REVIEW ARTICLE

HDlive Flow Silhouette Mode for Fetal Heart

[1]Toshiyuki Hata, [2]Uiko Hanaoka, [3]Kenji Kanenishi

ABSTRACT

The HDlive flow silhouette mode is the latest technology to demonstrate vitreous-like clarity of blood flow and can preserve and delineate the outline and borders of the blood flow while showing its core as semitransparent. Therefore, holographic visualization of the fetal cardiac blood flow can be achieved. We can choose the combination of the HDlive flow or HDlive flow silhouette mode with glass-body rendering mode or HDlive silhouette mode for evaluation of the fetal heart. We can also evaluate the fetal heart from any direction, especially using five special views (frontal, spatial three-vessel, panoramic, posterior, and right lateral views). In this paper, HDlive flow silhouette mode characteristics of the normal fetal heart and congenital heart anomalies are shown using various images. The HDlive flow silhouette mode may help evaluate the normal fetal heart and diagnose congenital heart anomaly during pregnancy as an adjunctive diagnostic tool.

Keywords: Congenital heart anomaly, Fetal heart, HDlive flow, HDlive flow silhouette mode, Prenatal diagnosis.

INTRODUCTION

HDlive uses an adjustable light source, creating lighting and shadowing effects, thereby increasing depth perception, to generate realistic images of the normal fetus and fetal anomalies.[1-17]

Using the HDlive silhouette mode, we can obtain novel information on normal fetal structures, congenital deformities, and placental abnormalities.[18-21] It can visualize outlines of structures of interest at the same time as visualizing the inner core, meaning that it is more effective for identifying normal anatomy and congenital deformities. The shadowing effect that enables the visualization of structures present behind the structure of interest makes it more effective than other advanced rendering modes that are available such as three-dimensional (3D)/four-dimensional (4D) ultrasound and HDlive.

[1]Professor and Chairman, [2]Lecturer, [3]Associate Professor

[1-3]Department of Perinatology and Gynecology, Kagawa University, Graduate School of Medicine, Kagawa, Japan

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

It allows more accurate assessments of the following: fetal heart and peripheral circulation, placental vasculature, and tumor vascularity in the presence of gynecologic disorders.[22-32] The use of HDlive to increase the resolution of 3D/4D color/power Doppler leads to a significant improvement in comparison with conventional 3D/4D color/power Doppler, facilitating clear visualization of fetal heart with great vessels, peripheral vessels, placental blood flow, and tumor blood flow in the presence of gynecologic disorders.

As cutting-edge technology, the HDliveFlow silhouette mode provides vitreous-like clarity of fetal heart blood flow and gynecologic tumors.[33-38] The core is shown as semitransparent while preserving the outline and borders of blood flow. Thus, it is possible to obtain holographic images of blood flow of the fetal heart and tumor vascularity, being its unique feature.

In this paper, the HDliveFlow silhouette mode features of the normal fetal heart and congenital heart anomalies with/without the HDlive silhouette mode are shown using various images.

HDLIVE FLOW AND HDLIVE FLOW SILHOUETTE MODE

HDlive Flow with Glass-body Rendering Mode

This has been suggested to improve the accuracy of diagnosing complex fetal cardiac anomalies, facilitating by its generation of images of outflow tracts and spatial relationships among cardiac structures (Fig. 1).[22,23]
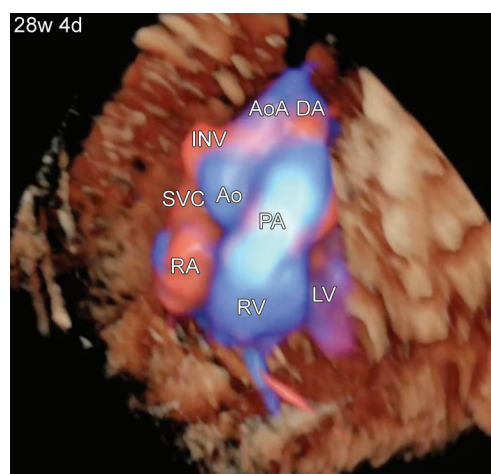

Fig. 1: HDlive Flow with glass-body rendering mode image of the normal fetal heart at 28 weeks and 4 days of gestation. (*Abbreviations:* Ao, aorta; AoA, aortic arch; DA, ductus arteriosus; INV, innominate vein; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava)

HDlive Flow with HDlive Silhouette Mode

When combining HDlive flow with the HDlive silhouette mode, the spatial visualization of blood vessels in both the normal and abnormal fetal heart becomes possible (Fig. 2), as well as that of peripheral blood vessels, placental abnormality, and gynecologic disorders, and so it is possible to not only spatially view these vessels but also visualize landmarks of adjacent structures. [24-32]

HDlive Flow Silhouette Mode with Glass-body Rendering Mode

Use of HDlive flow silhouette with the glass-body rendering mode enables more accurate evaluation of the fetal heart and peripheral circulation. [24] The resolution of HDlive flow is significantly more favorable than that of conventional 3D/4D color/power Doppler, and clear demonstration of the fetal heart with great vessels, small peripheral vessels, and blood flow in the placenta becomes possible (Fig. 3).

HDlive Flow Silhouette Mode with HDlive Silhouette Mode

On combining the HDlive flow silhouette mode and HDlive silhouette mode, we could observe overlapping blood vessels, facilitating vitreous-like clarity of the fetal heart simultaneously with a transparent core. [33,36,37] The holography-like blood flow imaging of the fetal heart is the main merit of the system (Fig. 4). This technique depicts the contour of cardiac chambers, and intra-cardiac-like flow can be identified.
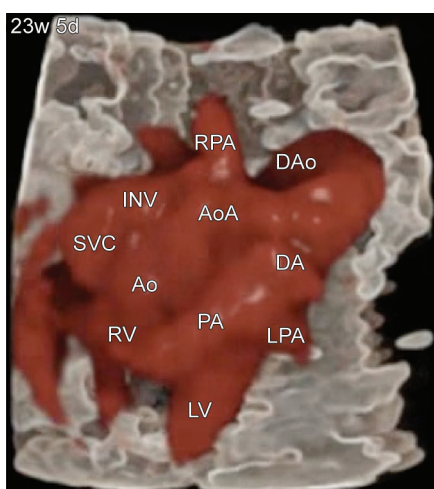
NORMAL FETAL HEART

Frontal View

With this view, spatial relationships can be ascertained among the right atrium with superior vena cava and inferior vena cava, right ventricular outflow tract, ascending aorta, and descending aorta (Figs 5 and 6). The primary objective when adopting this view is to examine inflow of the right atrium (superior and inferior vena cavae to the right atrium).

