

## The Applications of HD and B Flow in 4D Echocardiography

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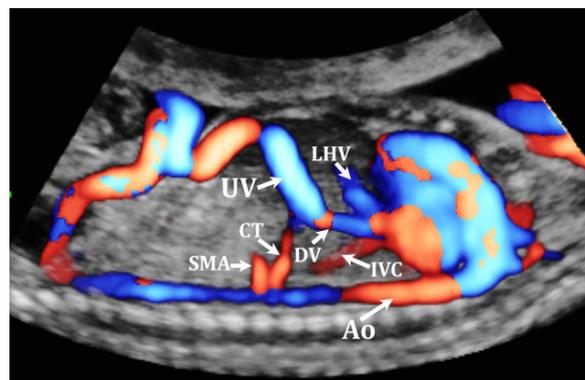
**Abstract:** High Definition Power Flow Doppler (HDPD) is a bi-directional power Doppler imaging mode. B-flow is a direct-volume non-gated scanning tool that images blood flow in real-time. These ultrasound modalities have improved images of the fetal cardiovascular system to near-angiographic quality. Each has its particular advantages, which are illustrated with examples of fetal cardiovascular malformations obtained with these tools. HDPD and B-flow provide images not available to practitioners even five years ago.

### INTRODUCTION

3D and 4D ultrasound (3D/4D US) modalities have provided new ways to look at fetal echocardiographic examination [1]. These modalities are the result of impressive technological advances in motion-gated scanning and in faster frame rates and computer processors. Near real-time 3D scanning is now a reality in the clinical setting and its application to fetal echocardiography continues to enrich our understanding of the fetal cardiovascular system. Two acquisition modes, B-flow and High Definition Power Flow Doppler (HDPD) each have unique capabilities that allow greater sensitivity in imaging fetal blood flow in the heart and vessels.

### HIGH DEFINITION POWER FLOW DOPPLER

High definition power flow Doppler (HDPD) is a bi-directional power Doppler mode that depicts flow at a lower velocity than color or power Doppler. It can be combined with STIC [2] or static 3D acquisition. HDPD uses small sample volume and higher resolution to achieve images with two color directional information while avoiding overwriting vascular walls. The result is a more accurate picture of vessel contours. This modality depicts blood flow at a lower velocity than color or power Doppler, making for a bidirectional and anatomically accurate depiction of blood flow. The sensitivity of HDPD results in imaging of systolic and diastolic blood flow at the same time: for example, when HDPD is combined with STIC acquisition the ductus venosus is shown to remain filled both in systole and diastole. Figure 1 shows the normal heart and vessels extracted from a STIC acquisition with high definition Doppler.



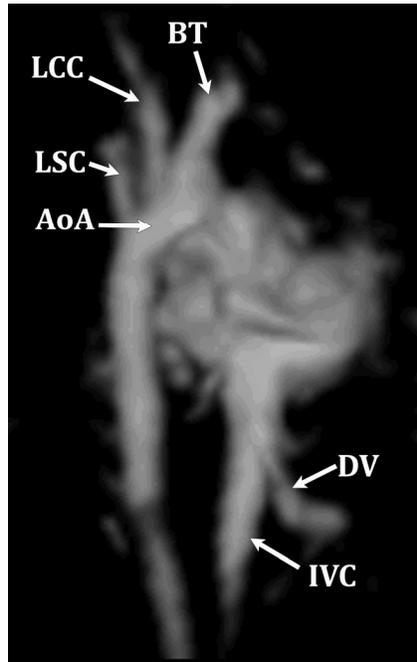
**Figure 1:** Normal heart and vasculature imaged in HDPD modality. UV, umbilical vein; LHV, left hepatic vein; SMA, superior mesenteric artery; CT, celiac trunk; DV, ductus venosus; IVC, inferior vena cava; Ao, aorta.

The caveats associated with 3D/4D technology and Doppler based images apply to HDPD as well: care must be taken when the volume is rotated, to avoid confusion of flow direction. The operator must be vigilant in confirming suspected pathology by verifying the original scanning angle, and whether flow was toward or away from the transducer.

