Three-dimensional intrauterine sonography in the early first-trimester of human pregnancy: preliminary study

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Introduction

The embryonic period, which ranges from 4 to 8 weeks after the last menstrual period, is important for human development because most major anatomical structures start to develop during these 5 weeks. By the end of the embryonic period most major organ systems have been formed (Moore, 1982; Harkness and Baird, 1997a,b,c; Harkness et al., 1997). Transabdominal and transvaginal three-dimensional (3D) sonographic visualizations of the embryo have been reported (Steiner et al., 1995; Bonilla-Musoles, 1996; Hata et al., 1997a). Experience with the visualization of normal embryonic anatomy by 3D scanning has now provided some authors with the experience and confidence to recognize embryonic and fetal malformations in the first and early second trimesters (Feichtinger, 1993; Bonilla-Musoles et al., 1995; Bonilla-Musoles, 1996). However, image quality of those studies was poor because the frequencies of the transducer used were 3.5–7.5 MHz. Therefore, detailed assessments for the sequential appearance of embryonic surface anatomical structures have still not been obtained using those approaches.

Potential obstetric applications of intrauterine sonography with a specially developed catheter-based, high-resolution, real-time miniature (2.4 mm in outer diameter) ultrasound transducer (20 MHz) for systematic examination of the developmental stages of the early embryo or detection of gross embryonic malformations have been reported (Fujiwaki et al., 1995; Hata, 1996; Hata et al., 1996, 1997b,c). However, to the best of our knowledge, a detailed description of normal embryonic surface anatomical structures in the early first trimester of pregnancy has not yet been published. The objective of the current study was to attempt a systematic look for normal embryonal surface anatomy in the early first-trimester pregnancy by 3D intrauterine sonography with a 20 MHz flexible catheter-based, high-resolution, real-time miniature transducer.

Materials and methods

A total of 15 women (three at week 8, eight at week 9, and four at week 10) about to undergo therapeutic abortion at 7–9.9 weeks gestational age were studied by means of 3D intrauterine sonography using a specially developed catheter-based, high-resolution, real-time miniature transducer in the early first trimester pregnancy. A total of 15 women about to undergo therapeutic abortion at 7–9.9 weeks gestational age were studied by means of 3D intrauterine sonography with a 20 MHz catheter-based high-resolution, real-time miniature transducer. These results suggest that 3D intrauterine sonography can become an important modality in future embryological research and in detection of embryonic developmental disorders in the early first-trimester pregnancy.

Key words: first trimester/embryo/surface anatomy/2D intrauterine sonography/3D intrauterine sonography

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be stored with each drawing of the transducer into the patient data base of the Compact 3DTM (Aloka). Following image storage, we can observe three orthogonal planes of the embryo on the monitor screen. After obtaining the three orthogonal planes, we must search for the frontal plane which corresponds with the appropriate sagittal and horizontal planes of the structure to be studied. By placing the three desired planes over the same points, it is possible to eliminate undesired echoes with the computer or to generate a surface image using minimum or maximum transparency (Compact 3D software, Aloka). After loading a patient study from the data base, 3D images of the embryo can be displayed immediately.

Initially, we studied 18 women about to undergo therapeutic abortion at 7–9.9 weeks gestation using intrauterine sonography. The gestational age by menstrual history was compared with that by the crown–rump length (CRL) (Iwamoto, 1983). Only those cases with a discrepancy of <3 days were included in the study. Three cases (one at week 9, and two at week 10) were excluded from the study because this discrepancy was >3 days. Therefore, 15 women were
scanned using intrauterine sonography after the CRL measurements were found to be within a range of \(<3\) days from menstrual age.

Correlation of the detected structures with the appropriate structure in an embryological textbook (Moore, 1982; Harkness and Baird, 1997a,b,c; Harkness et al., 1997) was attempted for each gestational age. Pathological examination and chromosome analysis could not be done, because the embryo was damaged during the therapeutic abortion.