Spatial Three-vessel View

With this view, we can ascertain the course of the outflow tracts (crisscross arrangements of the pulmonary artery and aorta) and superior vena cava (Figs 7 to 11). This view is actually a superior or anterior view of the fetal heart, involving observation of the crisscross arrangements of the aorta, pulmonary artery, and superior vena cava, whose spatial relationships are easily identifiable. [33,37]

Panoramic View

With this view, we can ascertain spatial relationships among cardiac chambers and vessels, allowing visualization of the out- and in-flow tracts (Figs 12 to 16). This is a left, oblique, or lateral view, providing clear views of the two ventricles, two great arteries, and descending aorta. [33,37]

Posterior View

With this view, we can observe the vertical descending aorta, left and right pulmonary arteries left atrium with pulmonary veins, and right atrium with superior and inferior vena cavae (Figs 17 to 22). Conventional 2D fetal
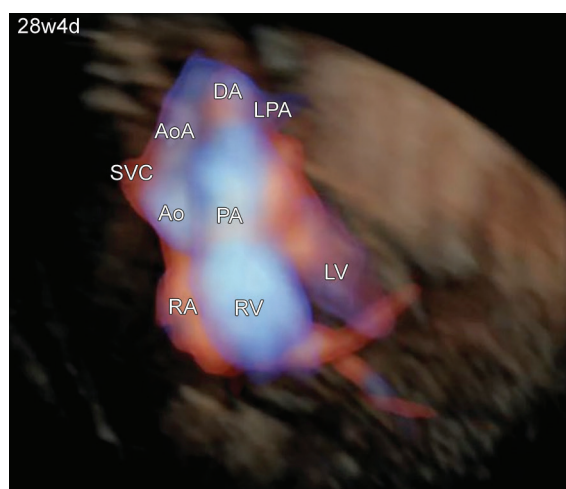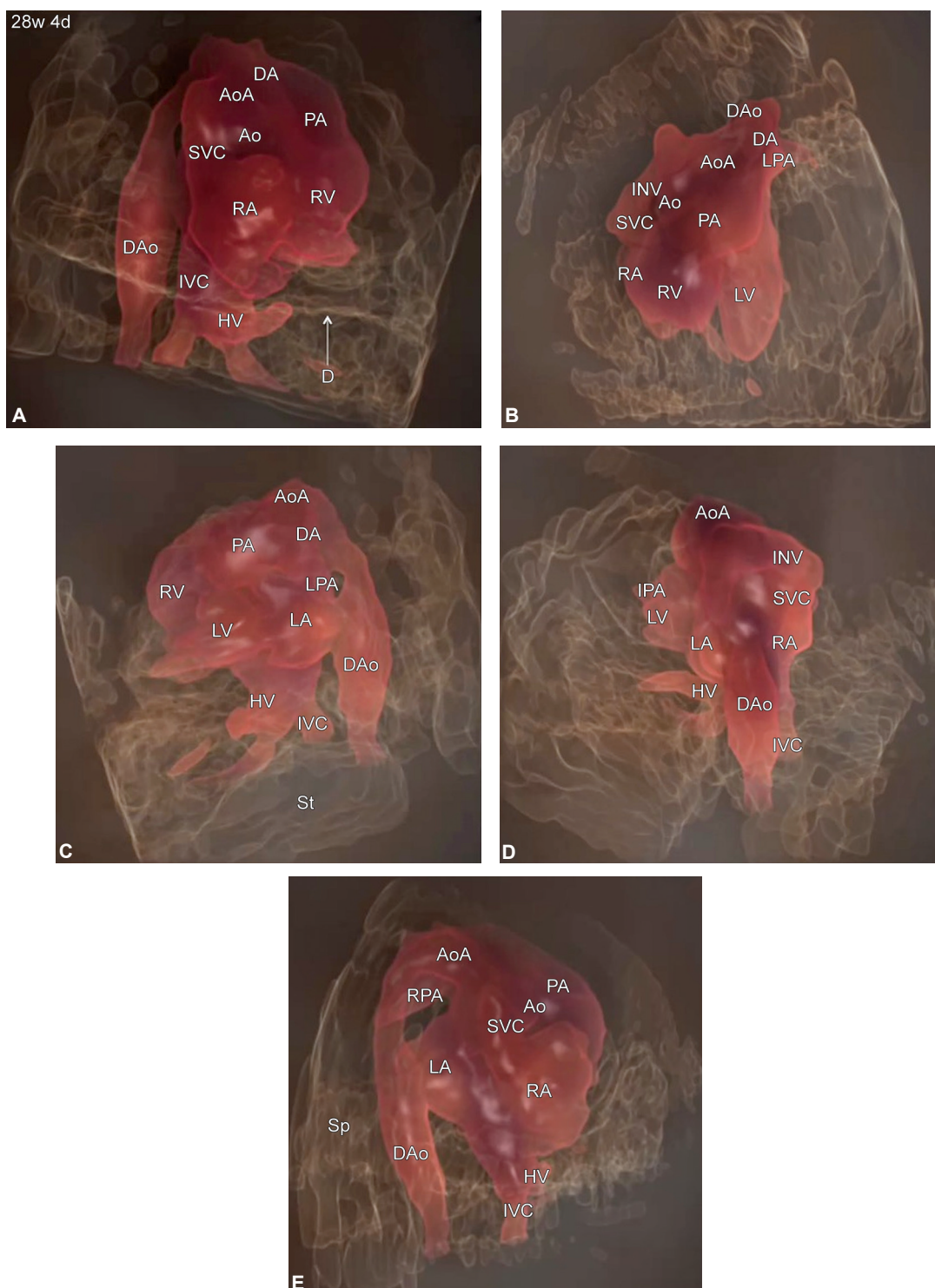

Fig. 2: HDlive flow with HDlive silhouette mode image of the normal fetal heart at 23 weeks and 5 days of gestation.
(*Abbreviations:* Ao, aorta; AoA, aortic arch; DA, ductus arteriosus; DAo, descending aorta; INV, innominate vein; LPA, left pulmonary artery: LV, left ventricle; PA, pulmonary artery; RPA, right pulmonay artery; RV, right ventricle; SVC, superior vena cava)

Fig. 3: HDlive flow silhouette mode with glass-body rendering mode image of the normal fetal heart at 28 weeks and 4 days of gestation.
(*Abbreviations:* Ao, aorta; AoA, aortic arch; DA, ductus arteriosus; LPA, left pulmonary artery: LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava)

Figs 4A to E: HDlive Flow silhouette mode with HDlive silhouette mode image of the normal fetal heart at 28 weeks and 4 days of gestation. (A) Frontal view; (B) Spatial three-vessel view; (C) Panoramic view; (D) Posterior view; (E) Right lateral view
(*Abbreviations:* Ao, aorta; AoA, aortic arch; D, diaphragm; DA, ductus arteriosus; DAo, descending aorta; HV, hepatic vein; INV, innominate vein; IVC, inferior vena cava; LA, left atrium; LV, left ventricle; LPA, left pulmonary artery; PA, pulmonary artery; RA, right atrium; RPA, right pulmonary artery; RV, right ventricle; Sp, spine; St, stomach; SVC, superior vena cava)

echocardiography cannot provide this view, making it unique.[37]

Right Lateral View

With this view, we can identify the aortic arch and descending aorta, superior vena cava, and inferior vena cava (Figs 23 to 27). In order to evaluate the aortic arch, this view is unique.[37]

