

HDliveFlow in the Assessment of Fetal Circulation

¹Toshiyuki Hata, ²Mohamed Ahmed Mostafa AboEllail, ³Suraphan Sajapala, ⁴Megumi Ito

ABSTRACT

With the appearance of the latest three/four-dimensional (3D/4D) ultrasound machine (HDliveFlow, Voluson E10, GE Healthcare, Zipf, Austria), HDliveFlow with glass-body rendering mode or silhouette mode will facilitate more precise assessments of the fetal heart and peripheral circulation. The resolution of 3D/4D color/power Doppler using the HDlive technique shows a significant improvement compared to conventional 3D/4D color/power Doppler and the fetal heart with great vessels, small peripheral vessels, and placental blood flow can now be clearly recognized. HDliveFlow with glass-body rendering mode or silhouette mode combines the advantages of a spatial view of the great arteries in addition to the visualization of anatomical landmarks, such as the spine or diaphragm. Its use may provide potential advantages in cases of congenital heart anomalies and placental vascularity over the use of conventional 3D/4D color/power Doppler. This novel technique may assist in the evaluation of the fetal cardiovascular system and fetoplacental vascularity, and offer potential advantages relative to conventional 2D color/power Doppler assessments. In this article, we present the latest state-of-the-art HDliveFlow with glass-body rendering mode or silhouette mode of normal and abnormal fetal hearts, placentas, and umbilical cords. We also discuss the present and future applicability of 3D/4D color/power Doppler to assess the fetal circulation. HDliveFlow with glass-body rendering mode or silhouette mode may become an important modality in future research on fetal cardiac and placental blood flow, and assist in the prenatal diagnosis of fetal congenital heart disease and placental vascular abnormalities.

Keywords: Congenital heart disease, Fetal circulation, Fetal heart, Glass-body rendering mode, HDliveFlow, HDlive silhouette mode, Placenta, Three/four-dimensional color Doppler, Three/four-dimensional power Doppler, Umbilical cord.

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¹Professor and Chairman, ^{2,3}Research Fellow, ⁴Assistant Professor

¹⁻⁴Department of Perinatology and Gynecology, Kagawa University Graduate School of Medicine, Miki, Kagawa, Japan

Corresponding Author: Toshiyuki Hata, Professor and Chairman, Department of Perinatology and Gynecology, Kagawa University Graduate School of Medicine, 1750-1 Ikenobe Miki, Kagawa-761-0793, Japan, Phone: +81-(0)87-891-2174 e-mail: toshi28@med.kagawa-u.ac.jp

INTRODUCTION

There have been numerous reports on conventional three/four-dimensional (3D/4D) color/power Doppler evaluation of the normal fetal heart, congenital heart disease (CHD), and fetal peripheral circulation.¹⁻¹³ However, the spatial resolution of conventional 3D/4D color/power Doppler still remains unclear.

With the recent appearance of the latest 3D/4D ultrasound machine (HDliveFlow, Voluson E10, GE Healthcare, Zipf, Austria), HDliveFlow with glass-body rendering mode or silhouette mode will facilitate more precise assessments of the fetal heart and peripheral circulation. The resolution of HDliveFlow shows a significant improvement compared to conventional 3D/4D color/power Doppler, and the fetal heart with great vessels, small peripheral vessels, and placental blood flow can now be clearly demonstrated.^{14,15}

The glass-body rendering mode is based on the simultaneous display of gray and color Doppler images, and it allows the demonstration, at the same time, of the ventricular filling and crossing of the great arteries, without changing the scanning plane.^{11,16} The HDlive silhouette mode is a new technology that provides vitreous-like clarity of the fetus and placenta.^{17,18} This crystal-like image enables a clear view of fetal body folds, curves, and inner structures, and placental surface structures. This technique has the ability to preserve and show the outline and borders of the structure of interest, while leaving its core transparent. HDliveFlow with glass-body rendering mode or silhouette mode combines the advantages of a spatial view of the fetal heart and great vessels in addition to the visualization of anatomical landmarks, such as the spine or diaphragm. Its use may provide potential advantages in cases of congenital heart anomalies and normal and abnormal placental vascularity over the use of conventional 3D/4D color/power Doppler. The present paper describes the latest state-of-the-art HDliveFlow with glass-body rendering mode or silhouette mode imaging of normal and abnormal fetal hearts, placentas, and umbilical cords, and makes recommendations regarding future research in this field.

NORMAL FETAL HEART

HDliveFlow with glass-body rendering mode or silhouette mode facilitates visualization of the spatial relationships, size, and course of the cardiac chambers and outflow tracts (Figs 1 to 3). In normal fetal hearts, blood

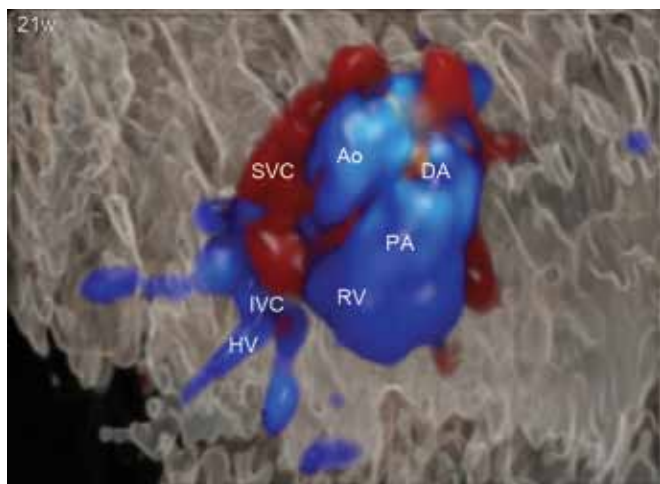


Fig. 1: HDliveFlow color Doppler with silhouette mode of a normal fetal heart at 21 weeks of gestation. The spatial relationship among great vessels of the heart can be clearly visualized (Ao: Aorta; DA: Ductus arteriosus; HV: Hepatic vein; IVC: Inferior vena cava; PA: Pulmonary artery; RV: Right ventricle; SVC: Superior vena cava)

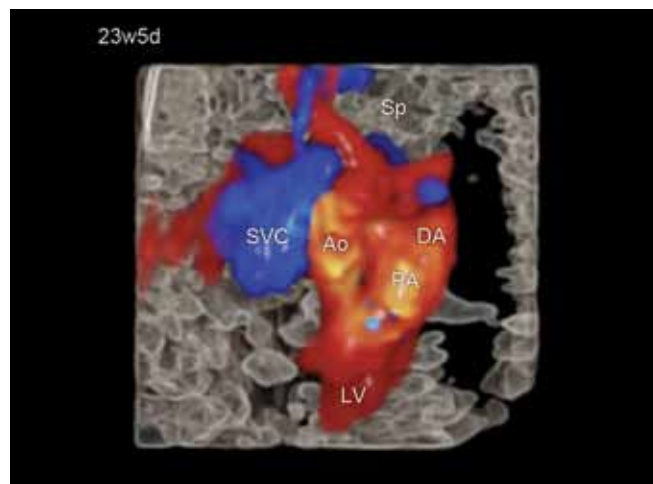


Fig. 2: Spatial three-vessel view of a normal fetal heart at 23 weeks and 5 days of gestation, reconstructed by HDliveFlow color Doppler with silhouette mode. The spatial relationship and size comparison between three vessels can be noted. Ductus arteriosus (DA) following the pulmonary artery (PA) to aorta (Ao) is also noted. Branching vessels from the aortic arch are evident (LV: Left ventricle; Sp: Spine; SVC: Superior vena cava)

