LETTERS TO THE EDITOR

Fetal Flow Impedance in Tapering Ductus Arteriosus Increases at the Narrower Aortic End: Morphometric Insights

To the Editor:

The influence of fetal ductus arteriosus (DA) morphometric features on its flow dynamics has been scarcely addressed.[1] Since the fetal ductal shape is that of a truncated cone with a tapering pattern, we hypothesized that DA velocities and impedance are higher (lower pulsatility index [PI]) at its narrower aortic end than at the larger pulmonary origin,[2-4] analogous to the rationale used to explain the higher pulmonary vein impedance noted at its narrower hilar origin.[5]

To investigate this issue, a cross-sectional study in normal singleton fetuses from normal mothers measured ductal diameter, Doppler systolic and end-diastolic velocities (SV and EDV), and PI at the DA pulmonary and aortic extremities (Figure 1). Exclusion criteria were any maternal or fetal abnormalities, including DA constriction, tortuosity, kinking, and loops.The DA was assessed at the longitudinal ductal arch by two dimensional view and three dimensional spatio temporal image correlation, but the measurements were made by two dimensional sections. The 2 mm Doppler sample was positioned at the most distal descending aortic end of the DA and at its proximal end, just after the origin of the ductus from the pulmonary trunk, with a maximum beam angle of 20º, 100 Hz filters, and 50 cm/sweep speed, considering the mean of three consecutive measurements for all parameters. For statistical analysis, Student's *t* test and Pearson correlation test were used. Reproducibility of proximal and distal ductal diameter measurements was assessed in 14 random cases (20% of the total sample) using Bland-Altman plots and intraclass correlation (ICC). Interobserver variability compared the mean and differences between two different researchers, and for intraobserver variability calculation the measurements were blindly repeated by the same author after 7 weeks.

Seventy-five singleton normal fetuses (22-37 weeks; median, 26 weeks) were scanned. The mean proximal ductal diameter was 4.4 ± 1.3 mm (median = 4.4 mm), and the mean distal diameter was 2.3 ± 0.8 mm (median = 2.3 mm), $P < .001$. Proximal mean ductal velocities were SV = 0.74 ± 0.24 m/sec, EDV = 0.13 ± 0.04 m/sec; and distal mean velocities were SV = 1.03 ± 0.25 m/sec; EDV = 0.21 ± 0.05 m/sec, $P < .001$. The mean PI was 2.75 ± 0.32 at the pulmonary end and 2.32 ± 0.18 at the aortic end, $P < .001$. There were inverse correlations between ductal diameter and SV ($r = -0.29$, $P < .001$) and EDV ($r = -0.45$, $P < .001$). A positive correlation between ductal diameter and flow PI was shown ($r = 0.67$ $P < .001$). Analysis of interobserver reproducibility at the ductal proximal diameter showed ICC = 94.8% (84.4%-98.3%), $P < .001$; and at the distal extremity, it showed ICC = 82.8% (17.2%-96.1%), $P < .001$. As for intraobserver agreement, the ICC at the proximal diameter was 96.1% (84.0%-98.8%), $P < .001$, and at distal end it was 86.0% (61.5%-95.3%), $P < .001$.

In conclusion, this original study demonstrates that, since the DA is a tapering vessel with the shape of a truncated cone, flow velocities and impedance are higher at the narrower distal aortic end than at the larger pulmonary end. This new information suggests that the sample volume should be positioned at the distal duct during Doppler analysis in order to identify the highest possible ductal flow velocity.

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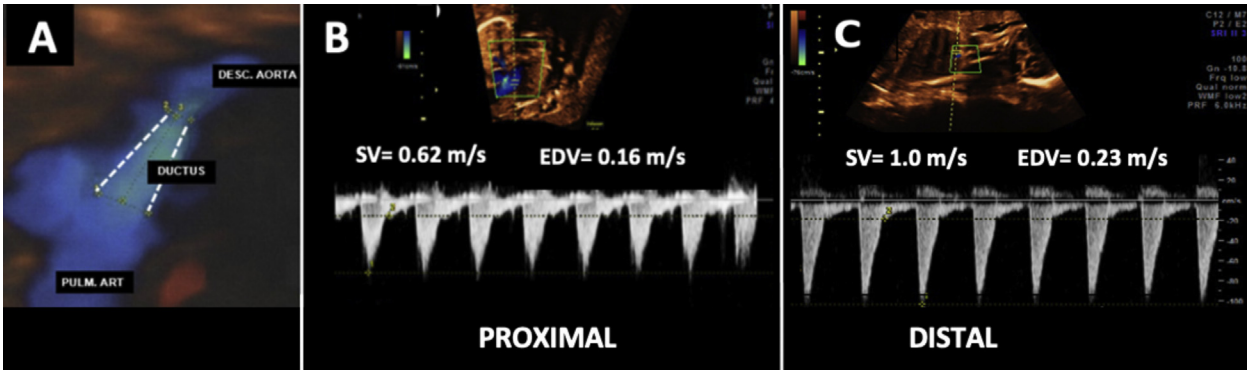

Figure 1 **(A)** Color Doppler two-dimensional echocardiographic frame imaging in a 27-week fetus showing DA morphology and its proximal (pulmonary) and distal (aortic) extremities. The truncated cone shape of the duct is clearly shown (*dotted lines*). **(B)** Pulsed Doppler tracing of ductus arteriosus proximal flow in the same fetus (pulmonary origin). **(C)** Pulsed Doppler tracing of ductus arteriosus distal flow (aortic end). Notice the higher ductal velocities (SV = 1.00 m/sec; EDV = 0.23 m/sec) at the distal extremity than at the proximal extremity (SV = 0.62 m/sec; EDV = 0.16 m/sec). *DESC. AO*, Descending aorta; *DUCTUS*, DA; *PULM ART*, pulmonary artery.

REFERENCES

1. Alvarez L, Aránega A, Saucedo R, López F, Aránega AE, Muros MA. Morphometric data on the arterial duct in the human fetal heart. Int J Cardiol 1991;31:337-44.
2. Segers P, Verdonck P. Role of tapering in aortic wave reflection: hydraulic and mathematical model study. J Biomech 2000;33:299-306.
3. van de Vosse FN, Stergiopulos N. Pulse wave propagation in the arterial tree. Annu Rev Fluid Mech 2011;43:467-99.
4. Wang JJ, Parker KH. Wave propagation in a model of the arterial circulation. J Biomech 2004;37:457-70.
5. Zielinsky P, Piccoli A, Gus E, Manica JL, Satler F, Nicoloso LH, et al. Dynamics of the pulmonary venous flow in the fetus and its association with vascular diameter. Circulation 2003;108:2377-80.

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