The fetal circulation is unique in having the right ventricle perform as a systemic pump delivering oxygen-enriched placental blood to the distal fetal systemic circulation via the ductus arteriosus. Both ventricles then operate at similar systemic pressures. For this reason, the pressure gradient across the interventricular septum is known to be minimal. It has been noted, however, in fetuses with ventricular septal defects (VSDs) that shunt flow can be detected by color flow Doppler crossing the VSD, indicating that there are subtle differences in pressure between the ventricles at different times in the cardiac cycle. The isolated VSD thus provides a convenient physiological window for studying interventricular dynamics in the developing fetus.

The rapid fetal heart rate and absence of a fetal ECG make accurate timing of shunt dynamics by standard 2D echocardiography with color flow Doppler difficult. We present a case in which careful hemodynamic evaluation could be performed by combination of information from several different cardiac ultrasound modalities that possess a higher temporal resolution—continuous-wave Doppler, pulsed-wave Doppler, and color Doppler M-mode—to elucidate the temporal characteristics of VSD shunt flow.

A systematic fetal echocardiogram was performed on a 36-year-old gravida 4 woman whose previous child had been diagnosed with a perimembranous VSD. At 22 weeks of gestation in this pregnancy, a small defect of the perimembranous ventricular septum, measuring 2.1 mm in diameter (Figure 1, left), could be clearly seen in the 2D fetal echocardiogram. Accessory tissue was burgeoning close to the tricuspid region but remained rudimentary. All other structures and flows were considered normal. A bidirectional flow across the VSD was seen by 2D color Doppler. Left-to-right shunt was thought to occur during systole, but the temporal resolution of the cine-loop mode was not accurate enough to determine when reverse flow occurred (Figure 1, middle and right).

On the color M-mode tracing (Figure 2, left), systole can be determined by the time between mitral valve closure and mitral valve opening. A red color signal is shown crossing the VSD from left to right during systole. However, reverse shunting from right to left (blue) also occurs during systole and can be discerned by the pulsed Doppler sampling of the VSD shunt flow shown in Figure 2, middle. Late systolic flow below the baseline indicates right-to-left shunt that ends just before the closure of the semilunar valves (denoted on the pulsed Doppler spectral trace by the arrows). Flow velocities remain low (0.55 m/s on the continuous-wave Doppler tracing, Figure 2, right), because the peak systolic pressure gradient between the ventricles is small, estimated at 3 mm Hg. No shunt flow was detectable during diastole.

Conclusions
Because no ECG is available in the fetus, the combination of 3 Doppler techniques is necessary and sufficient to determine the true sequence of a shunt across a VSD. It should be noted that sampling of flow must be performed carefully within the VSD shunt to eliminate contamination from adjacent tricuspid diastolic inflow, which might create a false impression of diastolic VSD shunting. This case demonstrates that VSD shunt flow in this fetus is bidirectional and a purely systolic phenomenon, unlike previously published cases. This phenomenon may result from a more rapid increase in systolic pressure in the left ventricle or a delayed onset of pressure development in the right ventricle. This technique should help us to understand the hemodynamics in the normal and pathological fetal circulation.

Acknowledgment
Dr. Lethor is supported by the Federation Française de Cardiologie and the Grant Hélène de Marsan.

References
Figure 1. Echographic 2D images. Left, Defect in perimembranous region (arrow). Middle, Flow (red) from left ventricle (LV) to right ventricle (RV), across outflow of RV (blue) toward pulmonary artery (PA). Right, Reverse flow (blue) across VSD.

Figure 2. Flow across VSD. Left, Color M mode: systole (S) starts at closure of mitral valve. Mitral valve is open during diastole (D). Middle, Pulsed Doppler: systole ends at closure of semilunar valves (arrows). Bidirectional flow across septum occurs only during systole. Right, Continuous Doppler: atrioventricular flow with E and A waves occurs in diastole.
Physiology of Ventricular Septal Defect Shunt Flow in the Fetus Examined by Color Doppler M-Mode
Jean-Paul Lethor, Francois Marçon, Michael de Moor and Mary Etta E. King

Circulation. 2000;101:e93
doi: 10.1161/01.CIR.101.10.e93
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2000 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/101/10/e93

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/