STRUCTURAL VARIANT OF THE FETAL HEART

Right Aortic Arch

In the presence of a right aortic arch (RAA) and an aberrant left subclavian artery in a fetus, the five views provide clear visualization of the typical vascular ring of RAA (Fig. 28).[37] With a posterior view, the brachiocephalic and left
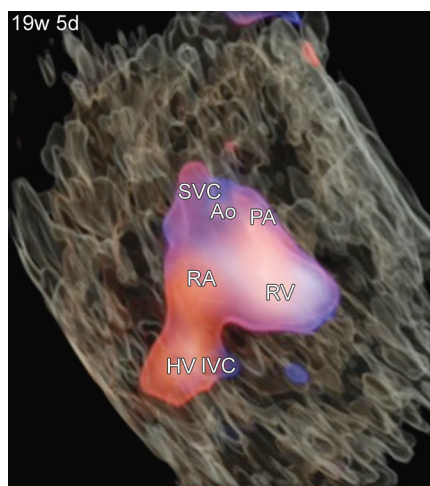
Fig. 5: Frontal view with HDlive Flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 19 weeks and 5 days of gestation (*Abbreviations:* Ao, aorta; HV, hepatic vein; IVC, inferior vena cava; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava)
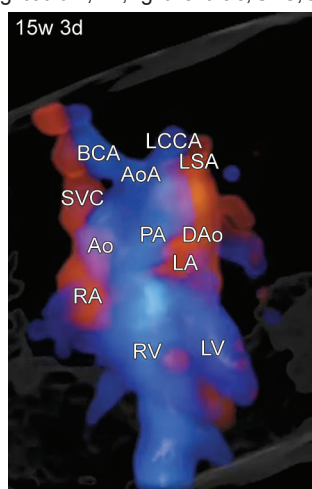

Fig. 6: Frontal view with HDlive Flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 28 weeks and 4 days of gestation.
(*Abbreviations:* Ao, aorta; AoA, aortic arch; DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; PA, pulmonary artery; RA, right atrium; RV, right ventricle; Sp, spine; SVC, superior vena cava)

Fig. 7: Spatial three-vessel view with HDlive Flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 15 weeks and 3 days of gestation (*Abbreviations:* Ao, aorta; AoA, aortic arch; BCA, brachiocephalic artery; DAo, descending aorta; HV, hepatic vein; LCCA, left common carotid artery; LSA, left subclavian artery; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava)
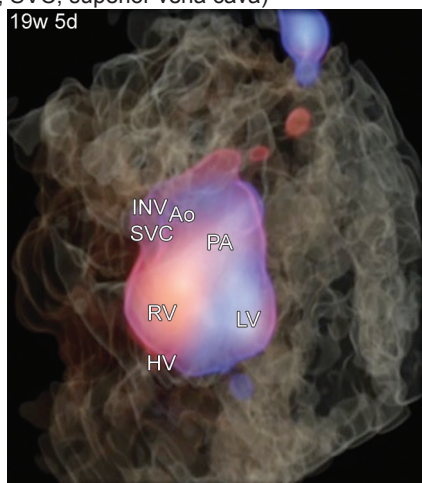

Fig. 8: Spatial three-vessel view with HDlive Flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 16 weeks of gestation.
(*Abbreviations:* Ao, aorta; AoA, aortic arch; DA, ductus arteriosus; DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; LA, left atrium; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava)

common carotid arteries from RAA, can be clearly demonstrated along with an aberrant left subclavian artery from the diverticulum of Kommerell (Fig. 28).

Persistent Left Superior Vena Cava

In a fetus with a persistent left superior vena cava (PLSVC), frontal, spatial three-vessel, and panoramic views clearly show the PLSVC on the left side of the pulmonary artery (Fig. 29).

CONGENITAL HEART ANOMALY

Transposition of Great Arteries

In a fetus with TGA at 32 weeks and 1 day of gestation, HDlive flow clearly showed the spatial parallel arrangement of the aorta left from the right

Fig. 9: Spatial three-vessel view with HDlive Flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 19 weeks and 5 days of gestation.
(*Abbreviations:* Ao, aorta; HV, hepatic vein; INV, innominate vein; LV, left ventricle; PA, pulmonary artery; RV, right ventricle; SVC, superior vena cava)
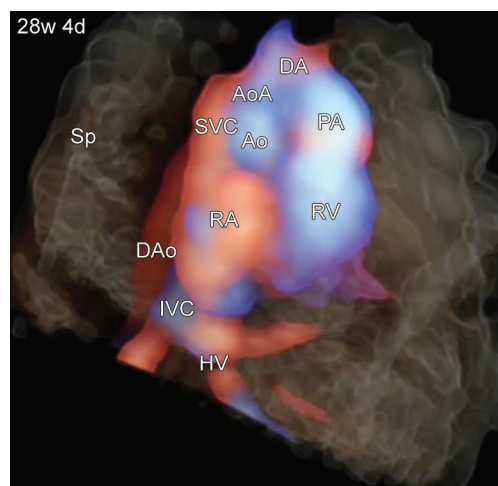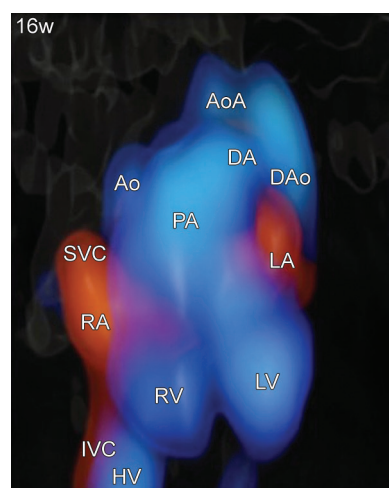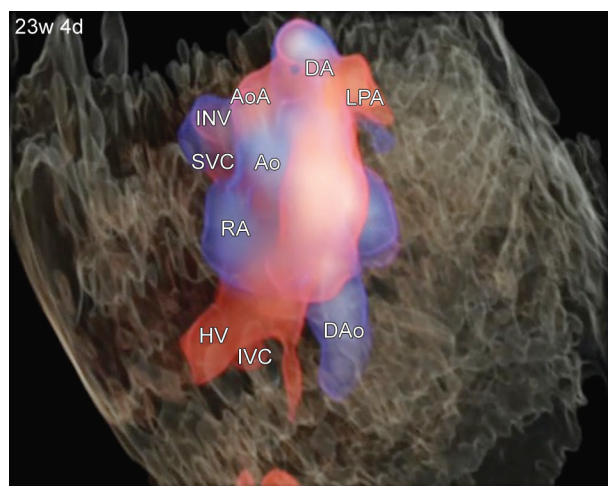
Fig. 10: Spatial three-vessel view with HDlive flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 23 weeks and 4 days of gestation.
(*Abbreviations:* Ao, aorta; AoA, aortic arch; DA, ductus arteriosus; DAo, descending aorta; HV, hepatic vein; INV, innominate vein; IVC, inferior vena cava; LPA, left pulmonary artery; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava)
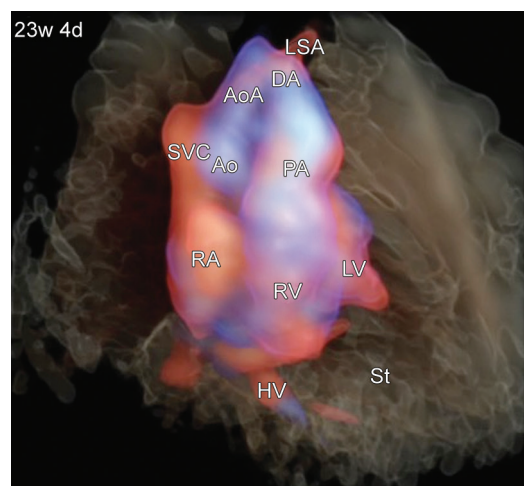

