Fetal Peripheral Blood Vessels and Organ Microvasculature Depicted by SMI and SlowflowHD
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ABSTRACT
Superb microvascular imaging (with Doppler Luminance) and SlowflowHD can detect low-velocity blood flow in fetal peripheral small vessels by significantly reducing motion artifacts. Fetal intracranial, intrathoracic, intra-abdominal, and small arm and leg vessels can be clearly identified using these techniques. Moreover, microvasculature of the lung, liver, spleen, adrenal gland, and kidney can also be noted. Superb microvascular imaging (with Doppler Luminance) and SlowflowHD may become a future modality to provide novel information on the antenatal diagnosis of fetal normal and abnormal peripheral vasculatures, and the physiologic progress and pathologic etiology of fetal intrathoracic and intra-abdominal organs in clinical practice and future research.

Keywords: 18-MHz probe, Fetus, Organ microvasculature, Peripheral blood vessel, SlowflowHD, Superb microvascular imaging.

Introduction
The novel Doppler technology of superb microvascular imaging (SMI) (Aplio i800; Canon Medical Systems, Tokyo, Japan) uses an algorithm that minimizes motion artifacts by filtering out tissue motion (clutter), and it can be used to visualize low-velocity blood flow by significantly reducing motion artifacts.¹ Superb microvascular imaging with Doppler Luminance is the most recent color Doppler modality, presenting three-dimensional (3D) SMI information on a two-dimensional (2D) gray-scale image by shading that is controlled by the amplitude of the Doppler signal.² Several SMI studies have been conducted on normal and abnormal placentas,¹⁻¹⁰ and fetal blood vessels.²,¹¹,¹² With an application of an 18-MHz probe, more meticulous reports of placental and fetal intra-abdominal blood vessels and organ microvasculature have been made.¹³⁻¹⁶

The novel Doppler technology of SlowflowHD (GE Voluson E10 BT 21; GE Healthcare, Zipf, Austria) can be used to visualize blood flow of smaller vessels in the branching vascular bed of the fetus and placenta.¹⁷⁻¹⁹ Its primary features are a high-display frame rate, high-line density (high-resolution), and favorable sensitivity.

Here, the most up-to-date state-of-the-art SMI (with Doppler Luminance) and SlowflowHD of normal fetal peripheral blood vessels and organ microvasculature are presented. Present and future applications of these techniques to examine normal and abnormal fetal peripheral blood vessels and organ microvasculature are also considered.

Fetal Intracranial Blood Vessels
The internal carotid artery, Circle of Willis, anterior cerebral artery, anterior communicating artery, M1 and M2 segments of the middle cerebral artery, recurrent artery of Heubner, lenticulostriate arteries, posterior communicating artery, posterior cerebral artery, superior cerebellar artery, basilar artery, and pontine arteries can be clearly recognized (Figs 1 to 9). Orbital vascularity can also be clearly shown (Fig. 10). Especially, the hyaloid artery can be identified before 30 weeks of gestation (Fig. 10). Detection of fetal intracranial blood vessels may help to understand fetal brain maturation and development, antenatal diagnosis of fetal central nervous system

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Fig. 2: Circle of Willis depicted by SlowflowHD at 30 weeks and 1 day of gestation. ACA, anterior cerebral artery; AChor, anterior choroidal artery; AComm, anterior communicating artery; MCA, middle cerebral artery; PCA, posterior cerebral artery; PComm, posterior communicating artery.

Fig. 3: Recurrent artery of Heubner (RA of Heubner) depicted by SlowflowHD at 30 weeks and 1 day of gestation. ACA, anterior cerebral artery; ICA, internal carotid artery; MCA, middle cerebral artery.

Fig. 4: Recurrent artery of Heubner (RA of Heubner) depicted by SMI at 23 weeks and 5 days of gestation. ACA, anterior cerebral artery; ICA, internal carotid artery; MCA, middle cerebral artery.

Fig. 5: Lenticulostriate artery (LSA) depicted by SlowflowHD at 30 weeks and 1 day of gestation. MCA, middle cerebral artery.

Fig. 6: Lenticulostriate artery (LSA) depicted by SMI at 23 weeks and 5 days of gestation. ICA, internal carotid artery; MCA, middle cerebral artery.

Fig. 7: Posterior cerebral artery (PCA) depicted by SlowflowHD at 30 weeks and 1 day of gestation. BA, basilar artery; MCA, middle cerebral artery; PComm, posterior communicating artery; SCA, superior cerebellar artery.
abnormality, and redistribution of blood flow in growth-restricted fetuses.