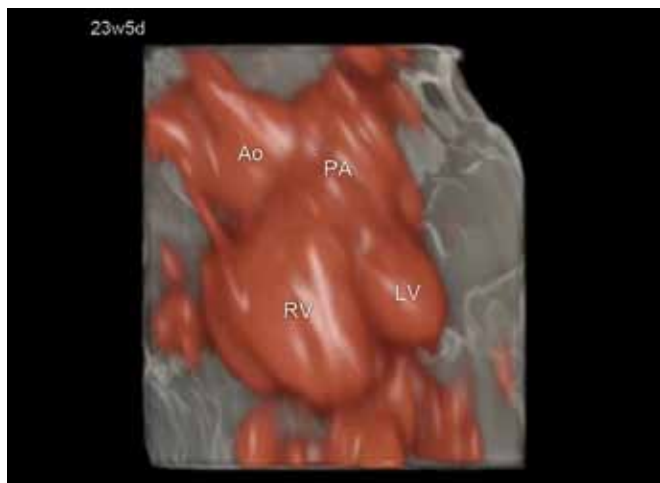
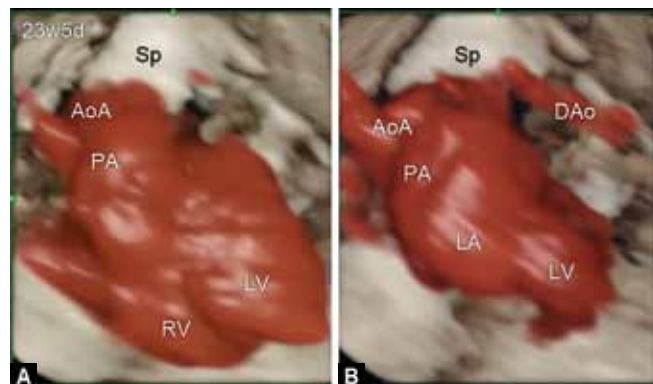


Fig. 3: HDliveFlow power Doppler with silhouette mode of a normal fetal heart at 23 weeks and 5 days of gestation. Crisscross arrangement of the pulmonary artery (PA) and aorta (Ao) with clear identification of their origins from the right (RV) and left (LV) ventricles respectively, is evident

flow through the four cardiac chambers and crisscross arrangements of the pulmonary artery and aorta can be clearly recognized in systole and diastole (Figs 4A and B). HDliveFlow with glass-body rendering mode or silhouette mode combines the advantages of a spatial view of the great arteries in addition to the visualization of anatomical landmarks, such as the spine or diaphragm (Figs 5 to 8). This technique also clearly demonstrates normal fetal aortic branches as well as different venous tributaries (Figs 9 and 10).

CONGENITAL HEART DISEASE

There have been only two reports on using the latest HDliveFlow with glass-body rendering mode or silhouette mode for the diagnosis of CHD (truncus



Figs 4A and B: HDliveFlow power Doppler with glass-body rendering mode of a normal fetal heart at 23 weeks and 5 days of gestation. Blood flow from both ventricles to the great arteries and crisscross arrangement of the pulmonary artery (PA) and aortic arch (AoA) during diastole (A) and systole (B) can be identified. The spine (Sp) as an anatomical landmark with the descending aorta (DAo) on its left side can be clearly noted (LA: Left atrium; LV: Left ventricle; RV: Right ventricle)

arteriosus and right aortic arch).^{14,15} In the case of holoprosencephaly, mild tricuspid regurgitant flow was noted using this technique at 19 weeks of gestation (Fig. 11). In the presence of a large ventricular septal defect (VSD), significant shunt flow through VSD between the left and right ventricles was evident (Figs 12A and B). In the case of hypoplastic left heart syndrome, giant tricuspid regurgitant flow was evident (Fig. 13). In cases of double-outlet right ventricle, both the pulmonary artery and aorta can be seen to arise in parallel from the right ventricle (Figs 14 and 15).

FETAL PERIPHERAL CIRCULATION

HDliveFlow with glass-body rendering mode or silhouette mode has the potential to evaluate embryonic and fetal

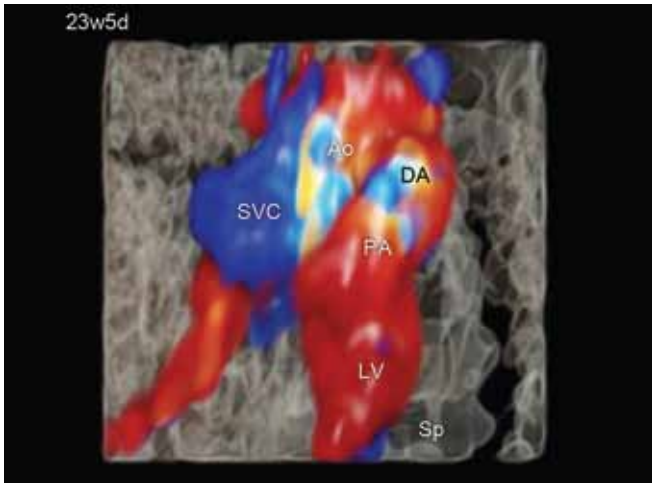


Fig. 5: HDliveFlow color Doppler with silhouette mode of a normal fetal heart at 23 weeks and 5 days of gestation at the level of the upper mediastinum. The spine (Sp) as an anatomical landmark in addition to a spatial three-vessel view can be noted. Cephalic vessels originating from the aorta (Ao) are also noted (DA: Ductus arteriosus; LV: Left ventricle; PA: Pulmonary artery; SVC: Superior vena cava)

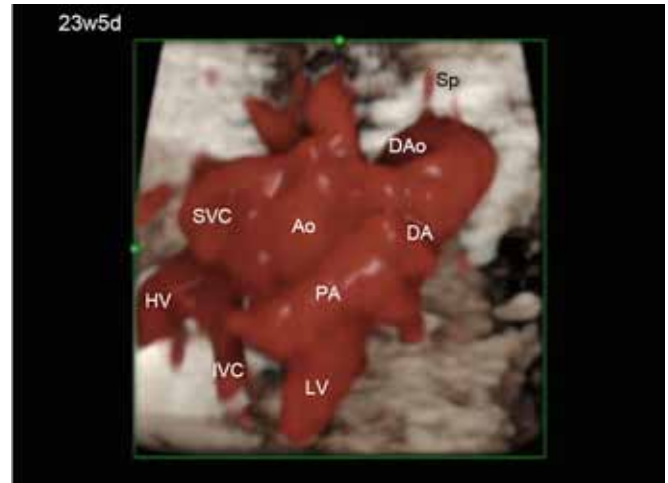


Fig. 7: HDliveFlow power Doppler with glass-body rendering mode of a normal fetal heart at 23 weeks and 5 days of gestation. The course of the descending aorta (DAo) in front of and to the left of the spine (Sp) can be seen. Ductus arteriosus (DA) following the pulmonary artery (PA) to the aorta (Ao) is evident (HV: Hepatic vein; IVC: Inferior vena cava; LV: Left ventricle; SVC: Superior vena cava)