Fig. 11: Spatial three-vessel view with HDlive flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 28 weeks and 4 days of gestation.
(*Abbreviations:* Ao, aorta; AoA, aortic arch; DA, ductus arteriosus; HV, hepatic vein; LSA, left subclavian artery; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle; St, stomach; SVC, superior vena cava)
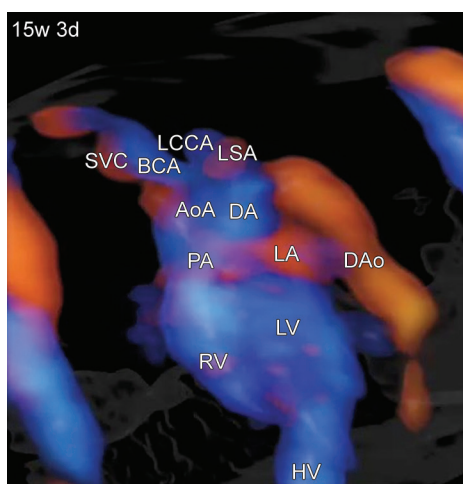

Fig. 12: Panoramic view with HDlive flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 15 weeks and 3 days of gestation.
(*Abbreviations:* AoA, aortic arch; BCA, brachiocephalic artery:DA, ductus arteriosus; DAo, descending aorta; HV, hepatic vein; LA, left atrium; LCCA, left common carotid artery; LSA, left subclavian artery; LV, left ventricle; PA, pulmonary artery; RV, right ventricle; SVC, superior vena cava)

Fig. 13: Panoramic view with HDlive flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 16 weeks of gestation.
(*Abbreviations:* AoA, aortic arch; DA, ductus arteriosus; DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; LA, left atrium; LV, left ventricle; PA, pulmonary artery; RV, right ventricle)

ventricle and pulmonary artery left from the left ventricle (Fig. 30A).[33] Hidden vessels such as pulmonary veins obscured by cardiac chambers could be observed using the HDliveFlow silhouette mode (Figs 30B and C).

Hypoplastic Left Heart Syndrome

In a fetus with hypoplastic left heart syndrome (HLHS) at 30 weeks and 1 day of gestation, a significant size difference could be noted on a spatial three-vessel view between the pulmonary artery and aorta (Figs 31A and B).[33] With a panoramic view, a very small ascending aorta and tear-drop-shaped heart could also be identified (Figs 31C and D). A difference in size between the
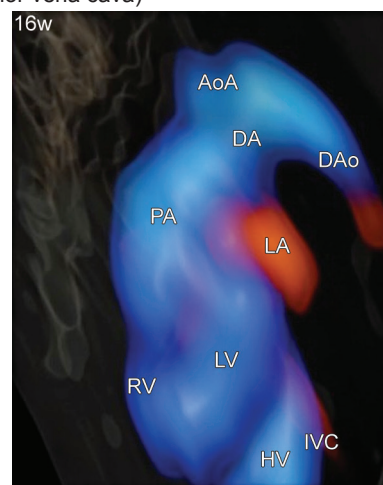
aortic arch and descending aorta could also be noted. The mode allowed clear visualization of the contour of the right atrium, right ventricle, pulmonary artery, and small aorta (Figs 31B and D).

Pulmonary Valve Stenosis

In a fetus with PS at 31 weeks and 5 days of gestation, HDlive Flow allowed the visualization of a large main pulmonary artery showing poststenotic dilatation (Fig. 32A).[33] A holography-like image of the fetal heart with a dilated pulmonary artery and hidden vessels could be obtained with the HDlive flow silhouette mode (Fig. 32B).

CONCLUSION

The HDlive flow and HDlive flow silhouette mode with STIC may be more readily usable by inexperienced
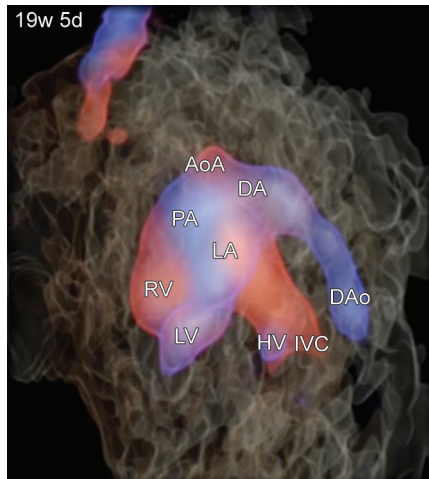
Fig. 14: Panoramic view with HDlive flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 19 weeks and 5 days of gestation.
(*Abbreviations:* AoA, aortic arch; DA, ductus arteriosus; DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; LA, left atrium; LV, left ventricle; PA, pulmonary artery; RV, right ventricle)
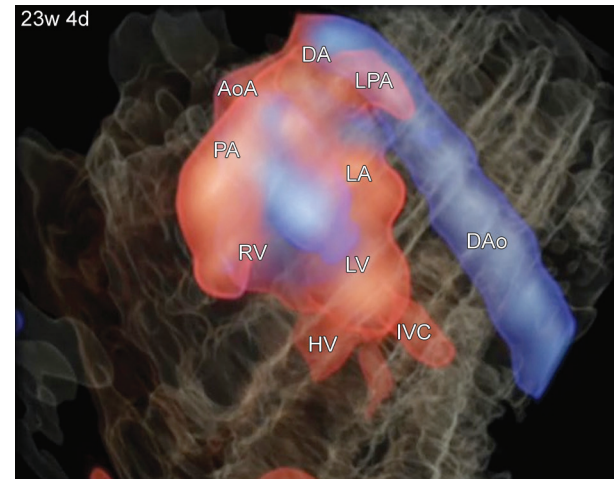

