Original Scientific Paper

Three-dimensional SlowflowHD for Assessment of Fetal Organ and Placental Microvasculature

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Abstract

Objective: To demonstrate spatial fetal organ and placental microvasculature using three-dimensional (3D) SlowflowHD.

Methods: Seventy normal pregnancies at 11–39 weeks of gestation were studied to demonstrate spatial fetal organ (brain, lung, liver, spleen, adrenal gland, and kidney) and placental microvasculature using 3D SlowflowHD with a new transabdominal mechanical matrix probe.

Results: In the first trimester of pregnancy, the whole-body vascularity of the fetus could be clearly depicted. Fetal intracranial vascularity including brain arteries and the venous system could be clearly identified. Characteristic spatial microvasculature of the fetal lung, liver, spleen, adrenal gland, and kidney could be clearly recognized. The microvasculature density of each organ increased with advancing gestation. Spatial relationships among fetal organs were also noted. The increased density of the placental microvasculature with advancing gestation was evident.

Conclusion: 3D SlowflowHD can clearly demonstrate spatial fetal organ and placental microvasculature. This modality may provide novel information on normal and abnormal developments of fetal organs and the placenta in clinical practice and future research.

Keywords: Fetal organ microvasculature, Placental microvasculature, 2D SlowflowHD, 3D reconstruction, 3D SlowflowHD.

Introduction

SlowflowHD™ (GE Healthcare) is a recent Doppler technology, which can visualize low-velocity blood flow of small peripheral vessels and organ microvasculature of fetuses and the placental microvasculature.¹⁻³ Its main characteristics are a high-display frame-rate, high-line density (high-resolution), and better sensitivity. Three-dimensional (3D) SlowflowHD is the latest Doppler technology for the spatial reconstruction of fetal organ and placental microvasculature using a new transabdominal mechanical matrix probe (RM7C, GE Healthcare). This probe is operated with XDclear technology™, which uses a revolutionary “single crystal layer,” an “acoustic amplifier” to apply acoustic power effectively, and a “cool stack” to reduce the rise in the probe temperature. Consequently, we can obtain good 3D SlowflowHD images with high-resolution and excellent visibility in the first- to third trimester of pregnancy. In the current study, we present our initial experience of demonstrating spatial fetal organ and placental microvasculature using 3D SlowflowHD.

Subjects and Methods

Seventy normal fetuses at 11–39 weeks of gestation were studied to demonstrate organ and placental microvasculature using 3D SlowflowHD (Voluson E10 BT21, GE Healthcare, Zipf, Austria) with a new transabdominal mechanical matrix probe (RM7C, 2–8 MHz, GE Healthcare, Zipf, Austria). Pregnancies with a high maternal or fetal risk (hypertensive disorders of pregnancy, gestational diabetes, thyroid disease, fetal growth restriction, polyhydramnios, oligohydramnios, and chromosomal abnormalities) were excluded from the study. The gestational age was calculated...
from crown-rump length measurements by the first-trimester two-dimensional (2D) sonographic examinations.

3D SlowflowHD examinations were performed by one experienced examiner (T.H.). All pregnancies were only examined once. The growth of all fetuses was normal, and there were no abnormalities on conducting 3D SlowflowHD examination. The study was conducted following approval by the Ethics Committee of Miyake Clinic. All participants provided informed consent after a full explanation of the aim of the study.

Volume datasets of the fetus and placenta were acquired with 3D SlowflowHD, which employs an automated transverse or sagittal sweep of the target structure. Using a transabdominal mechanical matrix transducer, volume acquisition lasted 3–10 seconds. The acquisition angle was 15–50° depending on the target structure. One to six recordings were obtained using a transabdominal probe. Fetal movement necessitated repeat volume acquisition to obtain satisfactory data. The fetus was monitored using 2D sonography before 3D SlowflowHD examination in each subject. The 3D SlowflowHD display of the fetal organ and placenta was produced after 2D SlowflowHD examinations. All volume data for each subject were examined, and optimal images were selected for further analysis.

**Results**

In the first trimester of pregnancy, the whole-body vascularity of the fetus could be clearly depicted using 3D SlowflowHD (Fig. 1).

Fetal intracranial and neck vessels with their branches could be identified late in the first trimester of pregnancy (Figs 1 to 3). Spatial relationships of intracranial vascularity including arteries and the venous system could be clearly identified using this technique (Figs 3 to 6).

Characteristic spatial microvasculature of the fetal lung (Figs 7–9), liver (Figs 10–12), spleen (Figs 13 and 14), kidney (Figs 15–18), and adrenal gland (Figs 16 and 17) could be clearly recognized using 3D SlowflowHD. Characteristic features of the lung, liver, spleen, adrenal gland, and kidney were a “wheat-field-like appearance” (Fig. 8), “soft-cod-roe-like appearance” (Fig. 12), “baobab-like appearance” (Fig. 13), “cactus-like appearance” (Fig. 17), and an “artichoke-like appearance” (Fig. 18), respectively. The microvasculature density of each organ increased with advancing gestation.
Spatial relationships among fetal organs were also noted (Figs 16, 17, 19, and 20).

The increased density of the placental microvasculature with advancing gestation was clearly shown using 3D SlowflowHD (Figs 21–24).