Fig. 6: HDliveFlow power Doppler with glass-body rendering mode of a normal fetal heart at 23 weeks and 5 days of gestation. Fetal great arteries and veins with spatial relationships among them and the spine (Sp) can be demonstrated (Ao: Aorta; DA: Ductus arteriosus; HV: Hepatic vein; IVC: Inferior vena cava; LV: Left ventricle; PA: Pulmonary artery; SVC: Superior vena cava)

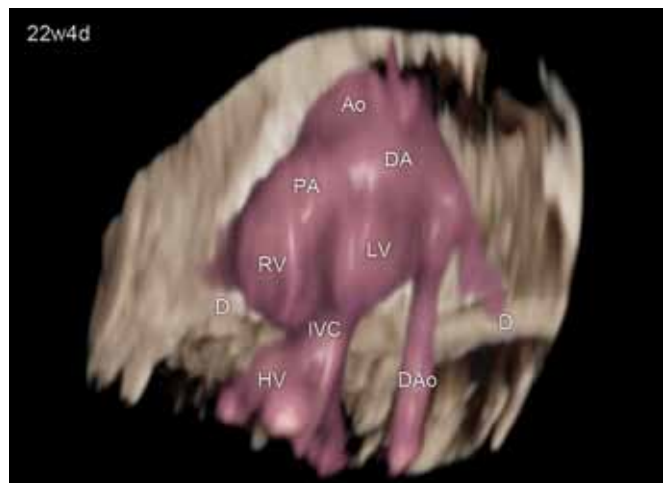


Fig. 8: HDliveFlow power Doppler with glass-body rendering mode of a normal fetal heart at 22 weeks and 4 days of gestation. The descending aorta (DAo) continues in the abdomen as the abdominal aorta by passing behind the diaphragm (D), which is clearly visualized as an anatomical landmark. Other cardiac great vessels are also seen (Ao: Aorta; DA: Ductus arteriosus; HV: Hepatic vein; IVC: Inferior vena cava; LV: Left ventricle; PA: Pulmonary artery; RV: Right ventricle)

circulation more precisely compared to conventional 3D/4D color/power Doppler in the first trimester of pregnancy (Figs 16 and 17). HDliveFlow color Doppler clearly shows intracranial vessels, three cephalic vessels, and ductus venosus at 11 weeks of gestation (Fig. 16). HDliveFlow with silhouette mode can separately delineate fetal vessels, the umbilical cord, and placenta in the first trimester of pregnancy (Fig. 17).

Intracranial vessels are clearly recognized using HDliveFlow power Doppler with glass-body rendering mode or silhouette mode in the second and third

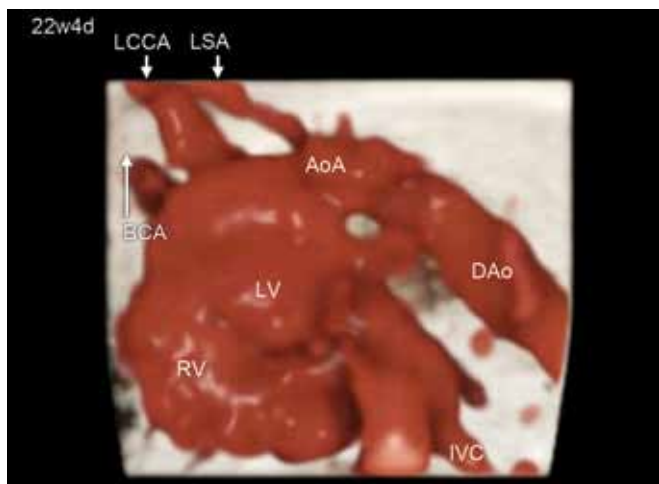


Fig. 9: HDliveFlow power Doppler with glass-body rendering mode of a normal fetal heart at 22 weeks and 4 days of gestation. The origin of the aorta from the left ventricle (LV), its three cephalic branches, the aortic arch (AoA), and descending aorta (DAo) are clearly recognized (BCA: Brachiocephalic artery; IVC: Inferior vena cava; LCCA: Left common carotid artery; LSA: Left subclavian artery; RV: Right ventricle)

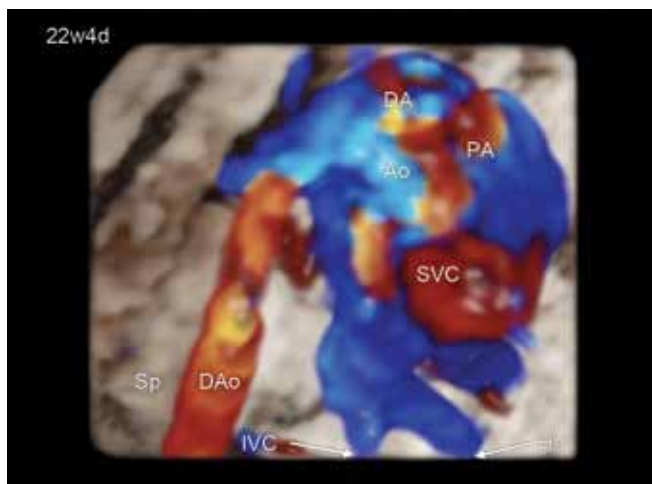


Fig. 10: HDliveFlow color Doppler with glass-body rendering mode of a normal fetal heart at 22 weeks and 4 days of gestation. Major veins can be recognized with a right lateral view (Ao: Aorta; DA: Ductus arteriosus; DAo: Descending aorta; HV: Hepatic vein; IVC: inferior vena cava; LV: Left ventricle; PA: Pulmonary artery; Sp: Spine; SVC: Superior vena cava)

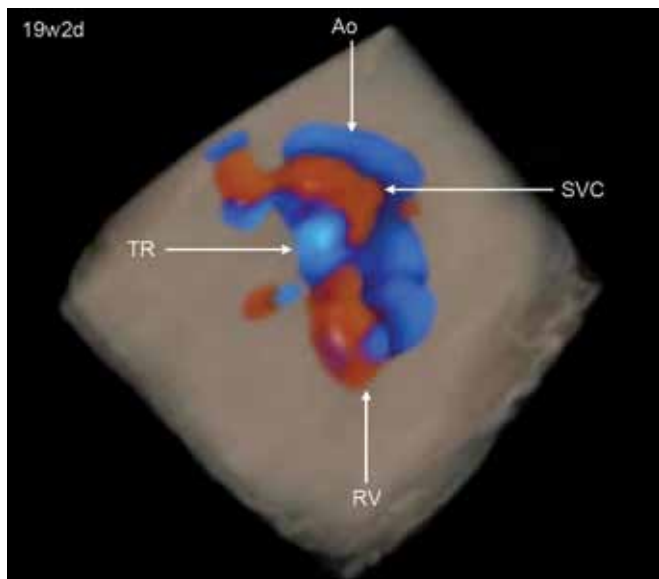
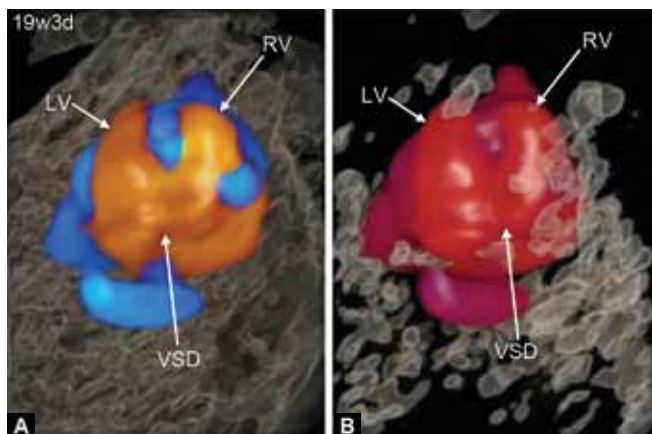