Fig. 15: Panoramic view with HDlive flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 23 weeks and 4 days of gestation.
(*Abbreviations:* AoA, aortic arch; DA, ductus arteriosus; DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; LA, left atrium; LPA, left pulmonary artery; LV, left ventricle; PA, pulmonary artery; RV, right ventricle)
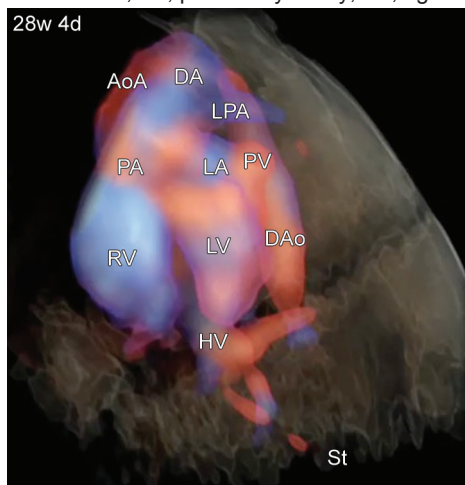

Fig. 16: Panoramic view with HDlive flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 28 weeks and 4 days of gestation.
(*Abbreviations:* AoA, aortic arch; DA, ductus arteriosus; DAo, descending aorta; HV, hepatic vein; LA, left atrium; LPA, left pulmonary artery; LV, left ventricle; PA, pulmonary artery; PV, pulmonary vein; RV, right ventricle; St, stomach)
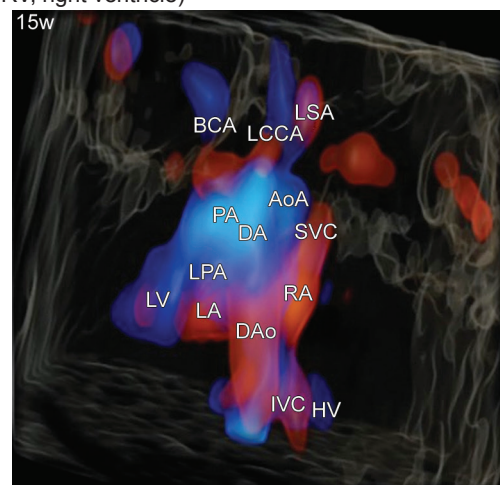

Fig. 17: Posterior view with HDlive flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 15 weeks of gestation.
(*Abbreviations:* AoA, aortic arch; BCA, brachiocephalic artery: DA, ductus arteriosus; DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; LA, left atrium; LCCA, left common carotid artery; LPA, left pulmonary artery; LSA, left subclavian artery; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle)
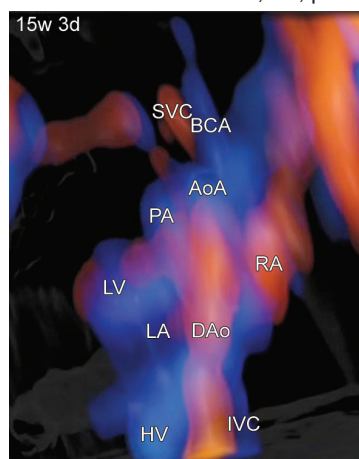

Fig. 18: Posterior view with HDliveFlow silhouette mode and HDlive silhouette mode of a normal fetal heart at 15 weeks and 3 days of gestation.
(*Abbreviations:* AoA, aortic arch; BCA, brachiocephalic artery: DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; LA, left atrium; LV, left ventricle; PA, pulmonary artery; RA, right atrium; SVC, superior vena cava)
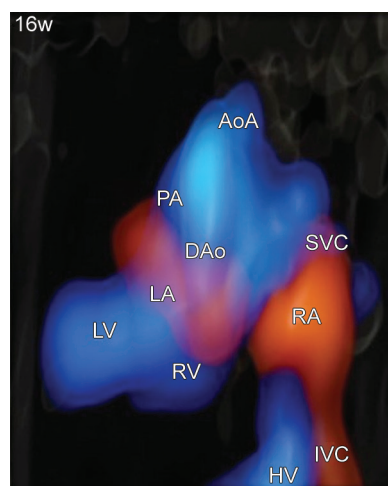
Fig. 19: Posterior view with HDlive flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 16 weeks of gestation. (*Abbreviations:* AoA, aortic arch; DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; LA, left atrium; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava)
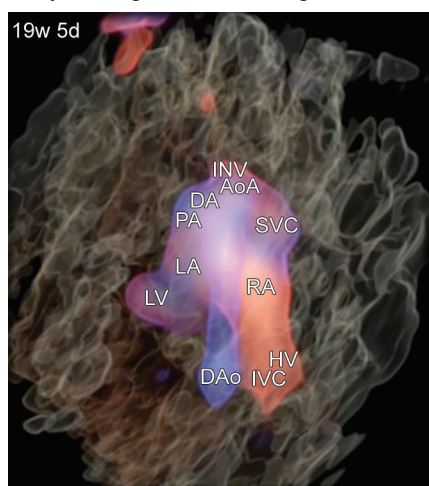

Fig. 20: Posterior view with HDlive flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 19 weeks and 5 days of gestation.
(*Abbreviations:* AoA, aortic arch; DA, ductus arteriosus; DAo, descending aorta; HV, hepatic vein; INV, innominate vein; IVC, inferior vena cava; LA, left atrium; LV, left ventricle; PA, pulmonary artery; RA, right atrium; SVC, superior vena cava)
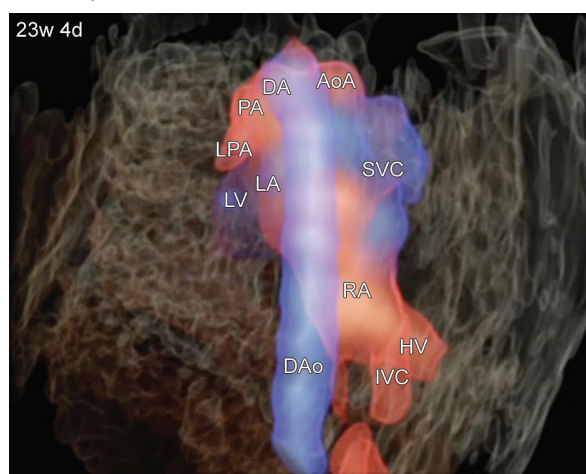

Fig. 21: Posterior view with HDlive flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 23 weeks and 4 days of gestation.
(*Abbreviations:* AoA, aortic arch; DA, ductus arteriosus; DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; LA, left atrium; LPA, left pulmonary arteryLV, left ventricle; PA, pulmonary artery; RA, right atrium; SVC, superior vena cava)
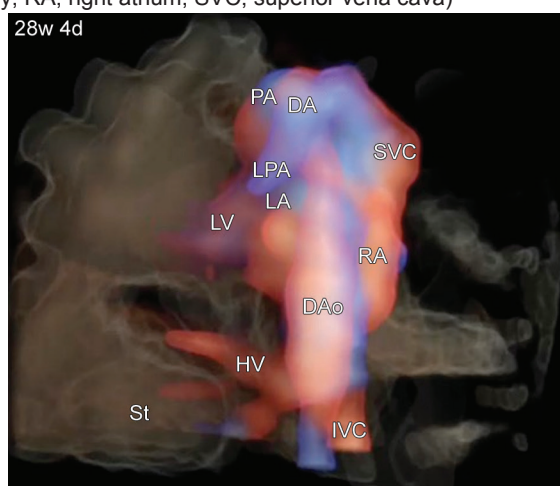

