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REVIEW ARTICLE

Early Normal and Abnormal Pregnancy

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ABSTRACT

The high resolution, safety and ease of performance make ultrasound the procedure of choice for routine ultrasonography in the first half of pregnancy as a standard of obstetric care. Transvaginal ultrasound has revolutionized the diagnosis and management of early pregnancy. Pregnancies can be detected earlier compared with abdominal ultrasound, patients reassured by showing normal development, accurate gestational age determination, sufficiently early characterization of multiple pregnancy, early diagnosis of lethal anomalies and screening of chromosomal defects can be done with first trimester ultrasonography. Furthermore, recent introduction of three-dimensional and four-dimensional ultrasounds combined with the transvaginal approach has produced more objective and accurate information on embryonal and early fetal development and made it possible to visualize fascinating aspects of embryonic differentiation.

Keywords: Early pregnancy, Transvaginal ultrasound, 3D-4D ultrasonography.

INTRODUCTION

Modern ultrasound technology, especially transvaginal techniques, has improved the assessment of early pregnancy development.[1] Currently, first trimester ultrasonography indications are to confirm the presence of an intrauterine pregnancy, to evaluate a suspected ectopic pregnancy, to define the cause of vaginal bleeding, to evaluate pelvic pain, to estimate gestational age, to diagnose or evaluate multiple gestations, to confirm cardiac activity, as an adjunct to chorionic villus sampling, embryo transfer, or localization and removal of an intrauterine device, to evaluate maternal pelvic masses or uterine abnormalities and to evaluate suspected hydatidiform mole.[2] The use of diagnostic ultrasound during pregnancy is considered to be safe for both mother and fetus. Even in critical periods of development and using high-frequency transvaginal transducers, no adverse bioeffects have been demonstrated.[2,3] Ultrasound provides reassurance, charts normal development and identifies women with abnormal or high-risk pregnancies.[4] Sensitive biochemical assays and high-resolution ultrasonography now make the diagnosis of pregnancy highly sensitive and specific.[5]

Furthermore, recent introduction of three-dimensional and four-dimensional ultrasounds combined with the transvaginal approach has produced more objective and accurate information on embryonal and early fetal development and made it possible to visualize fascinating aspects of embryonic differentiation. Three-dimensional diagnostic ultrasound technique is changing our understanding tremendously. The opportunity to observe the volumetric morphology of the embryo from the very beginning of gestation is clearly of immense importance in understanding the events taking place in this key period of human development.[6-8]

Earliest Ultrasound Detection and hCG

Ultrasound examination was first adopted for obstetric use in the 1950s by Ian Donald and it has since become the mainstay of early pregnancy diagnosis.[4,9] Using transvaginal ultrasonography, Bree et al were able to discern a gestational sac, yolk sac and fetal cardiac activity at β-hCG levels of 1025, 7200 and 10,800 mIU/ml IRP,[10] International Reference Preparation (IRP) was developed in 1980.[11] The numerical value of the IRP in international units (IU) is about twice that of the second international standard respectively.[10,11] Transvaginal sonography was introduced in the late 1980s, and it provides superior images owing to the proximity to the pelvic organs. Additionally, a transvaginal scan can be used at earlier gestations;[12] it gives clearer images and can be performed instantly, as the patient needs an empty bladder. There are, however, some limitations; some women may feel it is an intrusion or may be concerned in case the pregnancy is harmed. Some women will refuse a transvaginal scan. Transabdominal ultrasonography is still widely used in this period of gestation for cultural and practical reasons.[4,12-14]

The occurrence of positive qualitative evidence of pregnancy occurs shortly after implantation at about 23 to 28 days (menstrual). The first ultrasound evidence of pregnancy occurs at about 32 to 35 days.[15,16] Routine ultrasonography during the first trimester is used for accurate pregnancy dating, early diagnosis of major malformations, characterization of multiple pregnancy and screening of chromosomal anomalies.[17,18] Failure to understand the limitations of diagnostic ultrasound or inadequate training of physicians in this technique can result in grave complications for the patient and liability for health care providers.[5]

Timing of Early Pregnancy[5,16,19-21]

The traditional duration of pregnancy dates from the first day of the last menstrual period an average of 40 weeks to delivery. The beginning of this period is made up of:

Preovulatory (follicular) phase of the ovarian cycle: 13 to 14 days ending with ovulation of oocyte from ovary into the peritoneal (fimbriated) end of the fallopian tube. Variation typically less than 3 days, occasionally 5 to 7 days.

Oocyte migration: The oocyte migrates into the tube, with fertilization in the tube within 24 hours, typically about day 14.

Fertilization and zygote migration: The zygote migrates from tube into the fundal uterus with implantation on days 22 to 25.

Implantation, or the process by which the embryo comes in contact, adheres and penetrates the endometrium, is necessary prior to the diagnosis of pregnancy. First contact between the blastocyst and the endometrium occurs 6 days after fertilization. This is known as apposition. Soon after apposition, the blastocyst becomes adherent to the endometrium, and the process of implantation has begun. Trophoblastic hCG production gains access to maternal circulation and sensitive pregnancy tests turn positive, this event occurs 3 to 5 days prior to the first missed period.

Following implantation, a cavity or sac develops which lies inside the chorionic layer. This subchorionic layer contains the yolk sac (secondary) and the embryonic disk (early embryonic cell mass) surrounded by its own small amniotic cavity.

FIRST TRIMESTER ULTRASOUND: NORMAL LANDMARKS (Figs 1 to 27) (Tables 1 to 4)

The definition of standard developmental morphological features may open the possibility of screening for structural defects early in the first trimester of pregnancy.[1]

There are key chronologic landmarks in the normal development of an embryo or fetus that can be identified by ultrasound scan, and therefore the distinction of a normal and abnormal pregnancy can be made.[4,6,7,22-27]

4th Week

The first suspicious image of a pregnancy is the persistence proximal to the menstrual days of a decidual transformed endometrium accompanied by a vascular active corpus luteum that can be disclosed by ultrasound.[24,25] A few days before the expected menses, a typical image of a hyperechogenic ring inside the uterine cavity can be identified by transvaginal

Fig. 1: Transvaginal sonogram showing early intrauterine pregnancy of 3 weeks (Decidual response to implanted pregnancy is seen), on the right and normal appearing gestational sac with a double decidual sac sign at 4 weeks' gestation (in the middle and on the left)

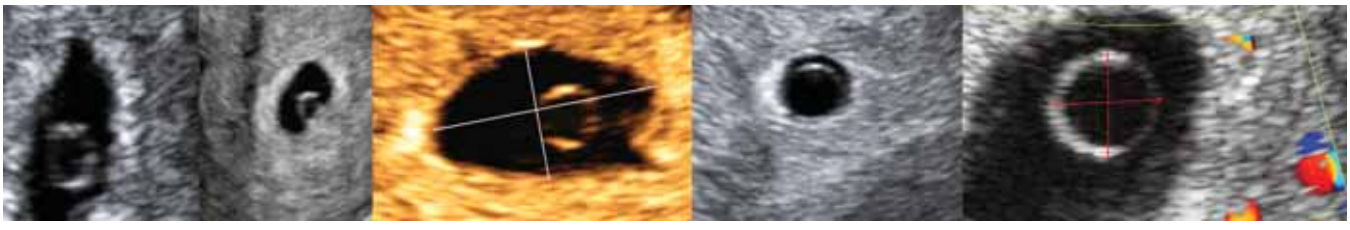


Fig. 2: The 2D ultrasound pictures of yolk sac in different pregnancies at about 5 weeks. Yolk sac is a source of nutrients for fetus. At the tenth week, yolk sac loses its function and begins to degenerate, losing its vascularity[3]. The third ultrasound picture from the left shows the measurement of GSD. The callipers are placed at the inner edges of the trophoblast.[12] The last ultrasound picture on the right shows the measurement of YSD. The callipers are placed at the center of the yolk sac wall.[12] The mean YSD and GSD, when the embryo first appears at 6 weeks of gestation, are about 3 and 10 mm respectively[12]

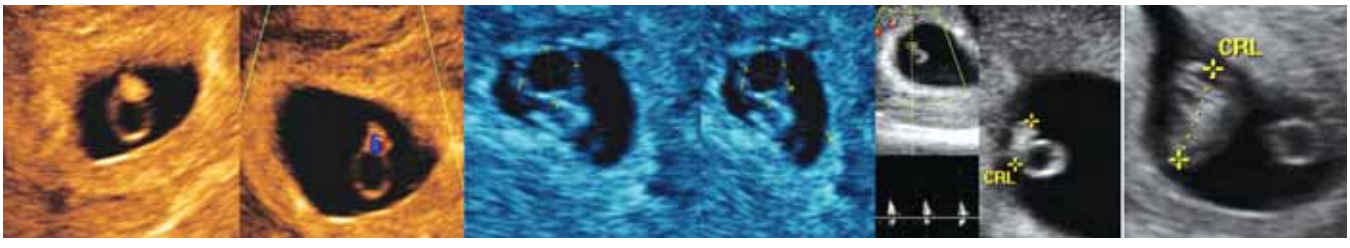


Fig. 3: Transvaginal color flow sonogram of 6 and 7 weeks pregnancies respectively illustrating vascularization of the sac and embryo. Early embryo adjacent to yolk sac is seen with embryonic heart beats. From 7 weeks onward, CRL is measured in a sagittal section of the embryo with care being taken to avoid inclusion of the yolk sac[12]

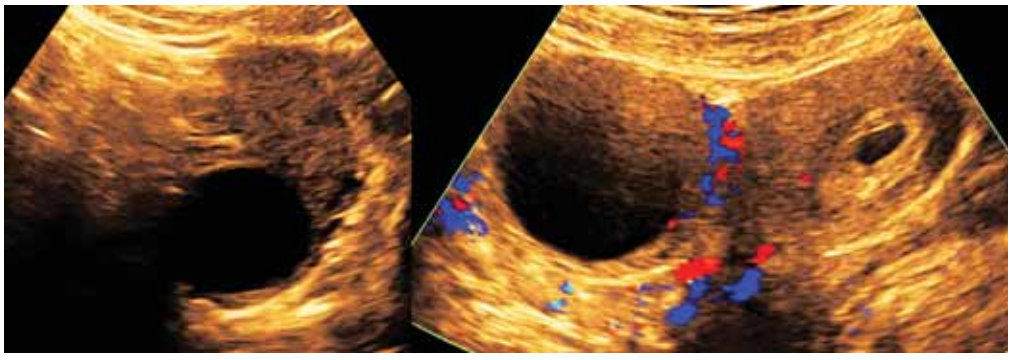


Fig. 4: 2D US of corpus luteum and in the right side of the image color Doppler makes possible to depict the vascularization of corpus luteum at 6 weeks of gestation