Fig. 11: HDliveFlow color Doppler with silhouette mode of mild tricuspid regurgitation (TR) in a case of holoprosencephaly at 19 weeks and 2 days of gestation (Ao: Aorta; RV: Right ventricle; SVC: Superior vena cava)



Figs 12A and B: HDliveFlow color Doppler with silhouette mode (A) and an HDliveFlow monochromatic map (B) of a large ventricular septal defect (VSD) at 19 weeks and 3 days of gestation. Shunt flow between the left (LV) and right (RV) ventricles is clearly depicted

trimesters of pregnancy (Figs 18 and 19). In particular, the spatial relationship between intracranial vessels and the skull base could be clarified using the glass-body rendering mode or HDlive silhouette mode (Figs 18 and 19).

Intrathoracic and intra-abdominal vessels are also clearly depicted using HDliveFlow power Doppler with glass-body rendering mode or silhouette mode (Figs 20 to 22).

UMBILICAL CORD AND PLACENTA

Three vessels in the umbilical cord and umbilical cord attachment to the placenta could be clearly identified

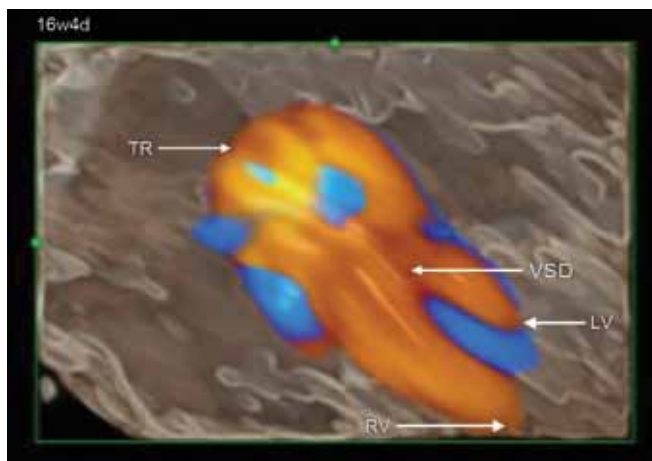


Fig. 13: HDliveFlow color Doppler with silhouette mode of hypoplastic left heart syndrome at 16 weeks and 4 days of gestation. A diminutive left ventricle (LV) and significant tricuspid valve regurgitation (TR) with shunt flow across a large ventricular septal defect (VSD) can be identified (RV: Right ventricle)

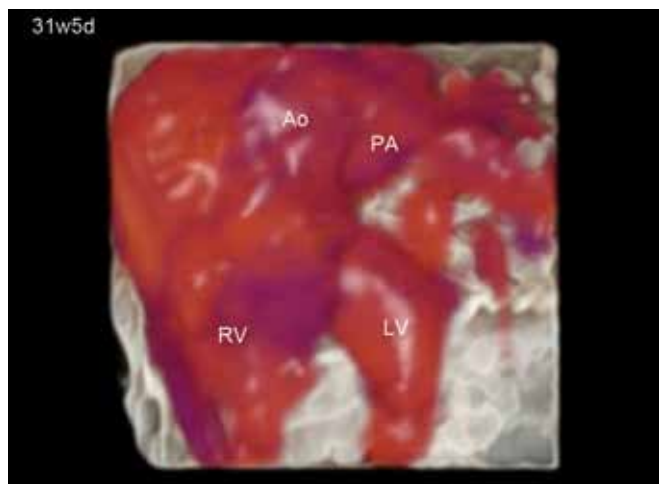


Fig. 14: HDliveFlow monochromatic map with silhouette mode of a double-outlet right ventricle at 31 weeks and 5 days of gestation. The large aorta (Ao) and small pulmonary artery (PA) leaving the right ventricle (RV) in parallel are clearly shown (LV: Left ventricle)

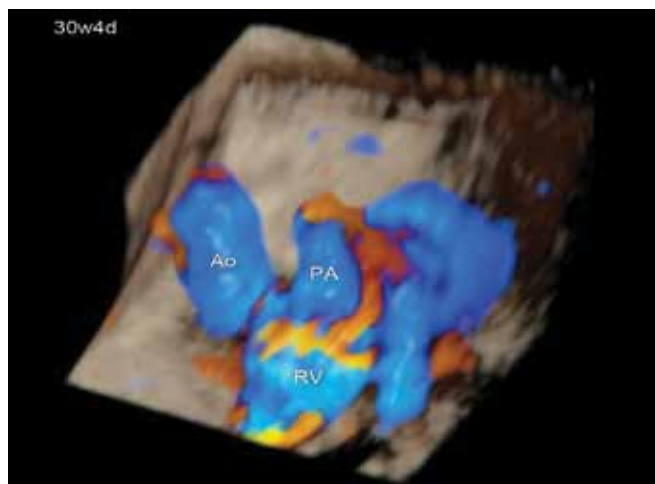


Fig. 15: HDliveFlow color Doppler with glass-body rendering mode of a double-outlet right ventricle at 30 weeks and 4 days of gestation. The large aorta (Ao) and small pulmonary artery (PA) leaving the right ventricle (RV) in parallel are clearly shown

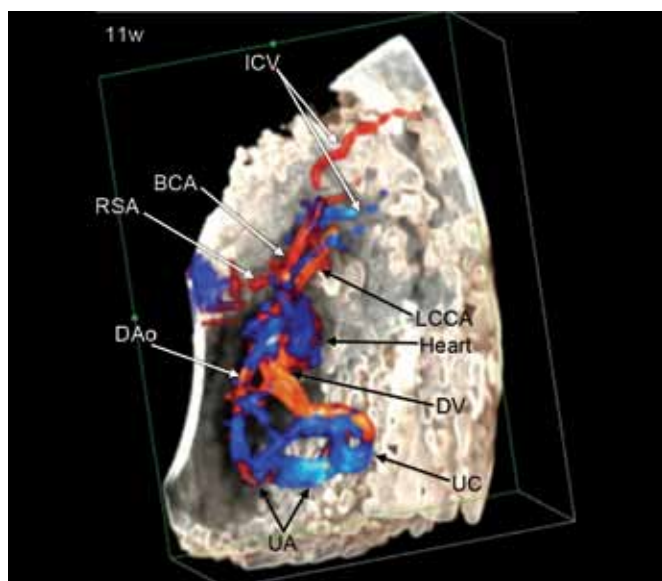


Fig. 16: HDliveFlow color Doppler with silhouette mode of fetal peripheral circulation as well as the heart at 11 weeks of gestation. Intracranial vessels (ICV), three cephalic branches of the aortic arch as well as ductus venosus (DV) are clearly shown (BCA: Brachiocephalic artery; DAo: Descending aorta; LCCA: Left common carotid artery; RSA: Right subclavian artery; UA: Umbilical artery; UC: Umbilical cord)