Fig. 22: Posterior view with HDlive flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 28 weeks and 4 days of gestation.
(*Abbreviations:* AoA, aortic arch; DA, ductus arteriosus; DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; LA, left atrium; LPA, left pulmonary artery LV, left ventricle; PA, pulmonary artery; RA, right atrium; St, stomach; SVC, superior vena cava)

Fig. 23: Right lateral view with HDlive flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 15 weeks of gestation.
(*Abbreviations:* AoA, aortic arch; BCA, brachiocephalic artery: DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; LA, left atrium; LCCA, left common carotid artery; LSA, left subclavian artery; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava)

Fig. 24: Right lateral view with HDlive Flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 15 weeks and 3 days of gestation.
(*Abbreviations:* AoA, aortic arch; BCA, brachiocephalic artery: DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; LA, left atrium; LCCA, left common carotid artery; LSA, left subclavian artery; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava)
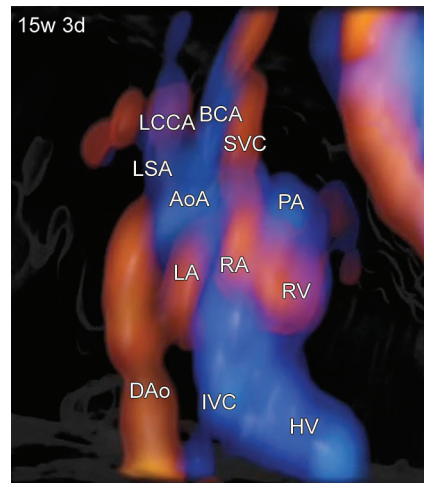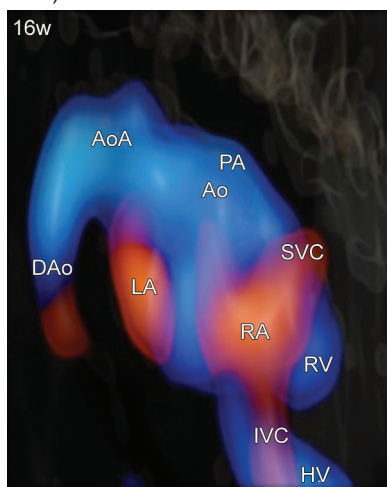

Fig. 25: Right lateral view with HDlive Flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 16 weeks of gestation.
(*Abbreviations:* Ao, aorta; AoA, aortic arch; DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; LA, left atrium; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava)
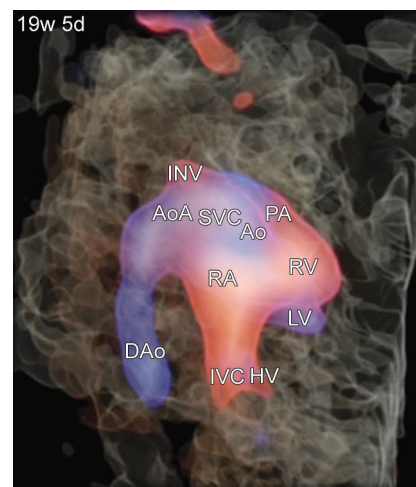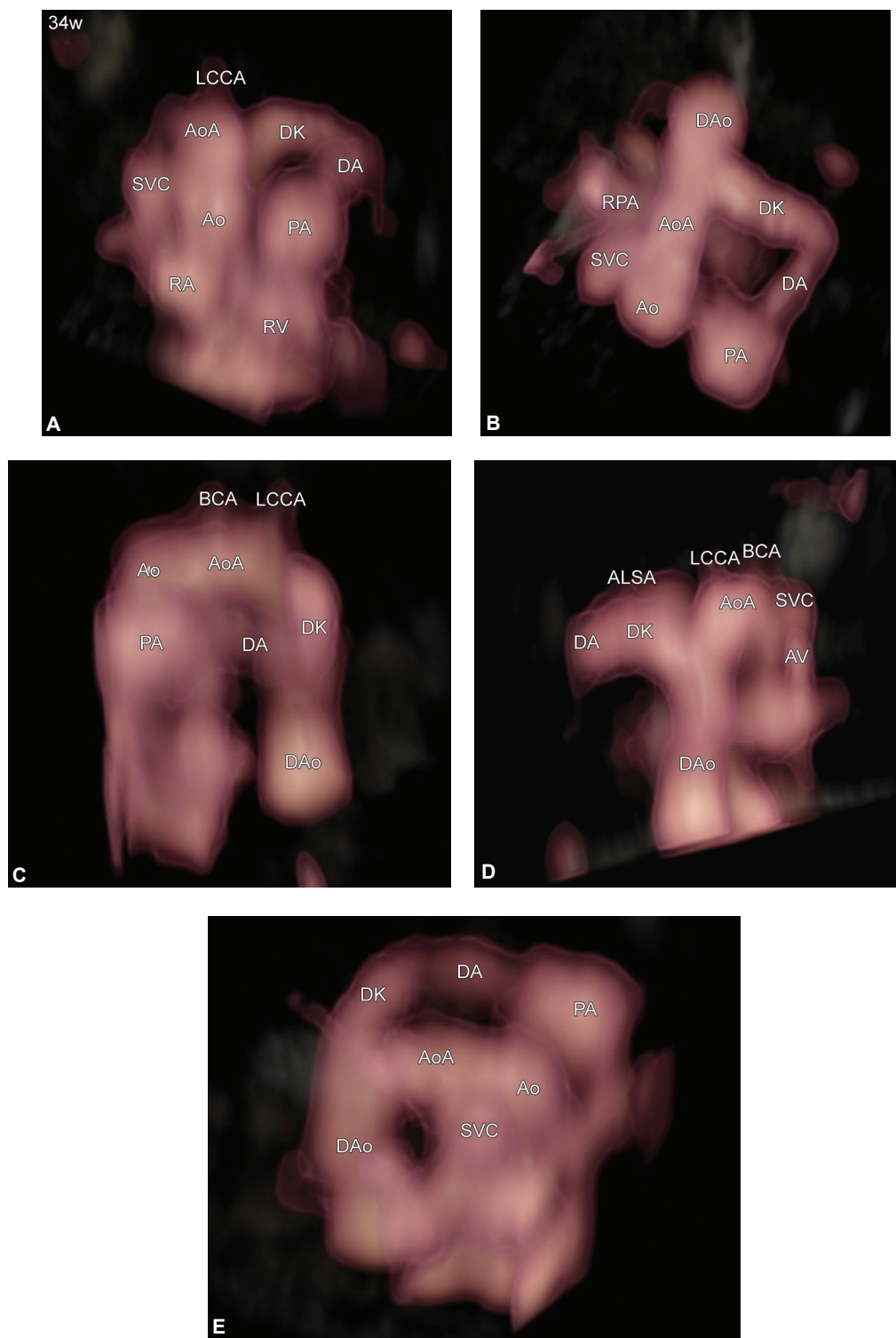