### B-FLOW

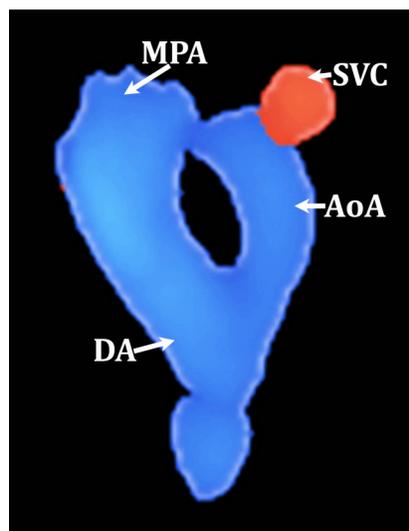
B-flow is a newer technology in fetal cardiac studies. It is a direct-volume non-gated scanning tool that displays blood flow in real time. It is based on B-mode imaging for direct depiction of blood cell reflectors. That is to say, B-flow does not rely on Doppler shift to produce an “indirect” image of blood flow, thus it avoids some of the drawbacks of Doppler imaging such as aliasing and signal dropout at orthogonal scanning angles. B-flow results in

faster frame rates by using digital encoding of one US beam into two separate sub-beams before transmittance. Echoes from the two sub-beams are decoded differently. One sub-beam serves for conventional gray-scale myocardial imaging while the other is enhanced to provide gray-scale blood-flow imaging [3, 4]. B-flow provides sensitive 'digital casts' [5] of blood flowing in its vessels and the cardiac chambers. This makes it an invaluable tool in fetal echocardiography in both normal and anomalous cases. It is particularly valuable as a teaching tool, as well as in multi-disciplinary consultation and in counseling parents, when complex anatomy must be elucidated. Figure 2 shows a normal fetal heart and great vessels acquired with B-flow combined with spatio-temporal imaging correlation (STIC).

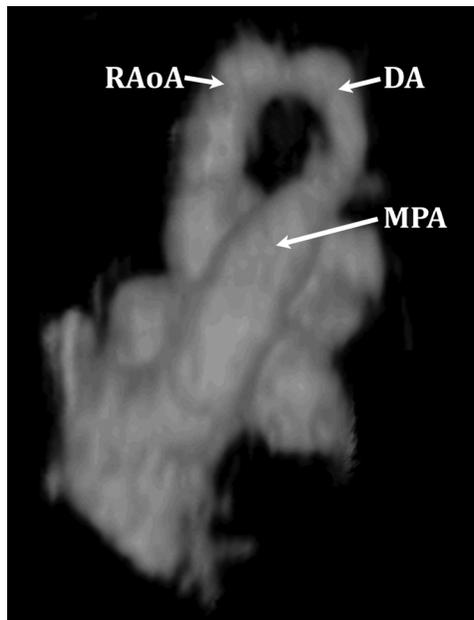


**Figure 2:** Normal heart and vasculature imaged in B-flow modality. AoA, aortic arch; LSC, left subclavian artery; LCC, left common carotid; BT, brachio-cephalic trunk; DV, ductus venosus; IVC, inferior vena cava.

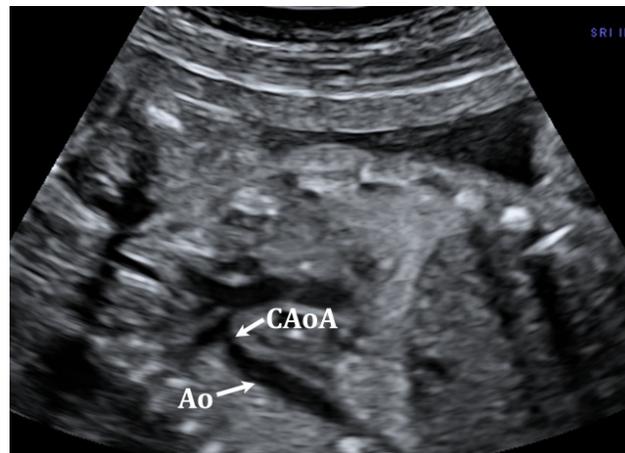
As the figures below (Figures 3-20) show through various examples of cardiovascular malformations imaged in HDPD and B-flow, these new modalities provide practitioners with near-angiographic images of the fetal heart and vessels.



**Figure 3:** Right aortic arch anomaly, three-vessels and trachea (3VT) view, imaged in HDPD. MPA, main pulmonary artery; SVC, superior vena cava, AoA, transverse plane of the aortic arch; DA, ductus arteriosus. The ellipse in the center is the space occupied by the esophagus and trachea.