Results

Two cases (one at week 9, and one at week 10) were excluded from the study because of the shallow scanning range of high-frequency transducers or inappropriate embryonal position. There was no difficulty in passing the imaging catheter through the cervix into the endometrial cavity. Neither bleeding nor leakage of amniotic fluid from the external cervical os was seen after removal of the catheter. There were no known immediate complications.

The image clarity of 3D intrauterine sonography was subjectively superior than those by two-dimensional (2D) intrauterine sonography in all cases studied, and it was possible to obtain finer image quality of very small embryonic surface anatomical structures with 3D IUS.

Week 8

Prominent embryonal forehead was evident, and upper and lower limbs and midgut herniation were clearly depicted (Figure 1).

Week 9

3D intrauterine sonography allowed sculpture-like 3D visualization of all structures of the conceptus such as embryo, umbilical cord, amniotic membrane, yolk sac, and vitelline duct (Figure 2). The existence of subchorionic catheter placement was also confirmed. Fingers and toes were depicted as small digital rays, and the sacral tail protruded caudally. The midline cranial ectodermal cleft was also identified.

Week 10

Facial structures such as eyes, nose, and mouth, and fingers were clearly noted (Figure 3).

Discussion

With respect to the common indications for sonography in the first trimester, 2D intrauterine sonography appears to lack the manoeuvrability, depth of penetration, or field of view necessary to permit evaluation of virtually all common problems (Hata et al., 1997b). However, as indicated in this study, some problems of 2D intrauterine sonography such as manoeuvrability and field of view could be resolved using 3D intrauterine sonography. Moreover, the ability to depict surface anatomical detail of the embryo and image clarity by 3D intrauterine sonography was superior to those by conventional 2D intrauterine sonography in all cases studied.

Potential obstetric applications of 3D sonography for systematic examination of the developmental stages of the embryo or detection of embryonal malformations have been reported (Feichtinger, 1993; Bonilla-Musoles et al., 1995; Bonilla-Musoles, 1996; Hata et al., 1997a). Good quality 3D images of the fetus could be obtained using the transabdominal transducer at 10 weeks gestation (Hata et al., 1997a). However, image quality for visualization of the embryo was slightly degenerated using transabdominal and transvaginal 3D sonography, and facial structures especially could not be identified at 8–9 weeks gestation (Hata et al., 1997a). In the current study 3D especially allowed sculpture-like 3D visualization of all structures of the conceptus in utero. Moreover, the embryonal face could be identified at 9 weeks gestation. Therefore, it may be possible to obtain finer image quality of very small embryonic surface anatomical structures using 3D intrauterine sonography in human pregnancy in utero.

With respect to the limitations of 3D sonography in the first trimester (Bonilla-Musoles et al., 1995), the most common reason for partial observation was active embryonal or fetal movement. Moreover, strong curvature of the gestational sac restricted satisfactory visualization of the embryo. In this study, two cases were excluded because of the shallow scanning range of high-frequency transducers or an inappropriate embryonic position. The depth of penetration of the ultrasound beam used in our study is \(<2\) cm, which might be sufficient to evaluate embryos \(<20\) mm. Therefore, examination of a larger embryo or one remote from the transducer is markedly limited because of the shallow scanning range of high-frequency transducers.
These problems with 3D intrauterine sonography embryonic imaging will be resolved as further technical advances are made.

With respect to limitations associated with intrauterine sonography, it is an invasive diagnostic procedure requiring sterile conditions; its safety has not been established. Although both ourselves and previous authors (Ragavendra et al., 1991, 1993; Fujiwaki et al., 1995; Hata, 1996; Hata et al., 1996; Hata et al., 1997b,c) encountered no immediate complications, the use of intrauterine sonography is not recommended for routine clinical examination in pregnancy at present.

In conclusion, 3D intrauterine sonography provides a novel means for visualizing surface anatomic structures of the embryo in utero. These results suggest that 3D intrauterine sonography can become an important tool in future embryological research and in the detection of embryonic developmental disorders in the early first-trimester pregnancy.

References

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