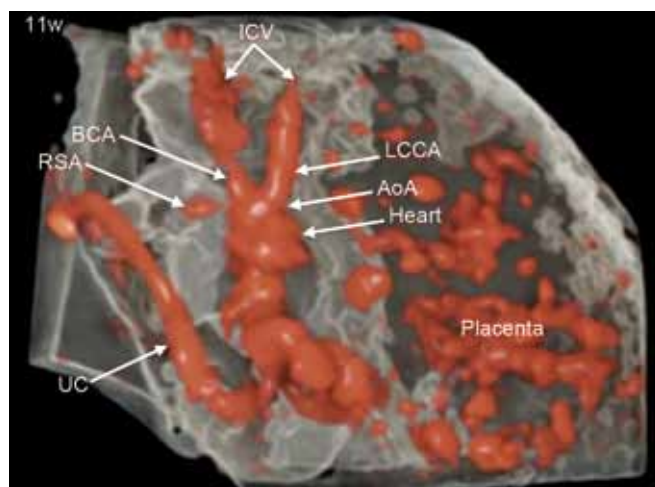


Fig. 17: HDliveFlow power Doppler with silhouette mode of fetal peripheral circulation as well as the heart at 11 weeks of gestation. Fetal vessels, the umbilical cord and placenta are separately delineated (AoA: Aortic arch; BCA: Brachiocephalic artery; ICV: Intracranial vessel; LCCA: Left common carotid artery; RSA: Right subclavian artery; UC: Umbilical cord)

using HDliveFlow color Doppler with glass-body rendering mode or silhouette mode (Figs 23A and B). Chorionic surface vessels on the placental surface and intraplacental vessels are also evident.

The spatial relationship between the umbilical cord, chorionic surface vessels, stem villi vessels, decidual vessels and placenta could be clearly achieved using HDliveFlow power Doppler with glass-body rendering mode or silhouette mode (Figs 24 to 26). The early budding of secondary stem villi can be seen at around 14 weeks of gestation (Fig. 24). The main stem vessel, secondary stem vessel, tertiary stem vessels, and ends of spiral arteries are clearly shown at around 20 weeks of gestation (Fig. 25).

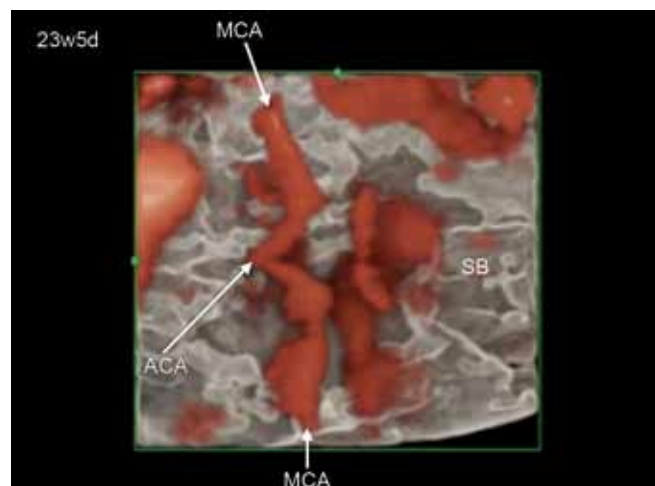


Fig. 18: HDliveFlow power Doppler with silhouette mode of fetal intracranial vessels and their spatial relationship with the skull base (SB) at 23 weeks and 5 days of gestation (ACA: Anterior cerebral artery; MCA: Middle cerebral artery)



Figs 19A and B: HDliveFlow power Doppler with glass-body rendering mode of fetal intracranial vessels and their spatial relationship with the skull base (SB) with superior (A) and posterior (B) views at 36 weeks and 2 days of gestation (ACA: Anterior cerebral artery; MCA: Middle cerebral artery; PCA: Posterior cerebral artery)

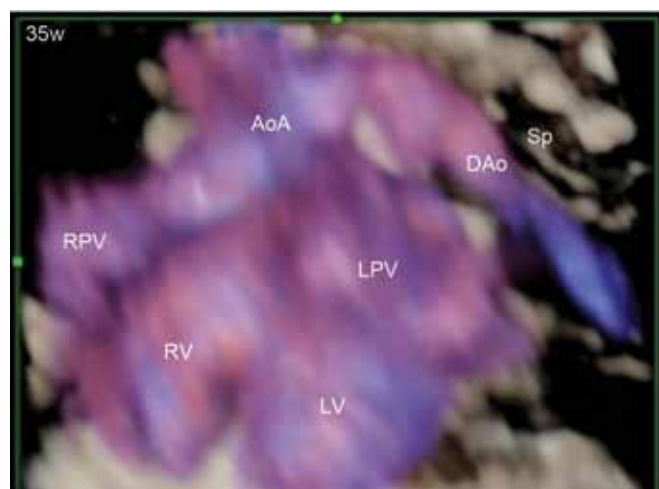
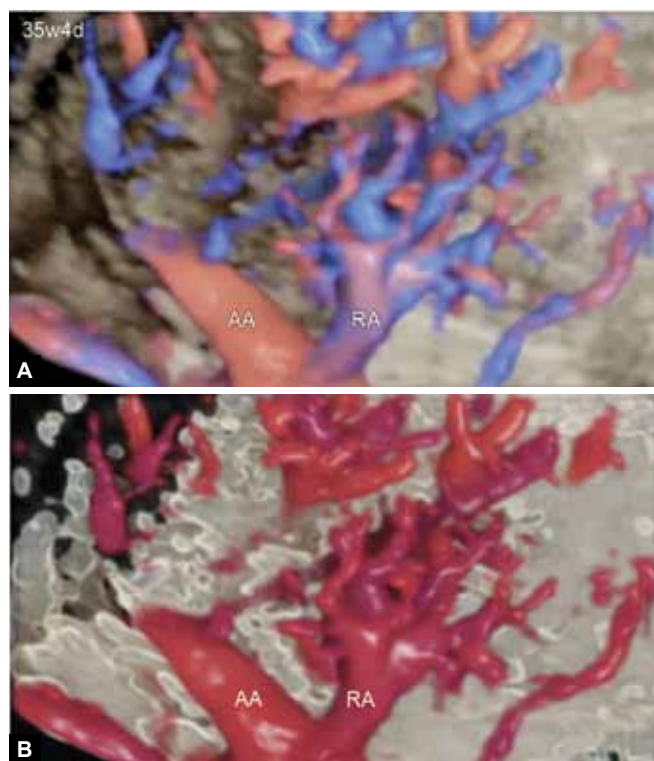