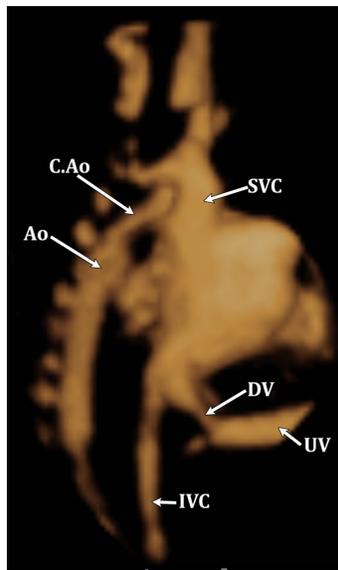
**Figure 4:** Another case of right aortic arch anomaly in the 3VT plane, imaged with B-flow. RAoA, right aortic arch; DA, ductus arteriosus; MPA, main pulmonary artery.



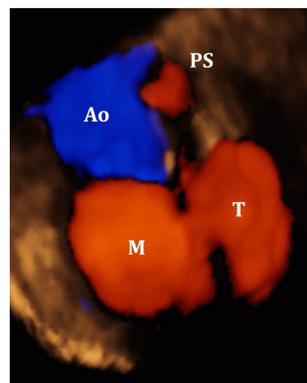
**Figure 5:** Segmental coarctation of the aorta in grayscale imaging of the long axis view aortic arch. Ao, descending aorta; CAoA, the coarctated aortic arch.



**Figure 6:** The same patient as figure 5: HDPD depicts reverse flow in the coarctation, however it does not demonstrate the narrowing of the vessel. Carets indicate the coarctation and the direction of flow.



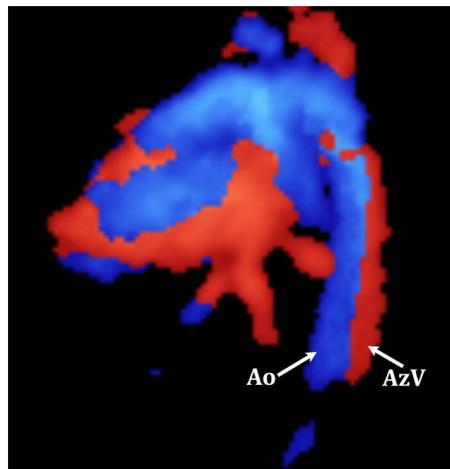
**Figure 7:** The same patient as figures 5 and 6, imaged in B-flow in right lateral view. Note that the narrowing of the aorta is clearly depicted. Ao, aorta; C.Ao, coarctation; SVC, superior vena cava; DV, ductus venosus; UV, umbilical vein; IVC, inferior vena cava.



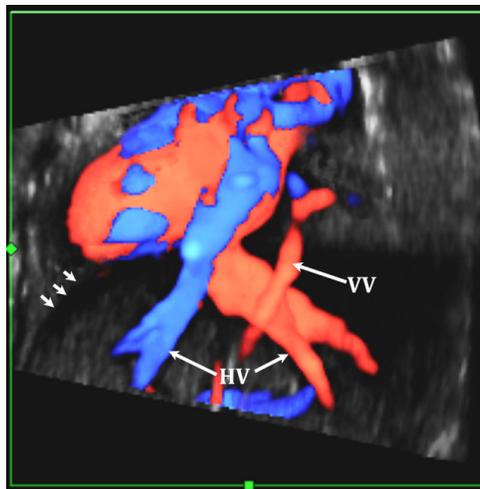
**Figure 8:** HDPD imaging with virtual planes [6] in a case of severe pulmonic stenosis. The coronal atrio-ventricular valves (CAV) plane shows the flow across the mitral (M) and tricuspid (T) valves and the aortic valve (Ao). Note the severe narrowing of the pulmonic valve annulus and reversed flow across the valve (PS).



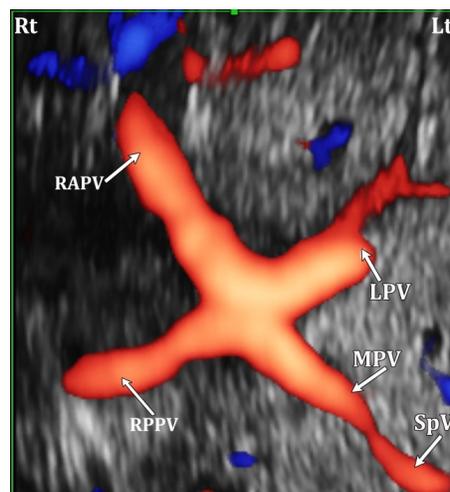
**Figure 9:** A complicated case of transposition of the great arteries (TGA). B-flow shows that the aorta (Ao) is anterior and to the right of the pulmonary artery (PA).



**Figure 10:** Azygos vein (AzV) flow is opposite the flow in the aorta (Ao) in this case of interrupted IVC with azygos continuation imaged in HDPD.