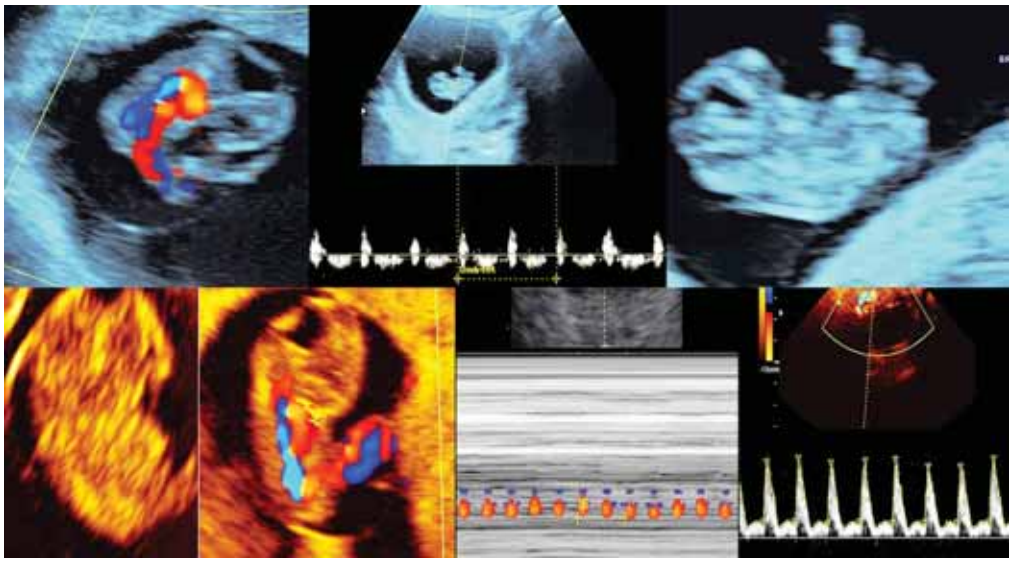
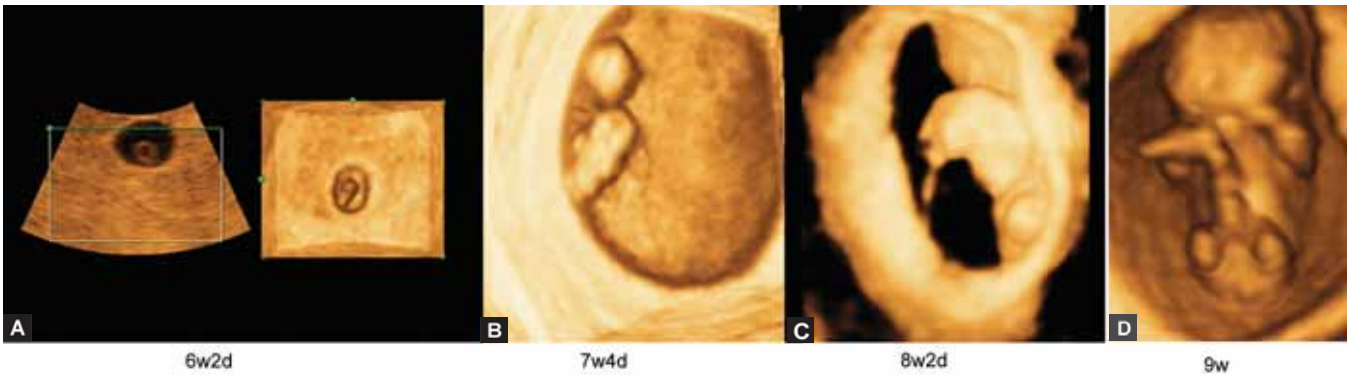


Fig. 5: Amniotic membrane encircling the developing embryo at 8 weeks visualized by 2D color flow ultrasound. Fetal circulation parallely with growing of embryo can be seen. Brain and heart vascularization can be depicted for the first time at this gestational age.[3] Fetal heart beat can be visualized with color M-mode function of the ultrasound. The last picture at the bottom shows the pulsatile uterine artery Doppler flow with notching at first trimester



Figs 6A to D: Transvaginal 3D sonogram of early pregnancy. (A) 6 weeks of gestation with a small fetal pole visible, (B) 7 weeks and 4 days (C) 8 weeks and 2 days of pregnancy, note that the visible limb buds, (D) 9 weeks of pregnancy with visible facial features and extremities

ultrasound. A small gestation sac (2-5 mm) appears in the endometrium. The sac is spherical, regular in outline and eccentrically situated toward the fundus. It is implanted just below the surface of the endometrium (midline echo) and is surrounded by echogenic trophoblast. This corresponds to the gestational sac, the echogenic ring being the chorionic villi surrounding the chorionic cavity. What is first observed is the gestational sac (day 31 ± 1), and the visualization threshold is nowadays established when the β-hCG values have surpassed the 1000 mUI. 3D diagnostic ultrasound makes it possible to

Fig. 7: Transabdominal 2D US showing CRL of fetuses beginning from 6 to 13 weeks of pregnancies respectively (left to right)

Fig. 8: Transvaginal sonogram of an 8-week pregnancy. Limb buds are seen on the left side. Transverse section of the head is seen. 4th ventricle is seen in the middle. In the 9th week of pregnancy, early spine can be examined in its whole length (on the right)

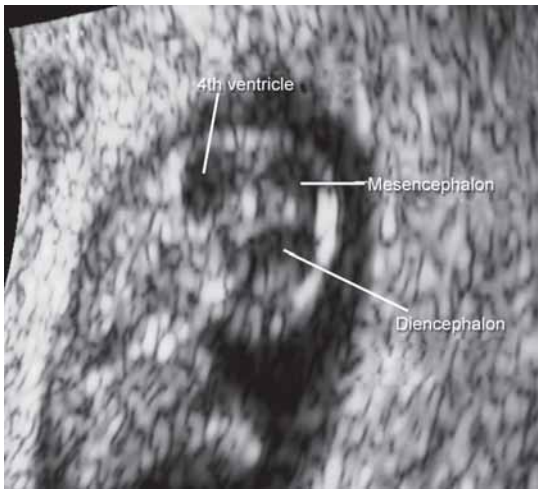


Fig. 9: In early embryonic period, brain appears as cystic formation. First, rhombencephalon is seen, followed with the development of mesencephalon and diencephalon. The ventricular cavities are characteristically cystic and must not be misdiagnosed as Dany Walker syndrome[3]

obtain images much earlier: On the 27th day of the cycle (13 days after fertilization). Being able to observe in the three orthogonal planes and with 3D rendering allows observation of the exact site of implantation in the endometrium.

5th Week

During the 5th week, the chorionic sac measures 7 to 10 mm. When this diameter reaches 9 mm, the yolk sac can always be identified as a round, fluid-filled and eccentric structure with a diameter of 3 mm. The secondary yolk sac is the first element seen in the gestational sac. It is a spherical membrane, quite echogenic and readily seen. Because it is reliably seen early, usually at 5 weeks, it is a critical landmark identifying a true gestation sac. The gestational sac can be observed with the following characteristics: An oval or round shaped with limpid boundaries, homogeneous trophoblastic rim greater than 5 mm, no internal contour irregularities. The gestational sac grows at a rate of about 1mm per day. The sac's shape is round between the fifth and sixth weeks and becomes oval later on during the end of the 5th week, the embryo is first seen on high resolution scans as a thickening on the margin of the yolk sac. The embryo attains a size of 2 mm and appears sonographically as a hyperrefringent area located on the yolk sac. Pulsations can be visualized on real-time imaging, close to the wall of the yolk sac and within a 2 to 3 mm echogenic line corresponding to the embryo. After this time, the heart rate can be measured using simultaneous M-mode.

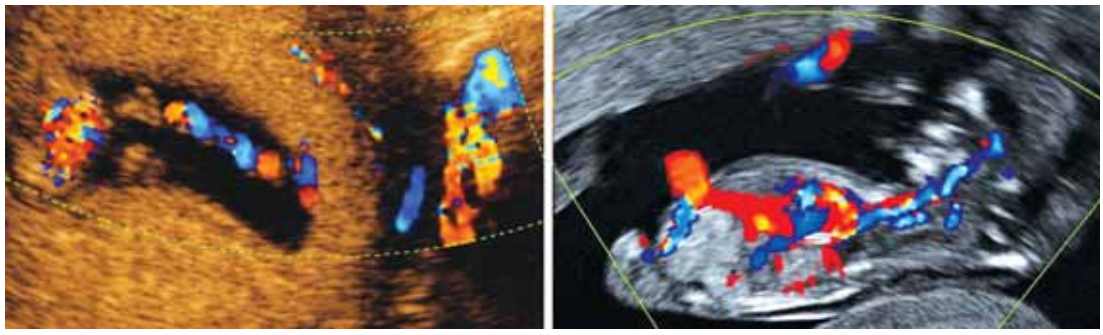


Fig. 10: 2D color flow sonogram shows intervillous circulation in the maternal site of placenta at 9 weeks of gestation with intense vascular activity. Visualization of the umbilical cord and its vascularization are also seen. On the right, 2D color flow TV sonogram of a fetus at 11 weeks of gestation. Umbilical vein can be followed from the abdominal umbilical insertion through the fetal liver and ending below the heart. Cerebral circulation can also be visualized in the first trimester[3]

Fig. 11: Transabdominal 2D sonogram of transverse section of normal fetal head showing cerebral hemispheres and lateral ventricles at the 10th, 11th, 12th and 13th weeks of pregnancy respectively (left to right). Choroid plexuses filling more than one-third of the lateral ventricles also called as butterfly-shaped choroid plexus: Normal finding for the first trimester of pregnancy at this gestational age. Butterfly-shaped choroid plexus—characteristic image at 11 weeks of pregnancy[3]

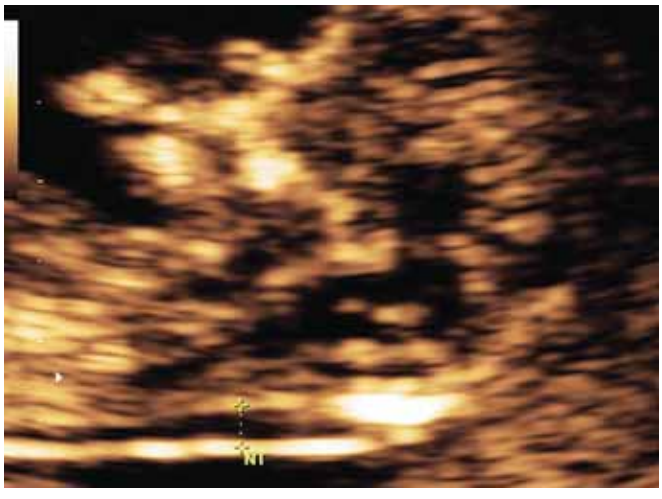


Fig. 12: Transabdominal 2D ultrasound of fetal brain at 12 weeks gestation with normal nuchal translucency. Nasal bone is also present at this fetus

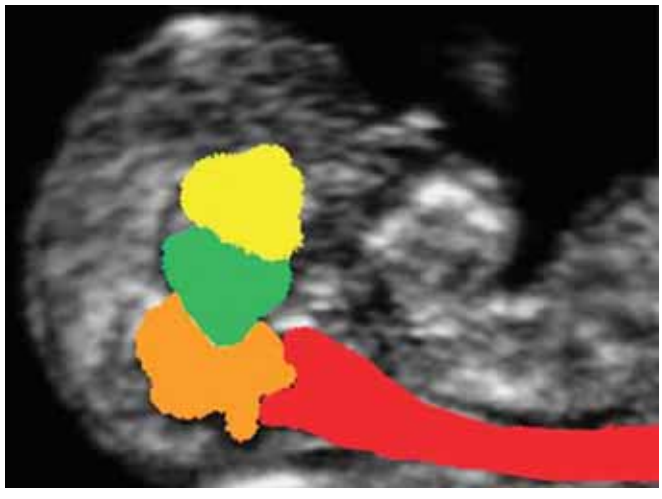


Fig. 13: Portions of the fetal brain are displayed in colors: Telencephalon (yellow), mesencephalon (green), metencephalon (orange), myelencephalon[21]

Measurement of the mean gestational sac diameter is an effective estimate of gestational age, used between 5 and 5.7 to 6 weeks. From fifth week onward, different organs and structures will appear.