Fig. 20: HDliveFlow with glass-body rendering mode of intrathoracic vessels and their spatial relationships with each other and the spine (SP) in a normal heart at 35 weeks of gestation. Left (LPV) and right (RPV) pulmonary vessels are clearly identified (AoA: Aortic arch; DAo: Descending aorta; RV: Right ventricle; LV: Left ventricle)



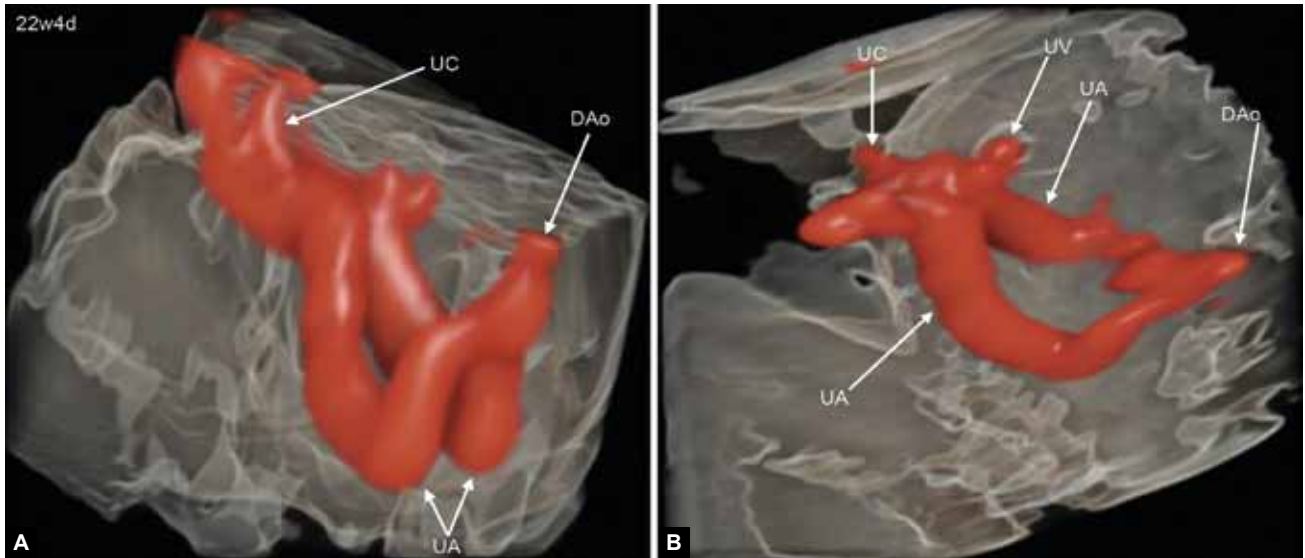
Figs 21A and B: HDliveFlow color Doppler with glass-body rendering mode (A) and HDliveFlow power Doppler with silhouette mode (B) of intra-abdominal vessels at 35 weeks and 4 days of gestation. The renal artery (RA) originating from the abdominal aorta (AA) and renal vasculature are clearly seen

Increases in the density and complexity of placental vessels can be seen after 20 weeks to term (Figs 26A and B).

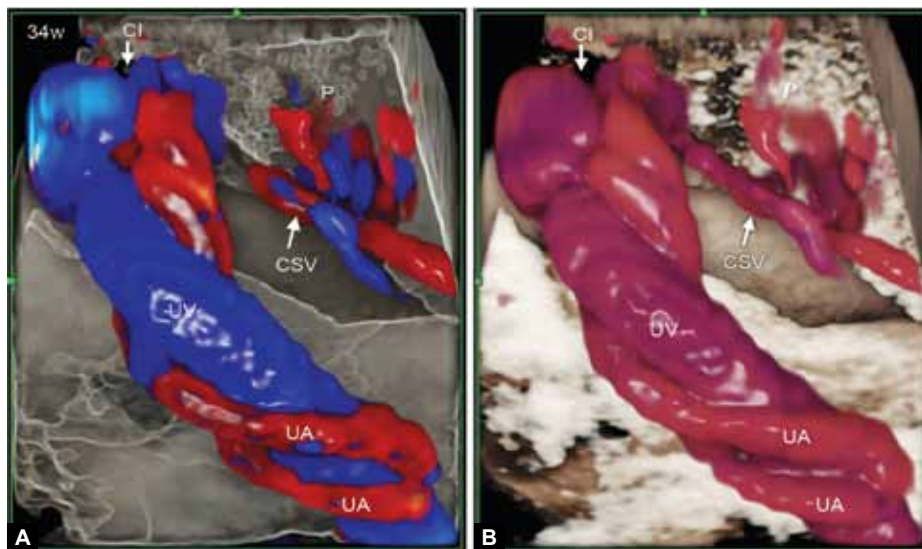
In the case of a circumvallate placenta, HDliveFlow power Doppler with glass-body rendering mode showed the thickened, curved edges of the placenta with the umbilical cord attached to its center (Fig. 27). Chorionic surface vessels were seen branching out from the umbilical cord over the fetal surface of the placenta to form the villous tree. The placental vascularity appears normal.

Figures 28A and B present the HDliveFlow power Doppler features of the serosa-bladder interface in the

case of placenta increta. The extent of the serosa-bladder wall interface with irregular neovascularization is evident (Fig. 28A). Placenta increta is evident at the serosa-bladder interface during the operation (Fig. 28B).



Figs 22A and B: HDliveFlow power Doppler with silhouette mode of intrapelvic vessels at 22 weeks and 4 days of gestation: (A) Left posterior lateral view and (B) superior view (DAo: Descending aorta; UA: Umbilical artery; UC: Umbilical cord; UV: Umbilical vein)



Figs 23A and B: HDliveFlow color Doppler with silhouette mode (A) and an HDliveFlow monochromatic map with glass-body rendering mode (B) of the two umbilical arteries (UA) and umbilical vein (UV) forming the umbilical cord as well as its attachment to the placenta (P). Chorionic surface vessels (CSV) on the placental surface and chorionic intraplacental vessels are also evident (CI: Cord insertion)