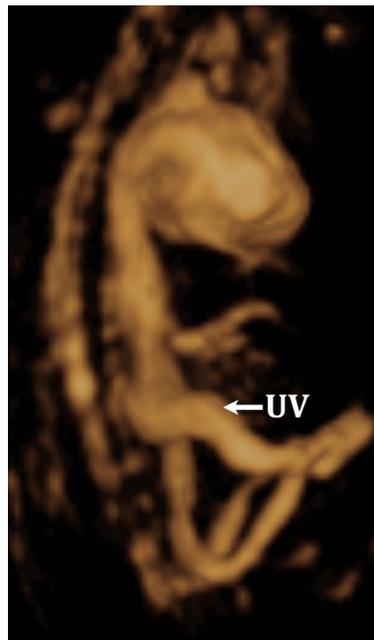
**Figure 11:** The vertical vein in a case of total anomalous pulmonary venous connections (TAPVC). The vertical vein (VV) is seen to cross the diaphragm (small arrows) and drains into the hepatic vessels. Note the presence of two left liver lobes and hepatic veins (HV) in this case of left isomerism.



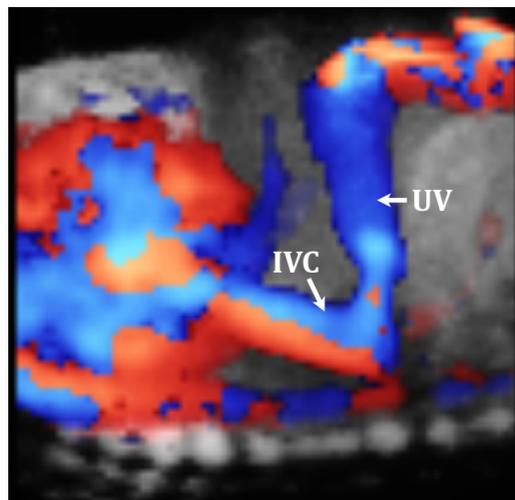
**Figure 12:** The great sensitivity of HDPD is demonstrated by this image of the normal fetal portal system, including the splenic vein. RAPV, right anterior portal vein; RPPV, right posterior portal vein; LPV, left portal vein; MPV, main portal vein; SpV, splenic vein (Rt, Lt: right and left).



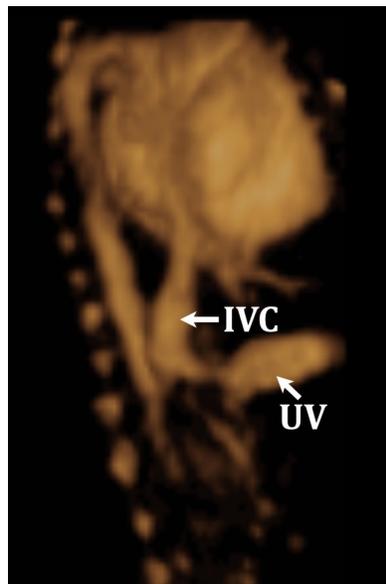
**Figure 13:** A case of agnesis of the ductus venosus (ADV) with a wide connection of the umbilical vein (UV) to the azygos-IVC shunt, and abnormal portal system.



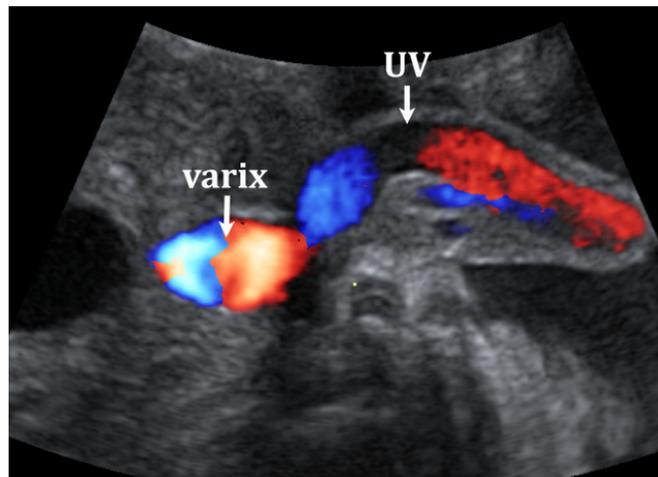
**Figure 14:** The same case as pictured in figure 13, imaged in B-flow. Note the wide connection of the UV to the azygos-IVC shunt and abnormal portal system.