6th Week

The most important finding is the embryonic visualization. The embryonic pole is visible and it measures 2 to 4 mm in length. Cardiac motion can be clearly seen and the mean heart rate at this gestational week is about 118 bpm. The amnion is not yet clearly seen, so the embryo and the yolk sac are apparently free floating in the chorionic cavity, although eccentrically fixed by the connecting body stalk. By high-resolution vaginal scanning, embryos should be seen at mean sac diameters (MSD) of 18 mm, with lower resolution abdominal scanning, embryos should be seen with MSD of 25 mm.

Fig. 14: 2D US shows posterior fossa of the fetal brain transverse section on the left and coronal section on the right at 12 weeks of gestation. Cerebellum and 4th ventricle are seen clearly

Fig. 15: Evaluation of the fetal face with 2D US at 12th week of gestation. Fetal orbits with oromaxillofacial triangle coronal view can be seen

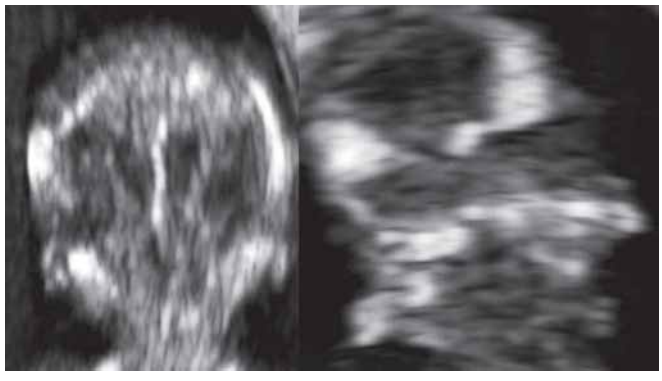


Fig. 16: 2D US appearance of fetal ear at 11 weeks of gestation at coronal sections

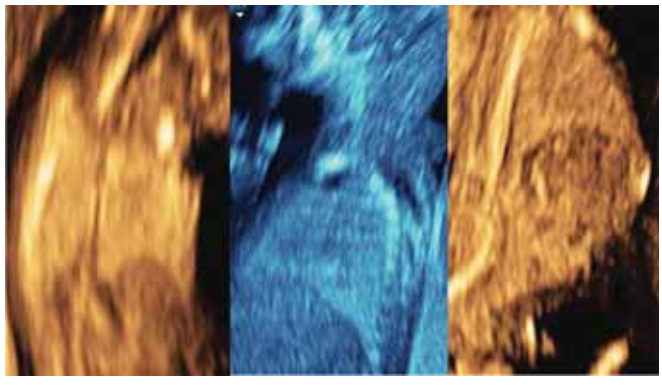
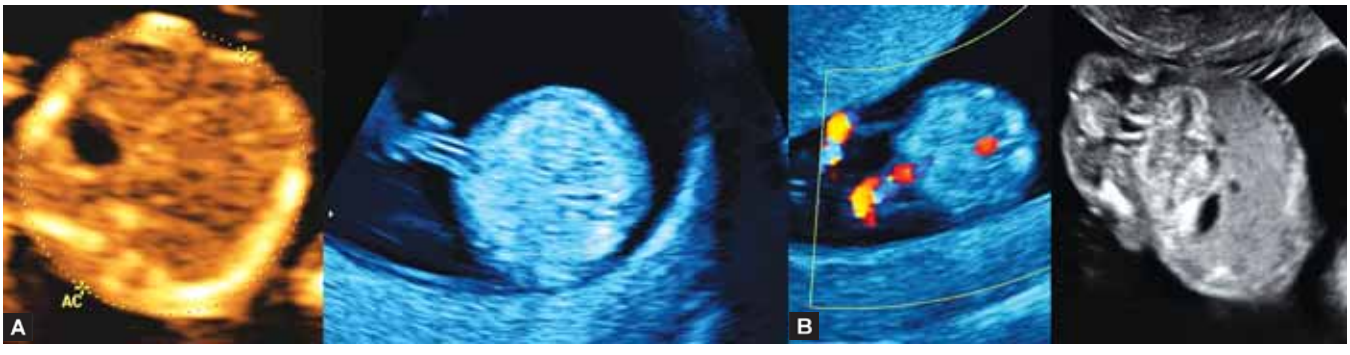


Fig. 17: 2D US images of fetal lungs and fetal diaphragm can be evaluated even at first trimester of pregnancy. Coronal view on the left and sagittal views in the middle and on the right



Figs 18A and B: Transverse section of fetal abdomen by transabdominal 2D ultrasound at 13th week of pregnancy. (A) The stomach, liver and hepatic vein are visible, (B) the entrance of umbilical cord is clearly seen. Abdominal wall defects can be diagnosed with this section even at the first trimester. Fetal intestines can also be seen easily (on the right)

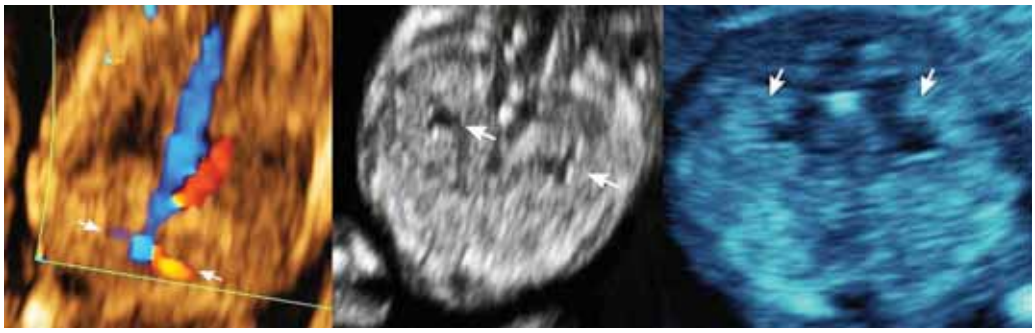


Fig. 19: 2D color US of 13 weeks old fetus showing renal arteries on the left and fetal kidneys coronal section in the middle and transverse section on the left can be visualized at this gestational week

Fig. 20: Transabdominal 2D sonogram of the two umbilical arteries running around the bladder at 9th, 10th, 11th, 12th and 13 weeks of pregnancies respectively (left to right). On the right side, single umbilical artery of the fetus at first trimester can be seen

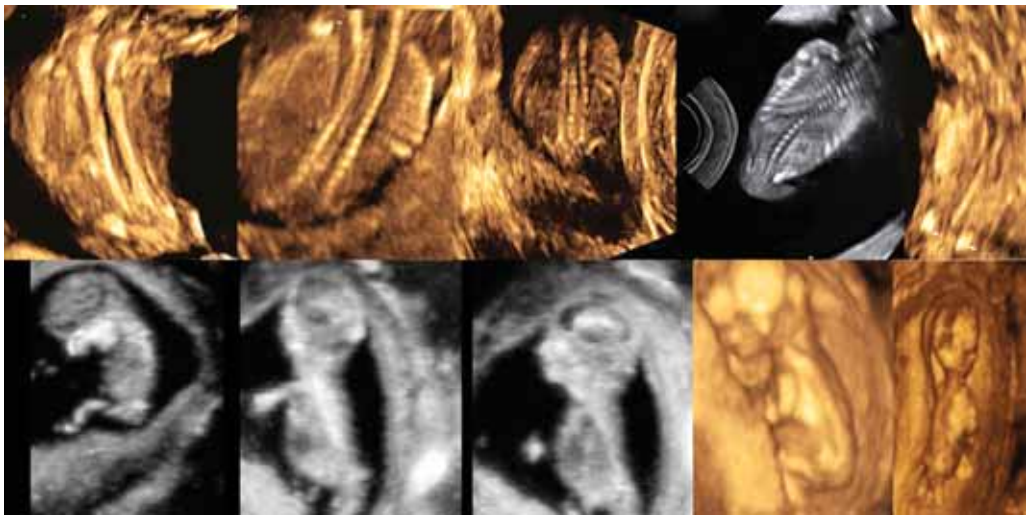


Fig. 21: Fetal spine can be evaluated successfully at the first trimester by 2D (above line) and 3D ultrasound VCI technique (bottom first 3 pictures) and 3D surface rendered image (last 2 on the right at the bottom line)

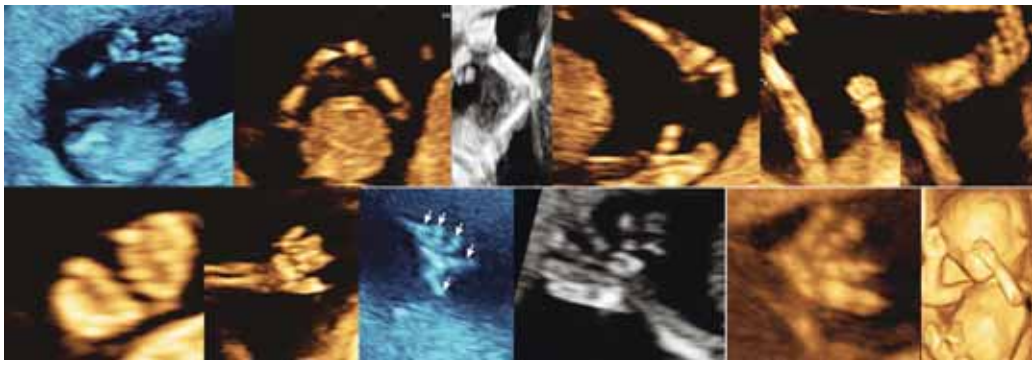


Fig. 22: Transabdominal 2D and 3D ultrasound evaluation of upper extremities at first trimester of pregnancy. Fetal arms, arm bones, hands and fingers can be visualized in detail successfully

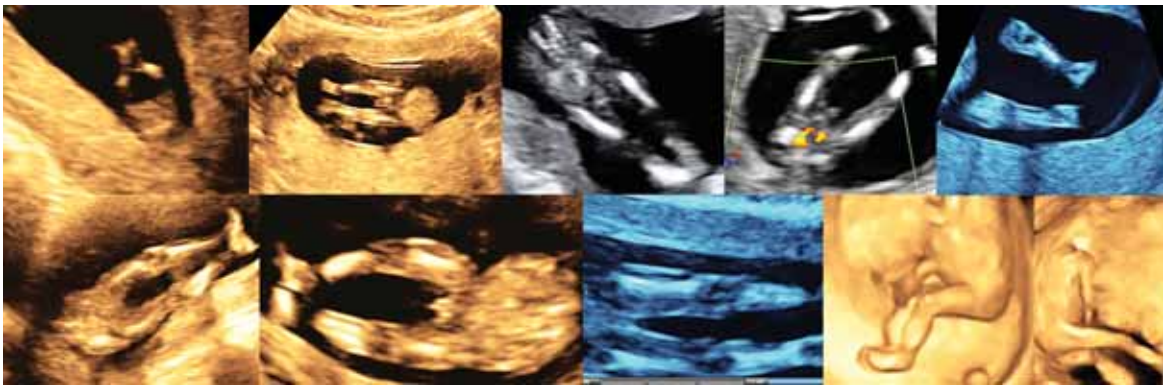


Fig. 23: Transabdominal 2D and 3D ultrasound evaluation of lower extremities at 12th week of pregnancy. Fetal legs, leg bones, feet and toes can be visualized and talipes can be picked up successfully