Fig. 26: Right lateral view with HDlive Flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 19 weeks and 5 days of gestation.
(*Abbreviations:* Ao, aorta; AoA, aortic arch; DAo, descending aorta; HV, hepatic vein; INV, innominate vein; IVC, inferior vena cava; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava)

Fig. 27: Right lateral view with HDlive Flow silhouette mode and HDlive silhouette mode of a normal fetal heart at 28 weeks and 4 days of gestation.
(*Abbreviations:* Ao, aorta; AoA, aortic arch; DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; LA, left atrium; PA, pulmonary artery; RA, right atrium; RPA, right pulmonary artery; Sp, spine; SVC, superior vena cava)
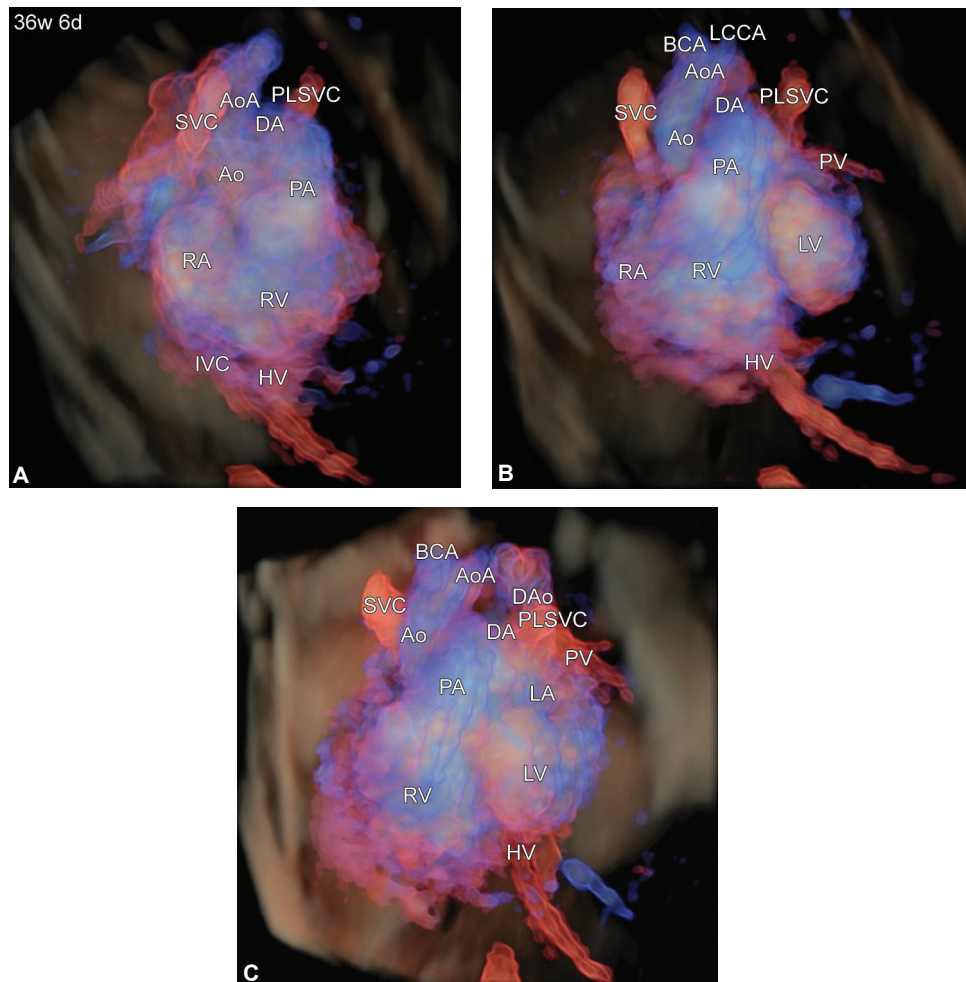
Figs 28A to E: Right aortic arch depicted by HDlive flow silhouette mode at 34 weeks of gestation. (A) Frontal view; (B) Spatial three-vessel view; (C) Panoramic view; (D) Posterior view; (E) Right lateral view. (*Courtesy:* Reprinted with permission from Jaypee Brothers Medical Publishers (P) Ltd)[37]

(*Abbreviations:* ALSA, aberrant left subclavian artery; Ao, aorta; AoA, aortic arch; AV, azygos vein; BCA, brachiocephalic artery; DA, ductus arteriosus; DAo, descending aorta; DK, diverticulum of Kommerell; LCCA, left common carotid artery; PA, pulmonary artery; RA, right atrium; RPA, right pulmonary artery; RV, right ventricle; SVC, superior vena cava)

physicians to accurately diagnose normal fetal cardiac structures and congenital heart anomalies. This system's usefulness may also be evident when explaining abnormalities to doctors and students in the absence of patients. It is also straightforward for parents and families to understand the conditions of fetuses *in utero*. HDlive flow and the HDlive flow silhouette mode provide families with important information, and their application as an adjunctive tool to conventional 2D fetal echocardiography to diagnose congenital heart

Figs 29A to C: Persistent left superior vena cava (PLSVC) depicted by HDlive flow silhouette mode with glass-body rendering mode at 36 weeks and 6 days of gestation. (A) Frontal view; (B) Spatial three-vessel view; (C) Panoramic view.
(*Abbreviations:* Ao, aorta; AoA, aortic arch; BCA, brachiocephalic artery; DAo, descending aorta; HV, hepatic vein; LA, left atrium; LV, left ventricle; LCCA, left common carotid artery; PA, pulmonary artery; PV, pulmonary vein; RA, right atrium; RV, right ventricle; SVC, superior vena cava)
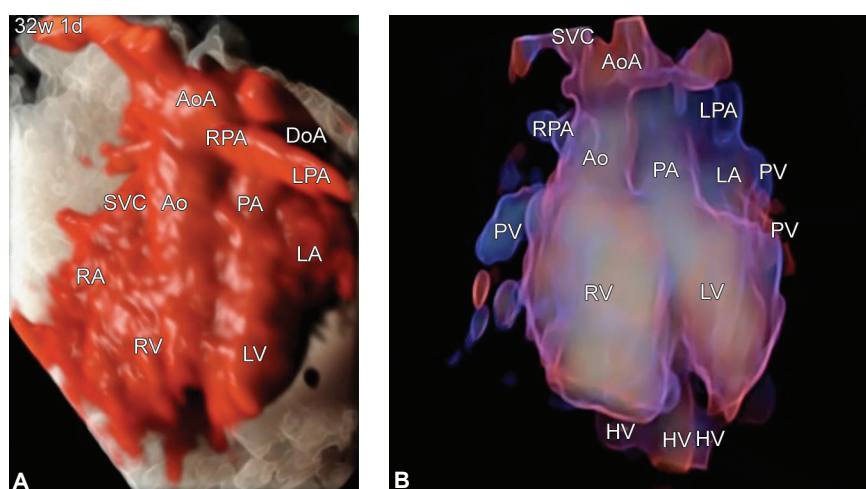