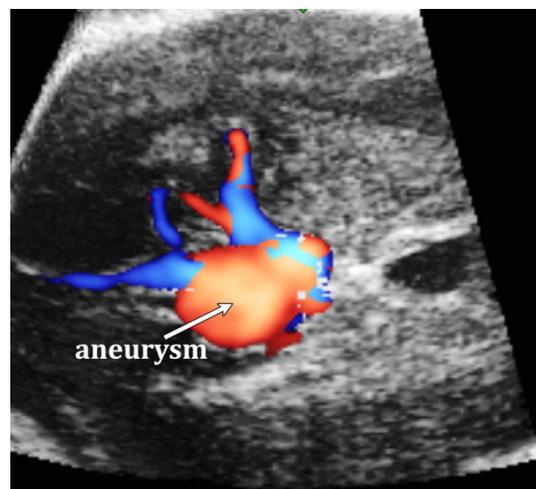
**Figure 15:** HDPD image of ADV to the IVC with a narrow shunt. The portal system (not shown) developed normally. UV, umbilical vein.



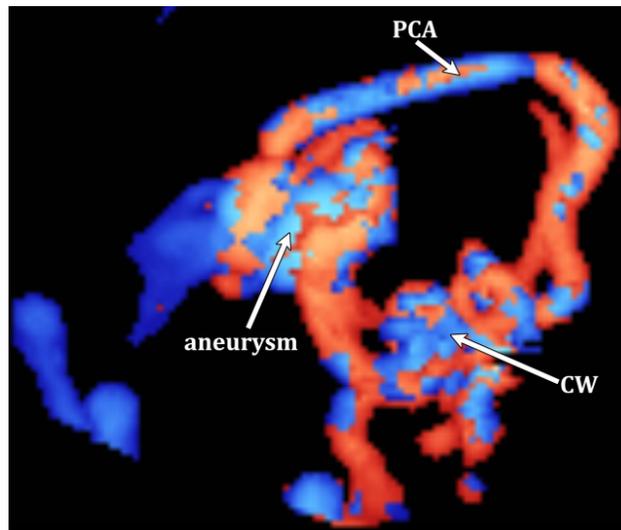
**Figure 16:** The same case imaged in B-flow as pictured in figure 15, showing the narrow shunt between the UV and IVC, which may account for the normal development of the portal system (not shown).



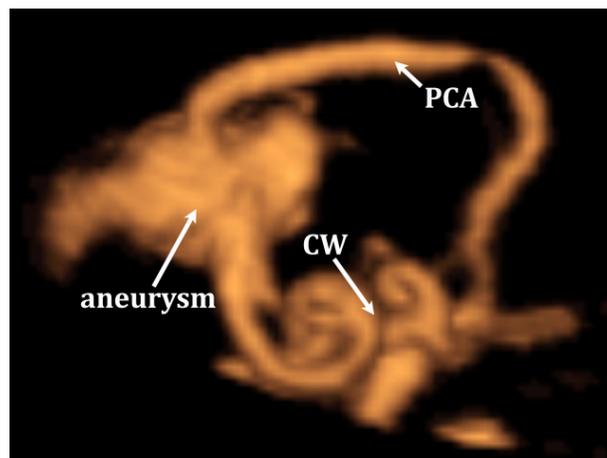
**Figure 17:** Fetal abdominal umbilical vein (FIUV) varix imaged in HDPD. Note the diameter of the varix is more than 1.5 times that of the umbilical vein (UV).



**Figure 18:** HDPD scan of aneurysm of the vein of Galen defect with surrounding tissue.



**Figure 19:** The same case as figure 18, showing the widened pericolossal artery (PCA) associated with this malformation, and the tortuous circle of Willis (CW).



**Figure 20:** The same case of vein of Galen defect as shown in figures 18 and 19, imaged in B-flow. CW, the tortuous circle of Willis; PCA, the widened pericolossal artery.

## CONCLUSIONS

The HDPD and B-flow modalities impart enormous advantages in fetal cardiovascular scanning, improving image clarity and thereby our understanding of the normal and anomalous fetal heart and vasculature.

## REFERENCES

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- [2] DeVore GR, Falkensammer P, Sklansky MS, Platt LD. Spatio-temporal image correlation (STIC): new technology for evaluation of the fetal heart. *Ultrasound Obstet Gynecol.* 2003; 22: 380-7.
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- [6] Yagel S, Benachi A, Bonnet D *et al.* Rendering in fetal cardiac scanning: the intracardiac septa and the coronal atrioventricular valve planes. *Ultrasound Obstet Gynecol.* 2006; 28: 266-74.