Fig. 24: 2D US pictures showing fetal feet at different gestational ages at first trimester

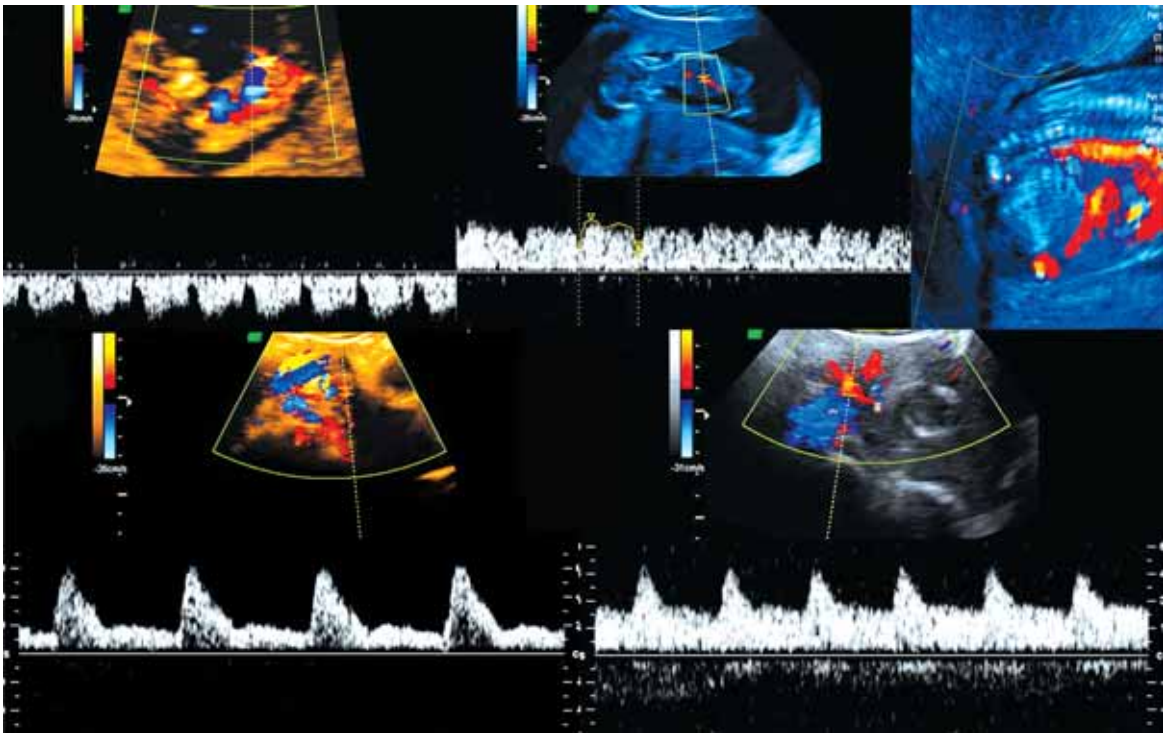


Fig. 25: Transabdominal color Doppler evaluation of the fetus at the first trimester. Above normal flow at the ductus venosus with a positive wave. Blood flow at aortic arch and descending aorta. Fetal circulation can be imaged easily even at the first trimester. Uterine artery color Doppler evaluation in the first trimester. Lower left picture shows uterine artery with notching and lower right picture shows uterine artery with normal flow at diastole

Following the visualization of the embryo, the crown-rump length should be measured. This is because later gestational sac measurements may not reflect the embryonic size (or even its presence), the embryonic CRL directly reflects embryonic growth. This measurement should be made from the cephalic pole to the rump taking care to measure the embryonic curvature.

The gestational sac grows approximately 1.15 mm per day, so that at the end of the sixth week it measures 20 mm, up from

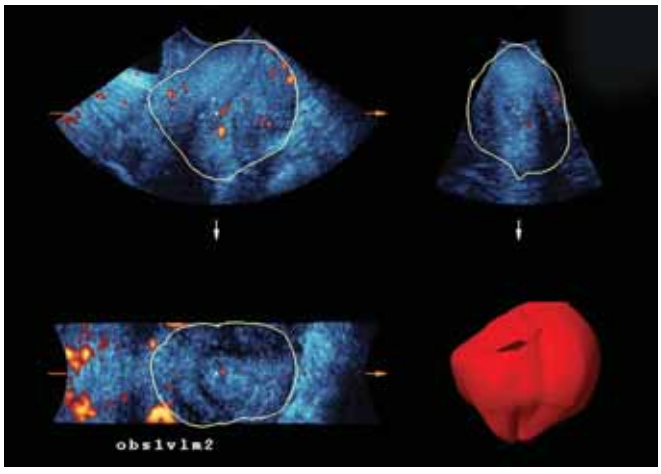


Fig. 26: Transvaginal 3D US power Doppler assessment of the cervix. Cervical volume and vascularization can be calculated easily using the virtual organ computer-aided analysis (VOCAL) program

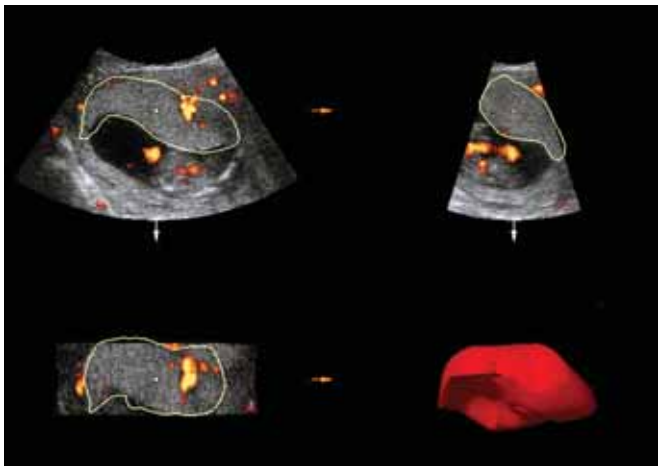


Fig. 27: Transvaginal 3D US power Doppler assessment of the placenta at the first trimester. Placental volume and vascularization can be calculated easily using the virtual organ computer-aided analysis (VOCAL) program

10 mm at the beginning of this week. The embryonic growth is of 1 mm per day.

7th Week

During the 7th week, the crown-rump length measures 11 to 16 mm and the yolk sac, with a diameter of 5 mm, separates from the embryo, probably owing to the growth of the vitelline duct.

The rhombencephalon becomes as a diamond-shaped cavity, enabling distinction of cephalad and caudal. The spine is seen as double echogenic parallel lines. The amniotic membrane becomes visible defining the amniotic cavity from the chorionic cavity. The umbilical cord can also be seen.

8th Week

The upper and lower limb buds are now visible in an embryo that is stil rounded in shape. The placental site can even be identified, following the umbilical cord from the abdominal wall of the embryo.

Crown-rump length is 17 to 23 mm. Forebrain, midbrain, hindbrain and skull are distinguishable. Midgut hernia is present. It is a round and well-defined structure, refringent and linked to the abdominal wall at the site of the umbilical cord insertion. Its refringency is that of the abdominal wall, its size is small, less than 7 mm, and always disappears between the 11th and 12th weeks. Although at this week, the profile, forehead, nose and mouth are visible, they will be clearly defined by the 10th week. The cranial pole is large and voluminous. The profile, face, orbits, mouth, jaw and maxilla can be identified.

The amniotic cavity expands and the umbilical cord and vitelline duct lengthens and embryonic movements are detectable.

Discrete undulating body movements can be sporadically seen on real-time imaging at the end of the 8th week. In the first 8 weeks of pregnancy, the corpus luteum is often identified as a cystic mass measuring 1 to 3 cm in diameter, although they may reach as large as 8 cm. These masses usually resolved spontaneously by the onset of the second trimester, if an adnexal mass persists into the second trimester. The two most common benign neoplasms of the ovary during pregnancy are serous cystadenoma and benign cystic teratoma. The risk of a persistent adnexal mass during pregnancy subsequently diagnosed as malignant has probably been overestimated: It is significantly less than 1%.

9th Week

Crown-rump length is 23 to 32 mm. The yolk sac is in a more peripheral location. The limbs lengthen and hands and feet are seen although the fingers are not yet visible. Embryonic heart rate peaks at 170 to 180 bpm, the head represents one-third of the entire body and, inside the head, the hyperechoic falx and choroid plexuses and a hypoechoic heart-shaped structure corresponding to the cerebral peduncles are visible. The physiological midgut herniation, which can be identified close to the anterior abdominal wall, will persist until the end of the 11th week. Body movements are now more frequently seen.

10th Week

The fetus occupies more than one-third of the space in the gestational sac; CRL is 32 to 41 mm and the embryo is slightly more curved. The choroid plexuses fill the lateral ventricles completely and are the most prominent structures in the cephalic pole.

The structural development of the heart begins on day 16 and it is finished by the 10th week. In the posterior fossa, the cisterna magna and cerebellum can be identified, though the development process of the posterior fossa will only be concluded by 16 weeks. In the trunk, the cardiac valvular apparatus can sometimes be distinguished inside the heart by the end of the 10th week, although more accurately from the 11th week onward.

Table 1: Glossary of terms and early pregnancy events[16]

Avoid	*Prefer*	*Ultrasound findings*
Egg	Oocyte	
Embryo	Fetus	Ultrasound-based definition to include fetal heart activity and/or crown-rump length > 10 mm
Embryonic age	Gestational age based on last menstrual period and/or ultrasound fetal measurement	
Postovulatory age		
Conceptual age		
Menstrual age		
Threatened abortion	Threatened miscarriage	
Spontaneous abortion	Spontaneous miscarriage	
Medical abortion	Termination of pregnancy	
Legal abortion		
Recurrent abortion	Recurrent miscarriage consisting of 3 early consecutive losses or 2 late pregnancy losses	
Habitual abortion		
Pregnancy test	Serum/urine level of hCG	
Preclinical embryo loss	Biochemical pregnancy loss with description of falling low positive serum/urinary hCG	No definition of pregnancy location
Trophoblast regression	Biochemical pregnancy loss	
Menstrual abortion preclinical abortion	Biochemical pregnancy loss	Pregnancy not located on scan
Early embryonic demise	Empty sac	Gestational sac with absent structures or minimal embryonic debris without heart rate activity
Anembryonic pregnancy		
Embryonic death	Fetal loss	Previous identification of crown-rump length and fetal heart activity followed by loss of heart activity
Early abortion	Early pregnancy loss	Ultrasound definition of intrauterine pregnancy with reproductive evidence of lost fetal heart activity and/or failure of increased crown-rump length over one week, or persisting presence of empty sac, at less than 12 weeks gestation
Missed abortion	Delayed miscarriage	Same as for early pregnancy loss (see above)
Late abortion	Late pregnancy loss	After 12 weeks gestational age where fetal measurement was followed by loss of fetal heart activity
Hydatidiform mole	Gestational trophoblastic disease (complete or partial)	
Partial mole		
Molar pregnancy		
	Heterotopic pregnancy	Intrauterine plus ectopic pregnancy (e.g. tubal, cervical, ovarian, abdominal)
	Pregnancy of unknown location (PUL)	No identifiable pregnancy on ultrasound with positive blood/urine hCG

Table 2: Guidelines for dating early pregnancy[2]

Stage of development	*Gestational age (weeks)*
Gestational sac (no yolk sac or embryo)	5.0
Gestational sac and yolk sac (no embryo)	5.5
Gestational sac and yolk sac (embryo that is too small to measure with cardiac activity)	6.0

Adapted from Laing FC, Frates MC. Ultrasound evaluation during the first trimester of pregnancy. In: Callen PW (Ed): Ultrasonography in Obstetrics and Gynecology (4th ed), Philadelphia: WB Saunders 2000;105-45.