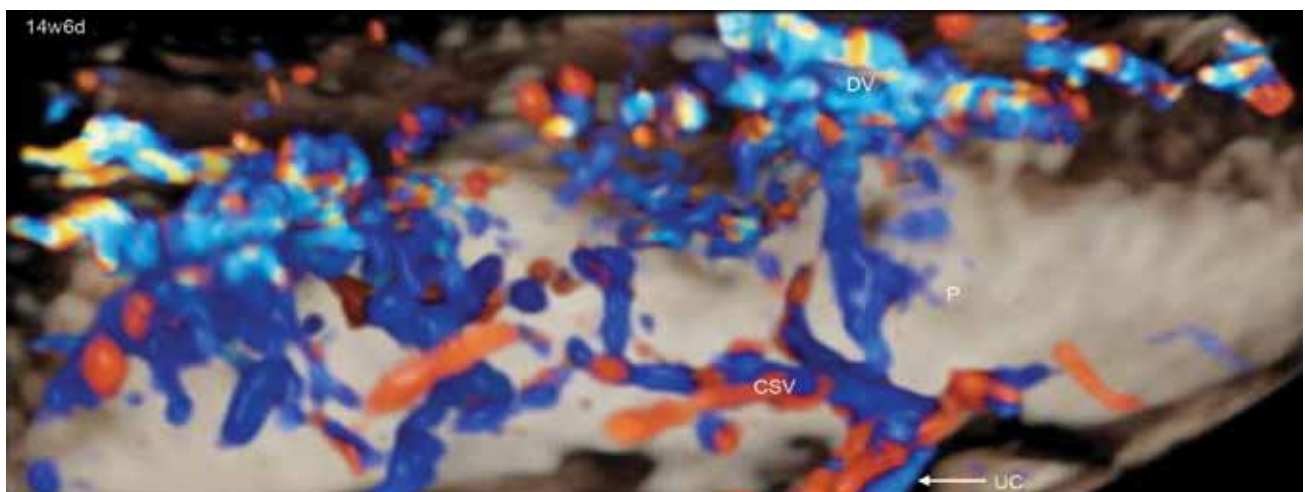


Fig. 24: HDliveFlow color Doppler with glass-body rendering mode of the placenta (P) at 14 weeks and 6 days of gestation. Normal spatial relationships among the umbilical cord (UC), chorionic surface vessels (CSV), decidual vessels (DV) and P. The early budding of secondary stem villi can also be seen early in gestation

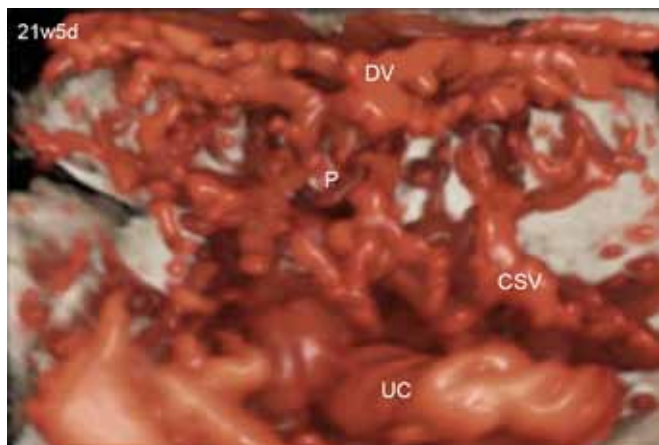


Fig. 25: HDliveFlow power Doppler with glass-body rendering mode of the normal placenta (P) at 21 weeks and 5 days of gestation. The main stem vessels, secondary stem vessels, tertiary stem vessels and ends of spiral arteries are clearly shown (CSV: Chorionic surface vessels; DV: Decidual vessels; UC: Umbilical cord)

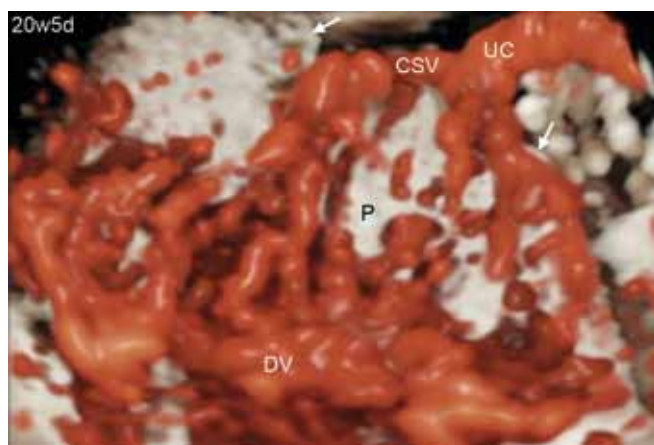
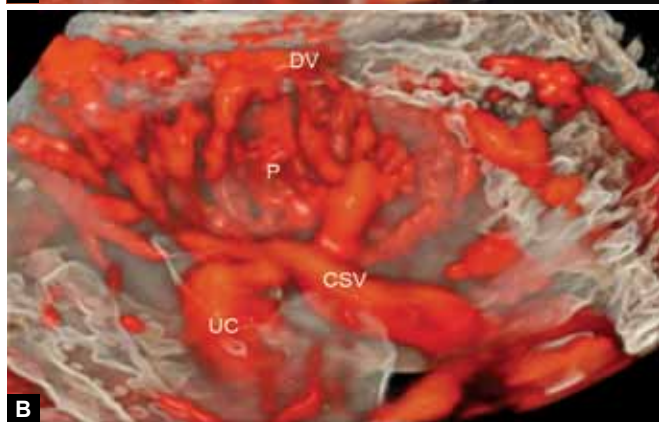
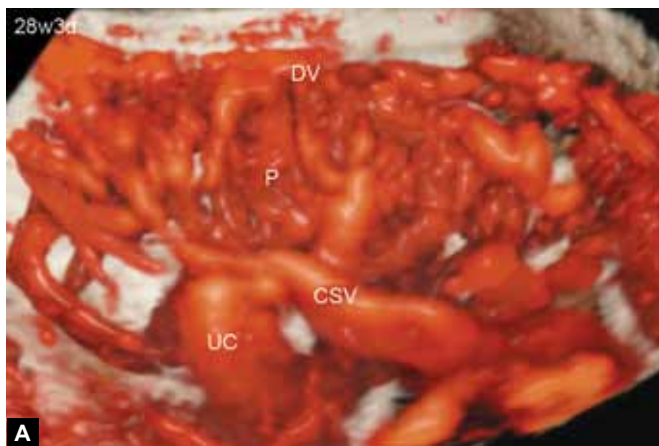
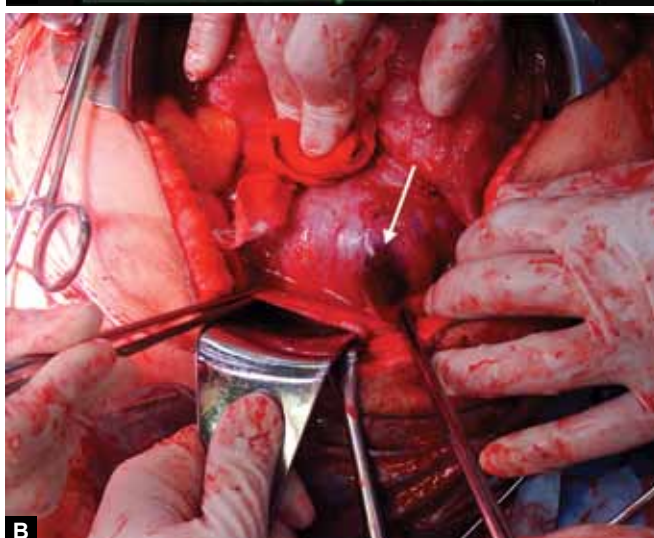
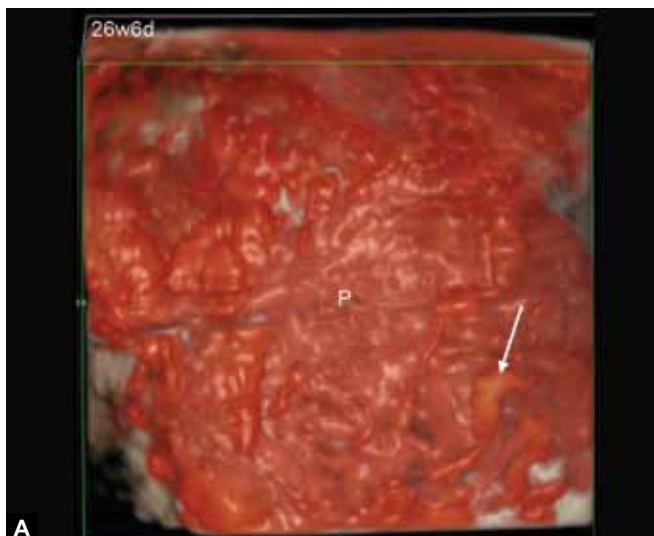


