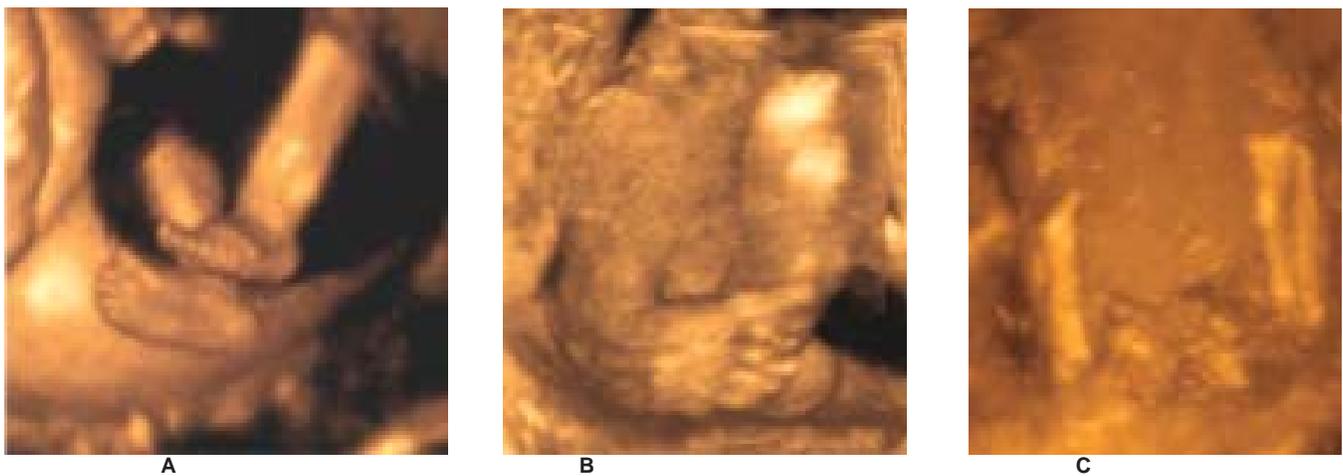


B

Figs 34A and B: Weeks 24, days 2: Normal male genitalia and hypospadias with tulip sign



Figs 35A to E: A to C: Weeks 23, day 0: 3D power colour angiography image showing double loop of umbilical cord.
D and E: 3D power angiography and 3D section of umbilical cord showing arteries and umbilical vein



Figs 36A to C: Weeks 22, day 0: Perfect image of lower extremities in which it is possible to count toes. The image is quickly obtained by 4D scan. Two images of bilateral congenital varus foot obtained in minimum and maximum mode; the latter mode enables a relatively correct diagnosis and hence a better prognosis



Fig. 36D: Weeks 22, days 4: Agenesis of left hand (by kind permission of Dr R Nannini)



A



B

Figs 37A and B: Life (A) before birth and (B) after birth

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