Also at the end of the 10th week, the stomach filled with a small amount of liquid can sometimes be identified in the abdomen.

The three segments of the upper and lower limbs are clearly identified with both hands and feet in the midline.

11th Week

At 11 weeks, the development of the head and neck continues. There is fusion of the parietal and capsular decidual layers, the fetus (no longer the embryo) occupies now half of the amniotic cavity. The CRL will be greater than 42 mm, reaching 76 mm at 13 weeks.

From now on, a more detailed anatomical survey can be obtained, including the cerebral and cardiovascular systems and the digestive and urinary tracts. The herniated midgut returns into the abdominal cavity. Stomach, bladder and the kidneys are visible. Fetal fingers and toes are easier to visualize.

12th Week

In 12-week, the skull is fully formed. Facial and abdominal structures can be observed. Hands and feet are fully developed. It is possible to count the fingers and toes.

Table 3: Relationship between GA and embryonic CRL, embryonic HR, mean GSD and mean YSD[12]

Gestation days	CRL, mm			Embryonic HR, bpm			GSD, mm			YSD, mm		
	50th	5th	95th	50th	5th	95th	50th	5th	95th	50th	5th	95th
40	2.4	1.1	4.1	105	90	121	12.9	8.0	18.9	3.2	2.4	4.1
41	2.9	1.4	4.8	108	92	124	13.8	8.7	19.9	3.3	2.5	4.2
42	3.4	1.9	5.5	111	95	127	14.7	9.4	21.0	3.4	2.6	4.3
43	4.1	2.3	6.3	114	98	131	15.6	10.2	22.1	3.4	2.6	4.4
44	4.7	2.8	7.1	117	101	134	16.5	10.9	23.2	3.5	2.7	4.4
45	5.4	3.4	7.9	120	104	138	17.4	11.7	24.3	3.6	2.7	4.5
46	6.1	3.9	8.8	124	107	141	18.4	12.5	25.4	3.6	2.8	4.6
47	6.9	4.5	9.7	127	111	145	19.3	13.3	26.6	3.7	2.9	4.7
48	7.7	5.2	10.6	131	114	149	20.3	14.1	27.7	3.8	2.9	4.7
49	8.5	5.9	11.6	135	117	153	21.3	14.9	28.8	3.8	3.0	4.8
50	9.4	6.6	12.6	138	121	157	22.3	15.7	30.0	3.9	3.0	4.9
51	10.2	7.3	13.6	142	124	161	23.3	16.6	31.1	4.0	3.1	5.0
52	11.2	8.1	14.7	146	128	165	24.3	17.4	32.3	4.0	3.1	5.0
53	12.1	8.9	15.7	149	131	168	25.3	18.3	33.4	4.1	3.2	5.1
54	13.0	9.7	16.8	153	134	172	26.3	19.1	34.6	4.2	3.3	5.2
55	14.0	10.6	17.9	156	137	176	27.3	20.0	35.8	4.2	3.3	5.2
56	15.0	11.4	19.1	159	140	179	28.3	20.8	36.9	4.3	3.4	5.3
57	16.0	12.3	20.2	162	143	182	29.3	21.7	38.1	4.3	3.4	5.4
58	17.1	13.2	21.4	165	146	185	30.3	22.6	39.2	4.4	3.5	5.4
59	18.1	14.2	22.5	167	148	188	31.3	23.4	40.4	4.5	3.5	5.5
60	19.1	15.1	23.7	169	150	190	32.3	24.3	41.5	4.5	3.6	5.6
61	20.2	16.0	24.9	171	152	192	33.3	25.2	42.6	4.6	3.6	5.6
62	21.3	17.0	26.1	173	153	193	34.3	26.0	43.7	4.6	3.7	5.7
63	22.4	18.0	27.3	174	154	194	35.3	26.9	44.9	4.7	3.7	5.8
64	23.5	18.9	28.5	174	154	195	36.3	27.8	46.0	4.7	3.8	5.8
65	24.6	19.9	29.7	174	154	195	37.3	28.6	47.1	4.8	3.8	5.9
66	25.7	20.9	30.9	174	154	195	38.2	29.5	48.2	4.8	3.9	5.9
67	26.8	21.9	32.1	173	153	194	39.2	30.3	49.2	4.9	3.9	6.0
68	27.9	22.9	33.3	171	152	192	40.2	31.2	50.3	4.9	4.0	6.0
69	29.0	23.9	34.5	169	150	190	41.1	32.0	51.4	5.0	4.0	6.1
70	30.1	24.9	35.7	167	147	187	42.0	32.8	52.4	5.0	4.0	6.2
71	31.2	25.9	36.9	163	144	183	43.0	33.6	53.4	5.1	4.1	6.2
72	32.3	26.9	38.1	159	141	179	43.9	34.4	54.4	5.1	4.1	6.3
73	33.3	27.9	39.3	155	136	174	44.8	35.2	55.4	5.2	4.2	6.3
74	34.4	28.9	40.4	150	131	169	45.6	36.0	56.4	5.2	4.2	6.4
75	35.5	29.9	41.6	144	126	163	46.5	36.8	57.4	5.3	4.2	6.4

Abnormal Ultrasound Findings in Early Pregnancy[4,22,24,25,28-34] (Figs 28 to 43) (Table 5)

Fetal demise, empty gestational sac, disproportionate fetal growth with the gestational sac can be a sign of abnormal early pregnancy. Transvaginal ultrasound is useful in determining the prognosis of the pregnancy and in the differential diagnosis of early pregnancy complications.

Actually, approximately 40% of early pregnancies result in miscarriage. Most of these miscarriages happen before the menstrual period is missed. Abortions (spontaneous abortion, threatened abortion, complete abortion, incomplete abortion, inevitable abortion, missed abortion) can be due to unknown etiology, morphologic and chromosomal abnormalities, infection, anatomic defects, endocrine factors, immunologic factors and maternal systemic disease. The risk of miscarriage lessens as the gestation progresses. For example, while the risk of miscarriage at 5 weeks is approximately 15 to 30%, it is less than 5% after 9 weeks of gestation. Similarly, while when CRL is less than 5 mm, the risk of pregnancy loss is around 8%, it is less than 1% when CRL is more than 10 mm.

In missed abortion, the fetus dies in the uterine cavity but a miscarriage has not yet occurred. Therefore, no fetal heart motion can be visualized and color or power Doppler ultrasound shows the lack of blood flow in the fetus. In blighted ovum or anembryonic pregnancy, the embryo fails to develop or died at a very early stage so that we cannot see it. Therefore, only a gestational sac, with or without a yolk sac, is seen in the ultrasound. When the crown-rump length measures 4 to 10 mm, the fetal heart beat should be detectable.

Slow fetal heart rate which is less than 85 bpm is associated with poor prognosis. When the gestational sac diameter is more than 12 mm, yolk sac should be visible at about 5 weeks of gestation. The scan should be repeated one week later to confirm if there is an early embryonic demise. If the gestational sac diameter is more than 20 mm, an embryo is usually visible. If not, the scan should be repeated one week later to confirm the problem.

Table 4: Relationship between embryonic CRL and GA, embryonic HR, mean GSD and YSD[12]

CRL, mm	Gestation days			Embryonic HR, bpm			GSD, mm			YSD, mm		
	50th	5th	95th	50th	5th	95th	50th	5th	95th	50th	5th	95th
1	41	38	44	99	85	113	12.9	8.1	18.7	3.2	2.4	4.1
2	42	39	46	104	90	119	13.9	9.0	20.0	3.3	2.5	4.2
3	43	40	47	109	94	125	15.0	9.9	21.3	3.4	2.6	4.3
4	44	41	48	114	99	130	16.1	10.8	22.6	3.5	2.7	4.4
5	45	42	49	119	104	135	17.2	11.7	23.9	3.6	2.7	4.5
6	47	43	50	124	108	140	18.4	12.6	25.2	3.6	2.8	4.6
7	48	44	51	129	113	145	19.5	13.5	26.5	3.7	2.9	4.7
8	49	45	52	133	117	150	20.6	14.5	27.8	3.8	2.9	4.8
9	50	46	53	137	121	155	21.7	15.4	29.1	3.9	3.0	4.8
10	51	47	54	141	125	159	22.8	16.3	30.4	3.9	3.1	4.9
11	52	48	55	145	128	163	23.9	17.3	31.7	4.0	3.1	5.0
12	53	49	56	149	132	167	25.0	18.2	32.9	4.1	3.2	5.1
13	54	50	57	152	135	171	26.1	19.1	34.2	4.2	3.3	5.2
14	55	51	58	156	138	174	27.2	20.0	35.4	4.2	3.3	5.2
15	56	52	59	159	141	177	28.2	21.0	36.6	4.3	3.4	5.3
16	57	53	60	161	144	180	29.3	21.9	37.8	4.3	3.4	5.4
17	58	54	61	164	146	183	30.3	22.7	38.9	4.4	3.5	5.4
18	59	55	62	166	148	185	31.3	23.6	40.1	4.5	3.5	5.5
19	59	56	63	168	150	187	32.3	24.4	41.2	4.5	3.6	5.6
20	60	57	64	170	151	189	33.2	25.3	42.2	4.6	3.6	5.6
21	61	58	65	171	153	190	34.1	26.1	43.3	4.6	3.7	5.7
22	62	59	66	172	154	192	35.0	26.8	44.3	4.7	3.7	5.7
23	63	60	66	173	154	192	35.9	27.6	45.2	4.7	3.8	5.8
24	64	60	67	173	155	193	36.7	28.3	46.2	4.8	3.8	5.8
25	65	61	68	174	155	193	37.5	29.0	47.0	4.8	3.8	5.9
26	66	62	69	174	155	193	38.2	29.7	47.9	4.8	3.9	5.9
27	66	63	70	173	155	193	39.0	30.3	48.7	4.9	3.9	6.0
28	67	64	71	173	154	192	39.6	30.9	49.5	4.9	3.9	6.0
29	68	64	71	172	153	191	40.3	31.5	50.2	4.9	4.0	6.0
30	69	65	72	170	152	190	40.9	32.0	50.8	5.0	4.0	6.1
31	69	66	73	169	151	188	41.5	32.5	51.5	5.0	4.0	6.1
32	70	67	74	167	149	186	42.0	33.0	52.1	5.0	4.0	6.1
33	71	68	74	165	147	184	42.5	33.4	52.6	5.0	4.0	6.1
34	72	68	75	163	145	182	42.9	33.8	53.1	5.1	4.1	6.2
35	72	69	76	160	142	179	43.3	34.1	53.5	5.1	4.1	6.2
36	73	70	77	157	140	176	43.6	34.4	53.9	5.1	4.1	6.2
37	74	70	77	154	137	173	43.9	34.7	54.2	5.1	4.1	6.2
38	74	71	78	151	134	169	44.2	34.9	54.5	5.1	4.1	6.2
39	75	72	79	147	130	165	44.4	35.1	54.7	5.1	4.1	6.2