Figs 30A and B

Figs 30A to C: Transposition of great arteries depicted by HDlive flow with HDlive silouette mode (A) and HDlive Flow silhouette mode (B, C) at 32 weeks and 1 day of gestation. (A) and (B) Spatial three-vessel view; (C) Panoramic view. (*Courtesy:* Reprinted with permission from John Wiley & Sons Ltd.)[33]

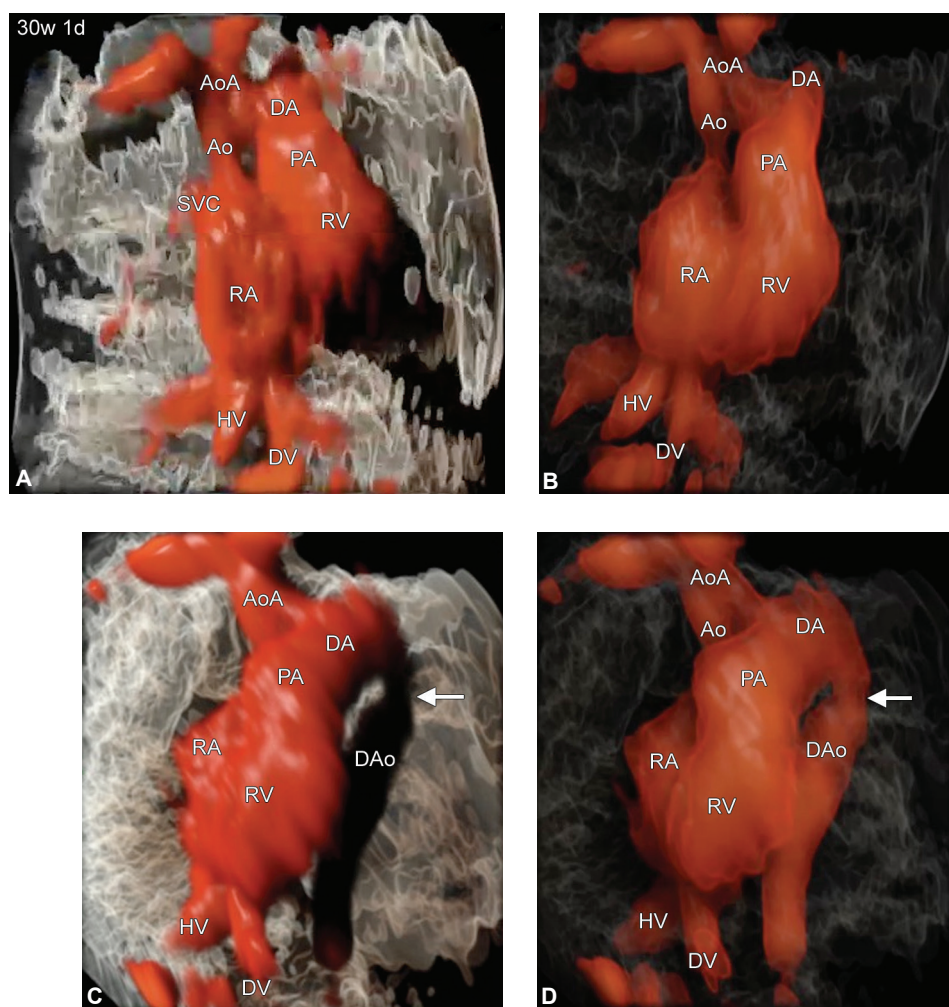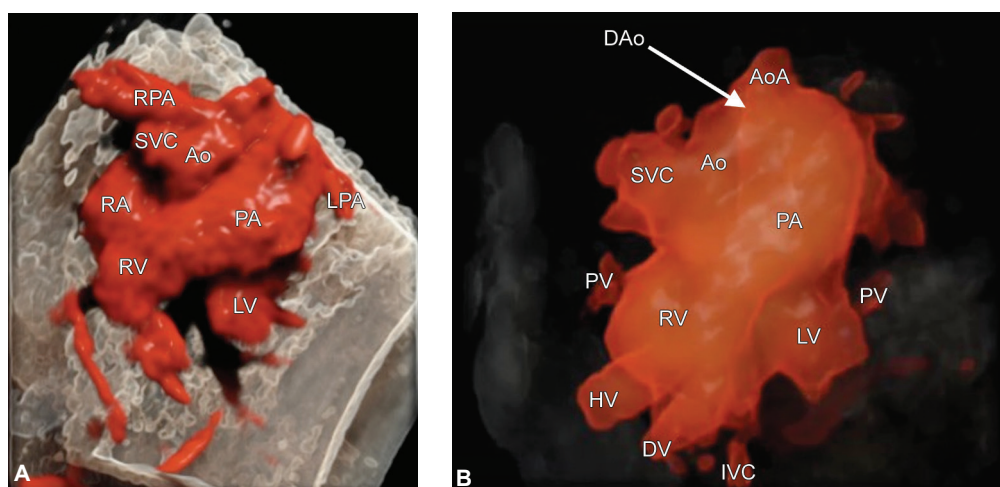(*Abbreviations:* Ao, aorta; AoA, aortic arch; DAo, descending aorta; HV, hepatic vein; IVC, inferior vena cava; LA, left atrium; LV, left ventricle; LPA, left pulmonary artery; PA, pulmonary artery; PV, pulmonary vein; RA, right atrium; RPA; right pulmonary artery; RV, right ventricle; SVC, superior vena cava)

Figs 31A to D: Hypoplastic left heart syndrome depicted by HDlive flow with HDlive silhouette mode (A and C) and HDlive Flow silhouette mode with HDlive silhouette mode (B and D) at 30 weeks and 1 day of gestation. Arrow indicates isthmus (C and D); (A and B) Spatial three-vessel view; (C and D) Panoramic view. (*Courtesy:* Reprinted with permission from John Wiley & Sons Ltd.)[33]

(*Abbreviations:* Ao, aorta; AoA, aortic arch; DA, ductus arteriosus; DAo, descending aorta; DV, ductus venosus; HV, hepatic vein; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava)

Figs 32A to B: Pulmonary valve stenosis depicted by HDlive Flow with HDlive silhouette mode (A) and HDlive flow silhouette mode (B) at 31 weeks and 5 days of gestation. (A and B) Spatial three-vessel view. (*Courtesy:* Reprinted with permission from John Wiley & Sons Ltd.)[33]
(*Abbreviations:* Ao, aorta; AoA, aortic arch; DAo, descending aorta; DV, ductus venosus; HV, hepatic vein; IVC, inferior vena cava; LV, left ventricle; LPA, left pulmonary artery; PA, pulmonary artery; PV, pulmonary vein; RA, right atrium; RPA, right pulmonary artery; RV, right ventricle; SVC, superior vena cava)

anomalies may be possible. In clinical practice, to assess the normal fetal heart and congenital heart anomalies, HDlive Flow and the HDlive Flow silhouette mode may become significant.[37]

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