**Fetal Heart and Thymus**

Jabak et al.\(^1\) reported that SMI has the potential to become a useful, adjunctive modality for conventional fetal echocardiography to detect the normal cardiac structure and congenital heart anomaly in the first trimester of pregnancy. Pulmonary veins and neck vessels can be clearly depicted using SMI and SlowflowHD (Figs 11 and 12). Internal mammary arteries were clearly noted, and small vessels in the thymus could be identified using SlowflowHD (Fig. 13).

**Lung Microvasculature**

The density of the lung microvasculature increases with gestational age (Figs 14 to 17). Superb microvascular imaging with an 18-MHz probe can show more precise lung microvasculature (Figs 18 to 20). Three-dimensional SMI with an 18-MHz probe facilitates the spatial reconstruction of the lung microvasculature (Fig. 21). Fetal lung maturation may be evaluated using these techniques in the future.
Figs 13A and B: Fetal thymus (T) depicted by SlowflowHD at 25 weeks and 1 day of gestation (A). Small vessels (arrow) are noted in the thymus (B). IMA, internal mammary artery

Fig. 14: Lung microvasculature depicted by SMI at 14 weeks of gestation

Fig. 15: Lung microvasculature depicted by SlowflowHD at 18 weeks and 5 days of gestation

Fig. 16: Lung microvasculature depicted by SMI at 23 weeks and 5 days of gestation

Fig. 17: Lung microvasculature depicted by SMI at 34 weeks and 3 days of gestation
Intra-abdominal Blood Vessels

The aorta, inferior vena cava, celiac artery, splenic artery and vein, common hepatic artery, adrenal artery, superior and inferior mesenteric arteries, renal artery and vein, umbilical vein, hepatic vein, ductus venosus, and common iliac artery and vein can be clearly noted using Slow flow HD (Figs 22 to 28).

Abdominal Organ Microvasculature

With respect to abdominal organ microvasculature using Slow flow HD, the liver microvasculature shows a fish-net-like appearance (Fig. 29). The spleen microvasculature reveals a honeycomb-like appearance (Fig. 30). The adrenal artery can be clearly noted using Slow flow HD (Fig. 31). The kidney microvasculature has a camphor tree-like appearance (Fig. 32).

With respect to the abdominal organ microvasculature using SMI, the liver microvasculature shows a coral-like appearance (Fig. 33). The spleen microvasculature shows a palisade arrangement of small vascular trees (Figs 34 and 35). The adrenal microvasculature...
has a cactus-like appearance (Fig. 36). The kidney microvasculature shows a baobab-like appearance (Figs 37 and 38).

## Arm and Leg Blood Vessels

Arm vessels and hand microvasculature are clearly described (Figs 39 and 40). Leg vessels can be clearly noted (Figs 41 to 43).

## Conclusion

Superb microvascular imaging and SlowflowHD facilitate the clear visualization of low-velocity blood flow in fetal intracranial, intrathoracic, intra-abdominal, and small upper and lower limb vessels. Also, microvasculature of the lung, liver, spleen, adrenal gland, and kidney can be noted. However, there are limitations in the presence of motion artifacts and noise resulting from the fetal heartbeat, fetal movements, and maternal respiratory movements, and obesity. Overall, such modalities may generate new knowledge...
Fig. 28: Fetal hepatic vessels depicted by SlowflowHD at 29 weeks and 5 days of gestation. Ao, aorta; DV, ductus venosus; IVC, inferior vena cava; PS, portal sinus; RPV, right portal vein; UV, umbilical vein

Fig. 29: Fetal liver microvasculature depicted by SlowflowHD at 25 weeks and 1 day of gestation. Ao, aorta; IVC, inferior vena cava

Fig. 30: Fetal spleen microvasculature depicted by SlowflowHD at 28 weeks and 5 days of gestation. St, stomach

Fig. 31: Fetal adrenal microvasculature depicted by SlowflowHD at 29 weeks and 5 days of gestation. AA, adrenal artery; Ao, aorta; IVC, inferior vena cava

Fig. 32: Fetal kidney microvasculature depicted by SlowflowHD at 33 weeks and 4 days of gestation. Ao, aorta; LRA, left renal artery; LRV, left renal vein

Fig. 33: Fetal liver microvasculature depicted by SMI at 31 weeks and 4 days of gestation
regarding the pathophysiology of fetal anomalies, fetal lung maturation, fetal growth restriction, fetal anemia, and intrauterine inflammation.
REFERENCES