Table 5: Overview of commonest pregnancy loss events and ultrasound[16]

Type of loss	Typical gestation (range in weeks)	Fetal heart activity	Principal ultrasound finding	β-hCG level
Biochemical loss	< 6 (0-6)	Never	Pregnancy not located on ultrasound	Low then fall
Early pregnancy loss	6-8 (4-10)	Never	Empty sac or large sac with minimal structures without fetal heart activity	Initial rise then fall
Late pregnancy loss	> 12 (10-20)	Lost	Crown-rump length and fetal heart activity previously identified	Rise then static or fall

The ultrasonographic appearance of the yolk sac can also predict the pregnancy-loss risk. Spontaneous-abortion risk can be predicted if one of the following ultrasound findings of yolk sac is present. Absence of the yolk sac, too large (> 6 mm), too small (< 3 mm), irregular shaped or having degenerative changes (calcifications or decreased translucency).

The presence of intrauterine hematoma carry the risk of abortion in the first trimester. The size and the location of the hematoma are important to determine the prognosis of the pregnancy. According to the localization, hematomas can be retroplacental, subchorionic, marginal and supracervical. Among these, retroplacental hematomas are the most severe

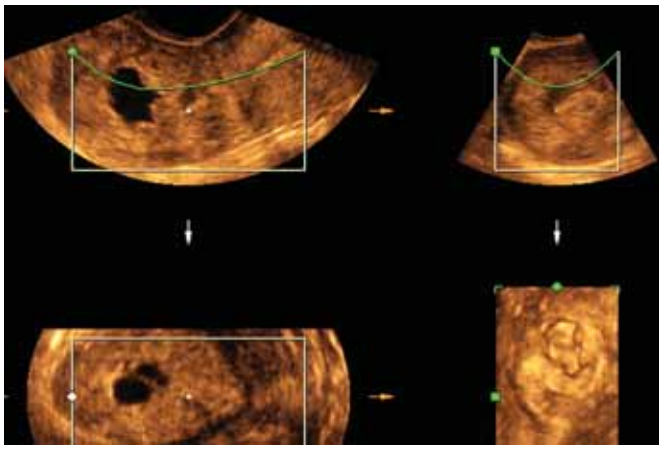


Fig. 28: A 3D multiplanar image of 5 weeks old pregnancy. Anembryonic gestation (blighted ovum), amniotic sac measuring more than 20 mm without a yolk sac and embryo

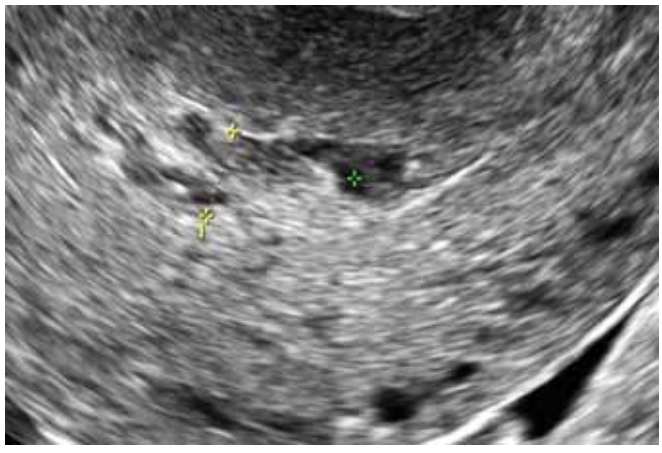


Fig. 29: 2D TV US picture of intrauterine cavity showing retained products of conception in an incomplete miscarriage. The patient had abortion at 7 weeks of pregnancy followed by revised uterine curettage

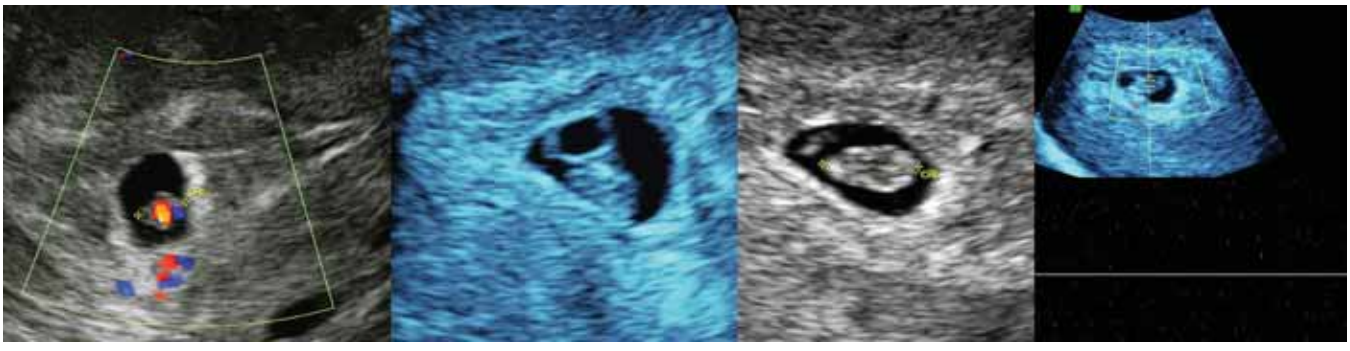


Fig. 30: 2D US image showing small gestational sac in comparison to 7 weeks of pregnancy. Fetal blood flow shown at this gestational age (on the left). One week later, the fetus had big yolk sac and no fetal heart beat was seen (last 3 on the right side)

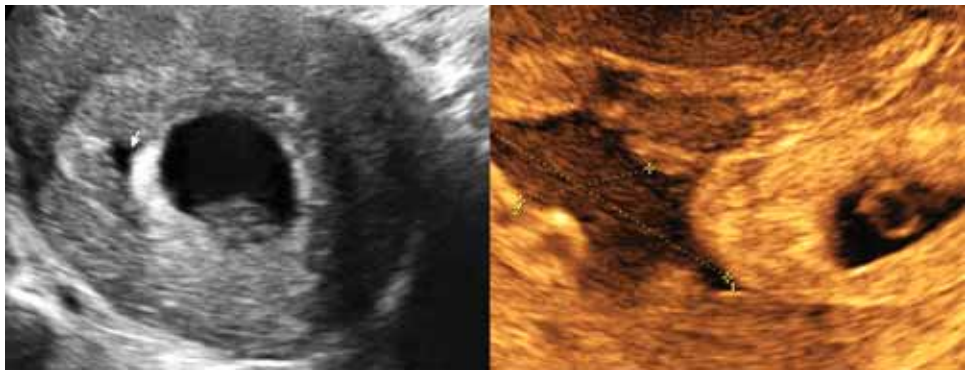


Fig. 31: Retrochorionic or subplacental hematoma at 6 weeks of pregnancy. Although, this localization of hematomas has worse prognosis in comparison to subchorionic hematomas.[29] This pregnant women now is at the 24th week, hematoma resolved and the patient is doing well

Fig. 32: 2D US image of large intrauterine hematoma also known as a subchorionic hematoma was seen after 10th gestational age at this women (on the left). At 14 weeks in the middle, the hematoma persisted with bleeding complaint of the patient till 16 weeks of pregnancy and resoved after that (on the right). The patient is at the 30th week of gestation and doing well. Subchorionic hemorrhages are generally followed with serial ultrasounds. Depending on the extent of the hemorrhage, the patient may be asked to abstain from sexual intercourse and strenuous activity. If the hemorrhage is large, increasing in size or is associated with multiple pregnancy, bed rest may be prescribed. Most often, the subchorionic hemorrhage resolves, bleeding stops and the pregnancy continues without complication[29]

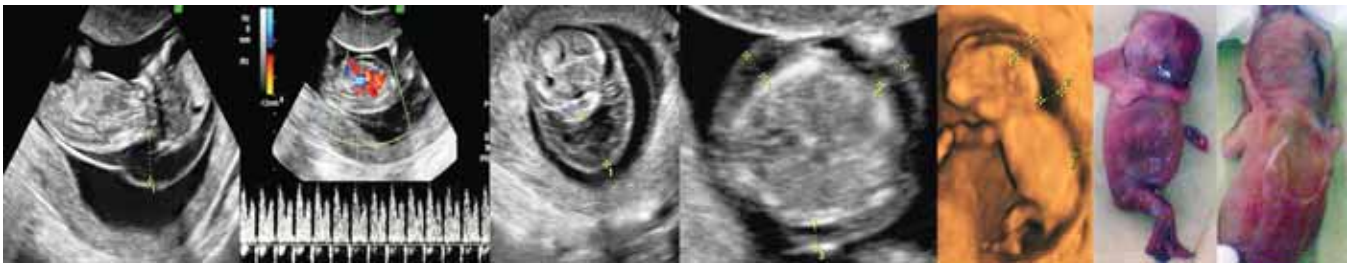


Fig. 33: Trisomy 13 and increased nuchal translucency at 12th week of gestation. Sagittal section of the fetus by 2D US shows increased NT. Fetal ductus venosus shows reversed a wave. Transverse section of the head also shows nuchal edema. Surface rendered image of the fetus by 3D US. Postabortive pictures of the fetus shows fluid-filled structures around fetal neck (left to right respectively). Fetal karyotyping by CVS revealed trisomy 13

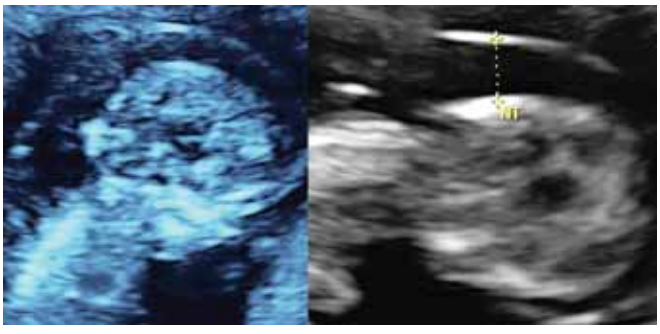


Fig. 34: 2D US picture showing increased nuchal translucency at 11th week of gestation. Fetal karyotyping by CVS revealed trisomy 18