Fig. 27: HDliveFlow power Doppler with glass-body rendering mode of a circumvallate placenta (P) at 20 weeks and 5 days of gestation. Thickened, rolled up edges of the placenta (arrows) with the umbilical cord (UC) attached to the center of P are seen. Chorionic surface vessels (CSV) are seen branching out from the umbilical cord over the fetal surface of the placenta to form the villous tree. Thickened P is evident but the placental vascularity appears normal (DV: Decidual vessels)



Figs 26A and B: HDliveFlow power Doppler with glass-body rendering mode (A) and silhouette mode (B) of the placenta (P) at 28 weeks and 3 days of gestation. Increases in the density and complexity of placental vessels can be clearly noted late in gestation (CSV: Chorionic surface vessels; DV: Decidual vessels; UC: Umbilical cord)



Figs 28A and B: HDliveFlow power Doppler feature of the serosa-bladder interface (arrow) in the case of placenta increta. The extent of the serosa-bladder wall interface with irregular neovascularization is evident (A). Placenta increta is evident at the serosa-bladder interface during the operation (B) (P: Placenta)

CONCLUSION

HDliveFlow with glass-body rendering mode or silhouette mode may allow the visualization of fetal structures with more favorable resolution compared to conventional

3D/4D Doppler. Spatial relationships among structures as well as the identification of anatomical landmarks, such as the spine and diaphragm, are additional advantages that might be valuable during detecting fetal anomalies especially when anatomical landmarks are needed to localize the lesion or clarify the spatial relationships among structures to confirm the diagnosis. This makes the technique helpful in diagnosing CHD, and increases the physician's confidence during diagnosing complicated anomalies. Moreover, this technique allows the visualization of small peripheral vessels; therefore, the fetal peripheral circulation can be clearly delineated and assessed. Placental vascular networks up to the level of tertiary stem vessels are also clearly demonstrated. Umbilical cord anomalies can also be detected. It may become an important modality in future research and assist in the prenatal diagnosis of fetal CHD and placental vascular abnormalities. Repeated training and a complete understanding of the normal anatomy might shorten the learning curve and lead to the accurate interpretation of reconstructed images.

REFERENCES

1. Chaoui R, Kalache KD, Hartung J. Application of three-dimensional power Doppler ultrasound in prenatal diagnosis. *Ultrasound Obstet Gynecol* 2001;17(1):22-29.
2. Chaoui R, Kalache KD. Three-dimensional power Doppler ultrasound of the fetal great vessels. *Ultrasound Obstet Gynecol* 2001;17(5):455-456.
3. Chaoui R, Schneider MBE, Kalache KD. Right aortic arch with vascular ring and aberrant left subclavian artery: prenatal diagnosis assisted by three-dimensional power Doppler ultrasound *Ultrasound Obstet Gynecol* 2003;22(6):661-663.
4. Hata T. Modern 3D/4D sonographic studies on fetal heart. *Ultrasound Rev Obstet Gynecol* 2006;6(3-4):115-122.
5. Hata T, Dai SY, Inubashiri E, Kanenishi K, Tanaka H, Yanagihara T, Nukazawa T. Real-time three-dimensional color Doppler fetal echocardiographic features of congenital heart disease. *J Obstet Gynecol Res* 2008;34(4):670-673.
6. Turan S, Turan OM, Maisel P, Gaskin P, Harman CR, Baschat AA. Three-dimensional sonography in the prenatal diagnosis of aortic arch abnormalities. *J Clin Ultrasound* 2009;37(5):253-257.
7. Gindes L, Hegesh J, Weisz B, Gilboa Y, Achiron R. Three and four dimensional ultrasound: a novel method for evaluating fetal cardiac anomalies. *Prenat Diagn* 2009;29(7):645-653.
8. Hsu KC, Hsieh CTC, Chen M, Tsai HD. Right aortic arch with aberrant left subclavian artery – prenatal diagnosis and evaluation of postnatal outcomes: Report of three cases. *Taiwanese J Obstet Gynecol* 2011;50(3):353-358.
9. El Guindi W, Dreyfus M, Carles G, Lambert V, Herlicoviez M, Benoist G. 3D ultrasound and Doppler angiography for evaluation of fetal cardiovascular anomalies. *Int J Gynecol Obstet* 2013;120(2):173-177.
10. Pashaj S, Merz E. Prenatal demonstration of normal variants of the pericallosal artery by 3D ultrasound. *Ultraschall Med* 2014;35(2):129-136.
11. Hata T, Kanenishi K, Mori N, Yazon AO, Hanaoka U, Tanaka H. Four-dimensional color Doppler reconstruction of the fetal heart with glass-body rendering mode. *Am J Cardiol* 2014; 114(10):1603-1606.
12. Campbell S. Placental vasculature as visualized by 3D power Doppler angiography and 3D color Doppler imaging. *Ultrasound Obstet Gynecol* 2007;30(6):917-920.
13. Hata T, Tanaka H, Noguchi J, Hata K. Three-dimensional ultrasound evaluation of the placenta. *Placenta* 2011;32(2):105-115.
14. AboEllail MAM, Kanenishi K, Tenkumo C, Kawanishi K, Kaji T, Hata T. Transvaginal 4D color Doppler in antenatal diagnosis of truncus arteriosus in the first trimester of pregnancy. *Ultrasound Obstet Gynecol* 2015;45(6):759-760.
15. AboEllail MAM, Kanenishi K, Tenkumo C, Mori N, Katayama T, Koyano K, Kusaka T, Hata T. 4D power Doppler with HDlive silhouette mode in antenatal diagnosis of right aortic arch with aberrant left subclavian artery. *J Ultrasound Med* 2015 (in press).
16. Turan S, Turan O, Baschat AA. Three- and four-dimensional fetal echocardiography. *Fetal Diagn Ther* 2009(4);25:361-372.
17. AboEllail MAM, Kanenishi K, Mori N, Kurobe A, Hata T. HDlive image of circumvallate placenta. *Ultrasound Obstet Gynecol* 2015;46(4):513-514.
18. AboEllail MAM, Hanaoka U, Numoto A, Hata T. HDlive image of fetal giant hemangioma. *J Ultrasound Med* 2015;34(12):2315-2318.