**Discussion**

There have been only three studies on 2D SlowflowHD assessment of small peripheral vessels and organ microvasculature of fetuses and the placental microvasculature. However, to the best of our knowledge, there has been no report on 3D SlowflowHD assessment of spatial fetal organ and placental microvasculature. Superb microvascular imaging (SMI) is another Doppler technology like SlowflowHD, which can visualize low-velocity blood flow of small peripheral vessels and organ microvasculature of fetuses and the placental microvasculature. Moreover, SMI has a smart 3D technology, which can spatially reconstruct normal fetal organ microvasculature and normal and abnormal placentas. However, a major concern and disadvantage of smart 3D is the manual acquisition of volume data. Therefore, the reproducibility of 3D reconstruction of fetal and placental vasculature is major problem on smart 3D technology with SMI. On the contrary, the transabdominal mechanical matrix probe for 3D SlowflowHD examination used in the current study facilitated automated volume acquisition of the fetus and placenta. Consequently, we could obtain better 3D reconstructed SlowflowHD images easily.

![Fig. 4: Fetal intracranial blood vessels using three-dimensional SlowflowHD at 22 weeks and 1 day of gestation.](image1)

![Fig. 5: Fetal intracranial blood vessels using three-dimensional SlowflowHD at 22 weeks and 5 days of gestation.](image2)

![Fig. 6: Fetal intracranial blood vessels using three-dimensional SlowflowHD at 32 weeks of gestation.](image3)

![Fig. 7: Fetal pulmonary microvasculature depicted by three-dimensional SlowflowHD at 27 weeks and 3 days of gestation.](image4)
3D SlowflowHD of Fetal Organ Microvasculature

Fig. 8: Fetal pulmonary microvasculature depicted by three-dimensional SlowflowHD at 35 weeks of gestation. RL, right lung.

Fig. 9: Fetal pulmonary microvasculature depicted by three-dimensional SlowflowHD at 36 weeks and 4 days of gestation. DAo, descending aorta; H, heart; IVC, inferior vena cava; RL, right lung.

Fig. 10: Fetal hepatic microvasculature depicted by three-dimensional SlowflowHD at 23 weeks and 4 days of gestation. L, liver; PV, portal vein; UV, umbilical vein.

Fig. 11: Fetal hepatic microvasculature depicted by three-dimensional SlowflowHD at 26 weeks and 1 day of gestation. H, heart; HV, hepatic vein; IVC, inferior vena cava; L, liver.

Fig. 12: Fetal hepatic microvasculature depicted by three-dimensional SlowflowHD at 37 weeks of gestation. DV, ductus venosus; L, liver; PS, portal sinus; UV, umbilical vein.

Fig. 13: Fetal splenic microvasculature depicted by three-dimensional SlowflowHD at 26 weeks and 5 days of gestation. S, spleen; SA, splenic artery; St, stomach; SV, splenic vein.
To the best of our knowledge, this is the first study to visualize fetal organ and placental microvasculature using 3D SlowflowHD. In this study, 3D SlowflowHD could visualize spatial intracranial blood vessels of the fetus even in the late first trimester of pregnancy. A significant feature of 3D SlowflowHD is that we can see spatial relationships of intracranial vascularity including arteries and the venous system. Especially, spatial intracranial venous sinuses can be clearly identified using this technique. 3D SlowflowHD may become a useful modality for the detection of intracranial vascular anomalies of the fetus.

There has been only one report on assessing fetal lung microvasculature using 3D SMI with an 18-MHz probe. However, the image quality of 3D SMI was poor because of the manual acquisition of volume data and noise.
due to fetal heartbeats. In the current study, 3D SlowflowHD clearly showed characteristic fetal lung microvasculature such as a “wheat-field-like appearance.” 3D SlowflowHD may provide novel information on the antenatal evaluation of fetal lung maturation in utero.

Also, there has been only one report on assessing the microvasculature of fetal intra-abdominal organs using 3D SMI with an 18-MHz probe. However, the image quality of 3D SMI was insufficient because of the manual acquisition of volume data. Moreover, this high-resolution abdominal probe is only applicable for near-field fetal intra-abdominal blood vessels and organ microvasculature because of the shallow penetration of an 18-MHz probe. In the current study, we could see the unique and characteristic microvasculature of fetal intra-abdominal organs. The hepatic microvasculature showed a “soft-cod-roe-like appearance” with 3D SlowflowHD. The splenic microvasculature had a “baobab-like appearance.” The adrenal microvasculature had a “cactus-like appearance.” The renal microvasculature had an “artichoke-like appearance” with this technique. 3D SlowflowHD may provide novel information on the antenatal diagnosis of abnormal fetal intra-abdominal organ microvasculature in clinical practice.

3D SMI showed an increased density of the placental microvasculature with advancing gestation, absent vascularity in placental infarction, decreased vascularity in placenta with fetal growth restriction, and significantly dilated decidual vessels in placenta acrrecte spectrum. However, the image clarity and visibility of 3D SMI were unsatisfactory because of the poor resolution and visibility of those images.
In the current study, we could obtain good 3D SlowflowHD images of the placenta with high-resolution and excellent visibility. 3D SlowflowHD may become a useful diagnostic modality for the assessment of normal and abnormal placental microvasculature in clinical practice.

Major limitations of 3D SlowflowHD are the same as those with 2D SlowflowHD, which are motion artifacts and noise due to fetal heartbeats, fetal movements, and maternal respiratory movements. Moreover, the intra-amniotic stream of amniotic fluid affected the volume acquisition of 3D SlowflowHD. The rapid acquisition of volume data with future technical advances in 3D SlowflowHD may overcome these limitations.

**References**