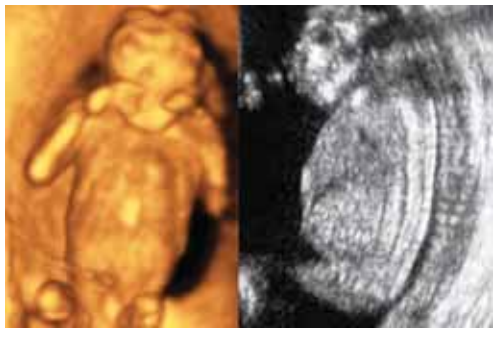


Fig. 37: Acrania at first trimester. 3D surface rendered image (on the left) and 2D sagittal section (on the right) of the body and extremities of a fetus with acrania

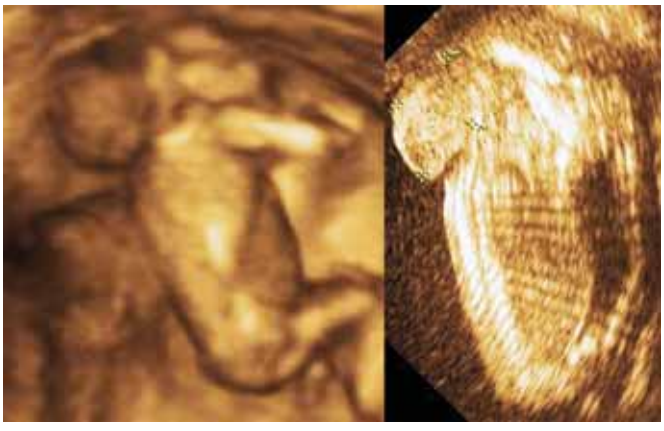


Fig. 35: Encephalocele at 13 weeks of gestation. 3D and 2D US images clearly show the abnormality

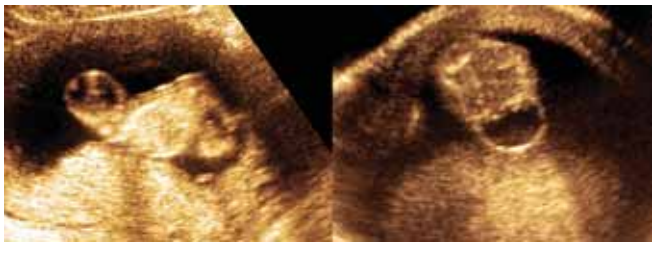


Fig. 36: 2D US sagittal and transverse sections show anencephaly at 10 weeks of gestation

regarding the risk of abortion. While retroplacental or central hematomas carry the worst prognosis, supracervical hematomas carry the best prognosis in terms of abortion. Literature data shows that fundocorporal hematomas are more likely to cause spontaneous abortion or preterm delivery than supracervical hematomas.

Fetal Sex Determination by Ultrasound at First Trimester[35,36] (Fig. 44)

Prenatal gender assignment by ultrasound has a high accuracy rate at 12 to 14 weeks. The accuracy of sex determination increased with gestation from 70.3% at 11 weeks to 98.7% at 12 weeks and 100% at 13 weeks. In the male fetuses, there is a significant increase in the angle of the genital tubercle from the horizontal with crown-rump length.

The genital region is examined in a midsagittal plane. The angle of the genital tubercle to a horizontal line through the lumbosacral skin surface can be measured. The fetus is usually thought to be male if the angle is >30°, and female gender if the genital tubercle is parallel or convergent (<10 degrees) to the horizontal line. At an intermediate angle of 10 to 30°, the gender is not determined.

First Trimester Nuchal Translucency Examination[37-39] (Fig. 45)

The ultrasonographic fetal examination in the late first trimester is useful for both screening and diagnostic purposes. Between 11 and 14 weeks of gestation, that is, between 45 to 84 mm crown-rump length, a subcutaneous translucency behind the neck region can be disclosed in a sagittal section of the fetus. The maximum thickness between the skin and the soft tissue overlying the cervical spine can be measured and was called nuchal translucency (NT). The term translucency is used,

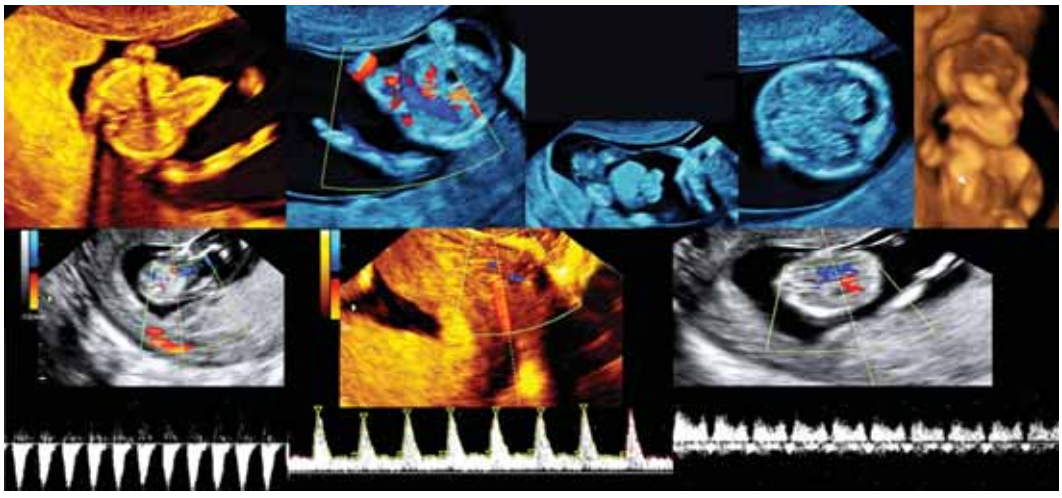


Fig. 38: Fetus with ectopia cordis at first trimester (left to right upper line), 2D US and color flow transverse section of the fetal chest show the fetal heart protruding from the anterior chest wall defect with vascularization. Coronal section and transverse section of the fetal head of the fetus, 3D surface rendered image of the fetus (bottom line left to right respectively), umbilical artery flow, uterine artery flow and reversed ductus venosus flow of this pregnancy

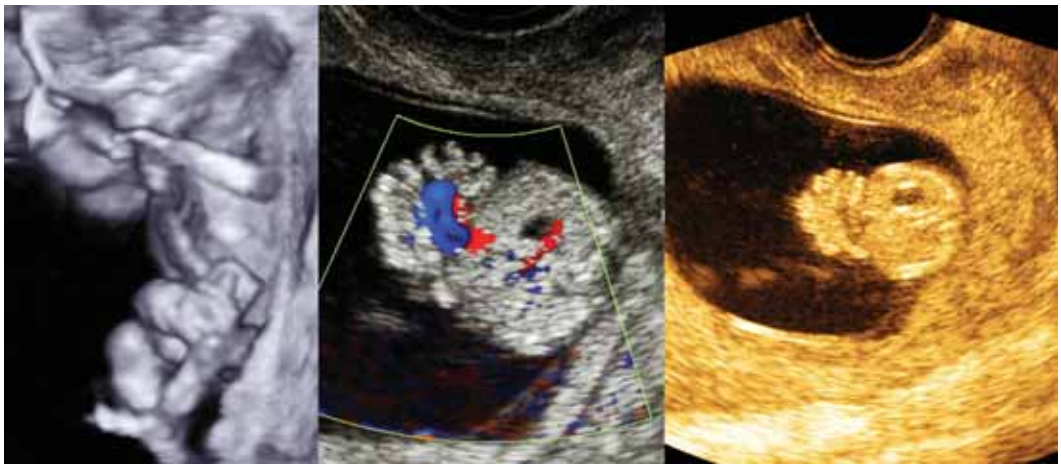


Fig. 39: Gastroschisis at first trimester. 3D surface rendered image of the fetus clearly shows fetal intestines protruding from the anterior abdominal wall defect on the left. 2D US (middle) and color flow of transverse (right) sections by 2D US

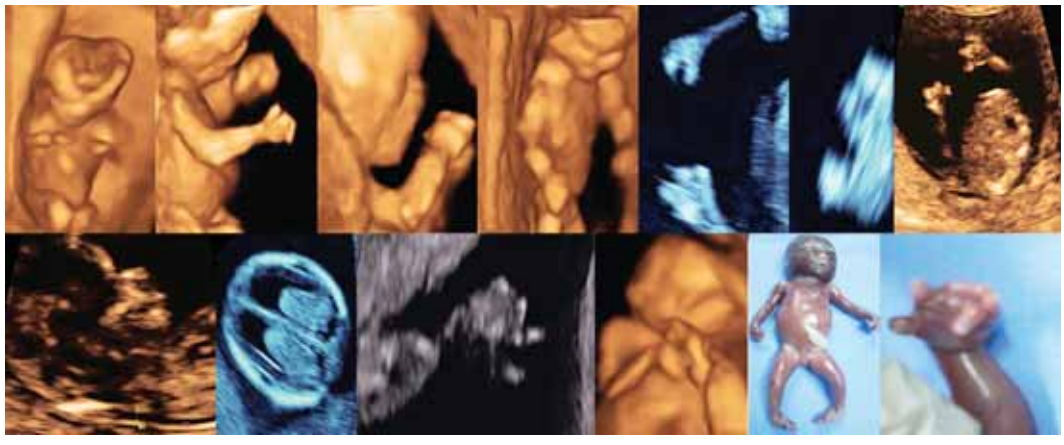


Fig. 40: 3D surface rendered images and 2D US images revealed finger abnormalities in the hands and drop hands in a fetus at 11th week of gestation. CVS karyotyping revealed normal karyotype. NT of the fetus was normal with present nasal bone. But at 20th gestational weeks, the fetus showed marked drop hands with bilateral talipes and terminated

irrespective of whether it is septated or not and whether it is confined to the neck or envelops the whole fetus. In fetuses with chromosomal abnormalities, cardiac defects and many genetic syndromes, the NT thickness is increased.

Other benefits of the 11 to 13 weeks scan include: Accurate dating of the pregnancy, early diagnosis of many major fetal defects, diagnosis of multiple pregnancies and early screening for severe pre-eclampsia.

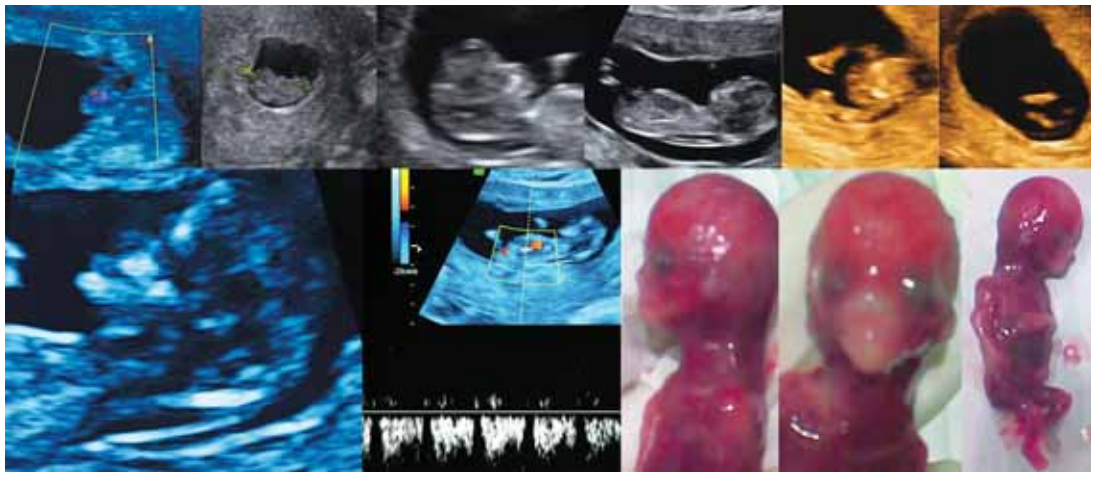


Fig. 41: Down syndrome detected with mildly elevated NT at 10th gestational weeks in a 40-year-old woman. The pictures show 2D US images of the same fetus beginning from the 6 weeks of pregnancy. Nasal bone of the fetus was found to be absent. Ductus venosus showed absent wave. Fetal karyotyping with CVS revealed trisomy 21 and postabortive pictures of the fetus are shown

Fig. 42: 2D US pictures showing generalized edema at the 11th week of gestation. Omphalocele, absent nasal bones, AVSD, single umbilical artery was the associated malformations of the same fetus

Fig. 43: Limb body wall complex. 2D US and postabortive pictures showing huge abdominal wall defect associated with variable spectrum of limb and visceral anomalies

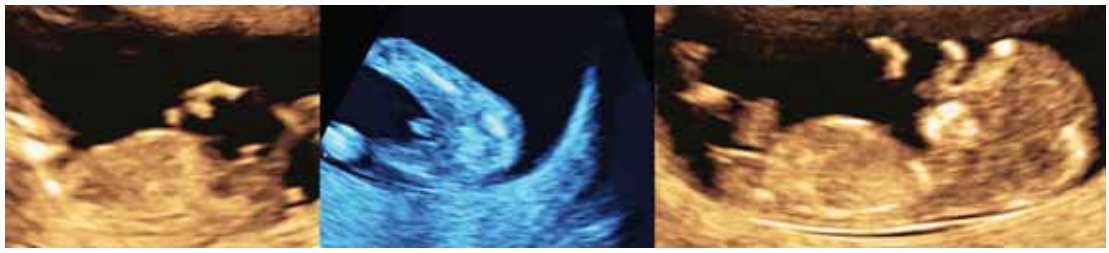


Fig. 44: Transabdominal 2D and 3D evaluation of fetal gender. 2D US of a male fetus sagittal and transverse sections (on the left and in the middle respectively). There is a significant increase in the angle of the genital tubercle from the horizontal with crown-rump length in female fetus (on the right). The genital tubercle is parallel or convergent (<30°) to the horizontal line

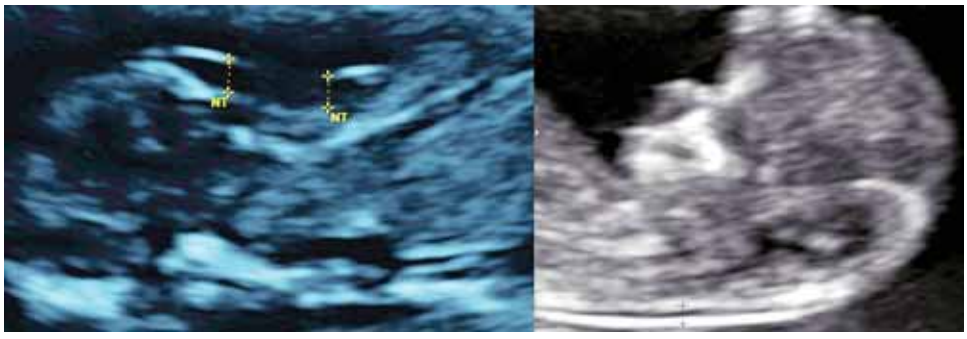


Fig. 45: Transabdominal 2D US evaluation of the fetal nasal bone and nuchal translucency between 11 and 14 weeks of gestations. On the left, fetus with increased NT at 11 weeks and, on the right, fetus with normal NT and present nasal bone

Fig. 46: Early fetal echocardiography by transvaginal 2D US. Normal four chamber view through a transverse section of the fetal chest can be seen at different gestational ages. Color Doppler evaluation of ventricular septum to diagnose VSD. Aortic outflow, pulmonary artery crossing over the aorta shown by color flow can be seen. Flow at the tricuspid valve can help us to diagnose chromosomal abnormalities at the first trimester. Three vessel view showing normal outflow tracts. Color flow also helps us to better visualize the outflow tracts

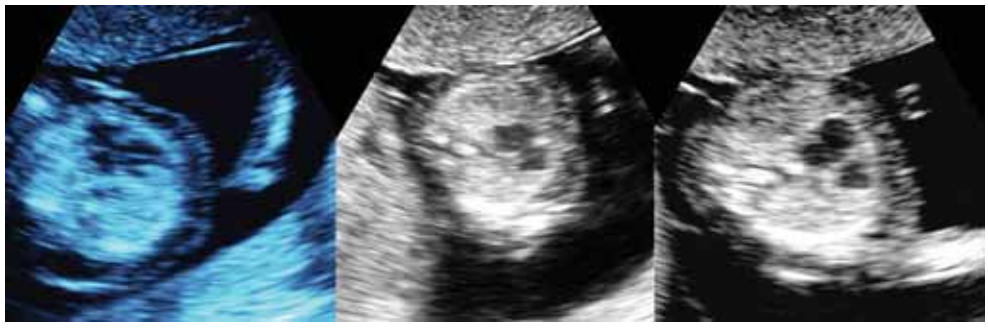


Fig. 47: 2D US of transverse section of the fetal chests in the fetuses with increased NT at first trimester. One can easily pick-up major abnormalities in the heart at first trimester. AVSD, single ventricle and dextraposition of the fetal hearts are seen

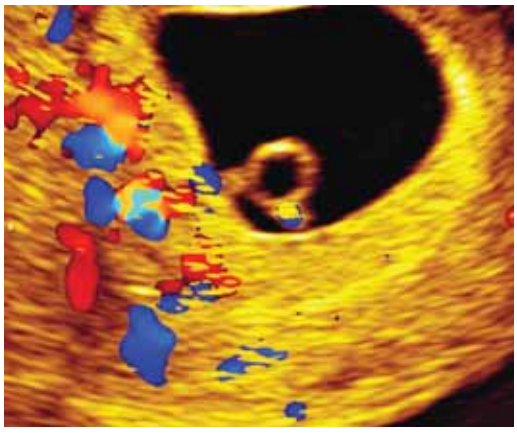


Fig. 48: An early 2D TV US evaluation revealed two embryos attached to one yolk sac. Further monitoring of the pregnancy showed monochorionic diamniotic twins

The Fetal Medicine Foundation promoted screening for Down syndrome at 11–13+6 weeks by nuchal translucency or a combination of nuchal translucency and maternal serum biochemistry.

Screening by nuchal translucency can detect about 80% of affected fetuses for a false-positive rate of 5%. The combination of nuchal translucency and maternal serum free β-hCG and PAPP-A improves the detection to 90%. There is now evidence that the detection rate can increase to about 95% and the false-positive rate can be reduced to 2.5% by also examining the nasal bone (in a high proportion of fetuses with trisomy 21 and other chromosomal abnormalities the nasal bone is hypoplastic or not visible at 11-13 weeks' gestation), facial angle (fetuses with trisomy 21 have a flat profile because the maxilla (upper jaw) is small and set back. This produces a wide angle in a line

drawn over the palate and between the maxilla and the forehead (facial angle)), ductus venosus flow (the incidence of reversed ductus venosus A-wave is related to NT and CRL as well as aneuploidy, being more common when the NT is high and the CRL is low) and tricuspid flow (if there is tricuspid regurgitation the risk is always increased).

Early Fetal Echocardiography[40] (Figs 46 and 47)

Early fetal echocardiography can also be done between 11 to 14 weeks successfully. The normality of the four chamber view through a transverse section of the fetal chest: Normal situs solitus; normal size and axis of the heart in relation to the chest can be evaluated.

Color Doppler also helps us to better visualize the outflow tracts and to identify normal systemic and pulmonary venous return.

Multiple Pregnancy and the Chorionicity Determination at the First Trimester[6-8,18,24,27] (Figs 48 to 51)

Twin pregnancy can be diagnosed after week 6, when two gestational sacs are clearly visible, each one with its own embryo. In cases of multiple pregnancies, monochorial or bichorial, sacs and embryos can be observed. It is not acceptable to miss a diagnosis of twins by transabdominal ultrasound examination after the 8 weeks of pregnancy.

Antenatal determination of chorionicity by ultrasound is much easier in the early first trimester. It is also accurate to perform an ultrasound scan between 10 and 14 weeks, relying on the demonstration of the lambda sign for dichorionic (with a positive predictive value of 100% for dichorionicity), or the T-sign for monochorionic twin pregnancies.

Fig. 51: Transabdominal 2D US imaging of a trichorionic triamniotic triplet pregnancy at 11th weeks of gestation with Mercedes sign

CONCLUSION

It is now possible to look at intrauterine events from the beginning of pregnancy, close to the time of implantation.[18]

The high resolution, safety and ease of performance make ultrasound the procedure of choice for routine ultrasonography in the first half of pregnancy as a standard of obstetric care.[18,41] Transvaginal ultrasound has revolutionized the diagnosis and management of early pregnancy. Pregnancies can be detected

Fig. 49: Dichorionic diamniotic twins. Transabdominal 2D and 3D US imaging of a dichorionic diamnionic twin pregnancy at 6 and 8 weeks, respectively, with lambda sign

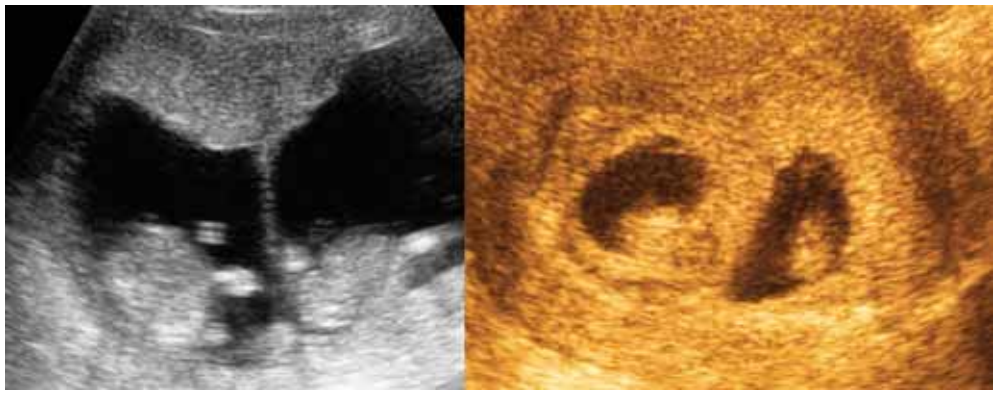


Fig. 50: Monochorionic twin gestation with T-sign (left). Lambda or placental peak sign of a dichorionic twin gestation (right)

earlier compared with abdominal ultrasound, patients reassured by showing normal development.[4]

Accurate gestational age determination, sufficiently early characterization of multiple pregnancy, early diagnosis of lethal anomalies and screening of chromosomal defects are important end points to be taken into account by health authorities and to recommend routine ultrasound examination in the late first trimester of pregnancy.[18,42,43]

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