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Prenatal Diagnosis of Coarctation of Aorta with the Multiplanar Display and B-flow Imaging Using 4-Dimensional Ultrasonography

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INTRODUCTION

Coarctation of aorta is characterized by narrowing of the distal aortic arch. This obstructive lesion may reduce the blood flow in the fetal aortic arch leading to arch hypoplasia, although in some cases this may only be clinically evident after birth. A sonographic finding described in neonates with coarctation of aorta is the “contraductal shelf”, which has been proposed to represent residual fibrous tissue derived from the ductus arteriosus. B-flow is a display modality in 4D ultrasound that enhances signals from weak blood reflectors from vessels, suppresses strong signals from surrounding tissues, and is angle-independent. Here, we report a case of coarctation of aorta diagnosed *in utero* where B-flow imaging provided important insight into the location and nature of this aortic arch anomaly.

CASE REPORT

A 22-year-old woman, G4P0121, was referred to our unit at 29 weeks of gestation with the diagnosis of hypoplastic left heart. Two-dimensional (2D) ultrasonography demonstrated that the aorta was smaller than the pulmonary artery. In addition, a posterior infolding of the aortic arch wall, at the level of ductal insertion, was noted in the sagittal view of the aortic arch (Figure 1). Four-dimensional (4D) ultrasound with B-flow imaging demonstrated a tortuous aortic arch in the aortic segment where the posterior infolding was located (see Figures 2a, 2b and video clips 1 and 2). The patient delivered vaginally at 37 weeks a female neonate weighing 2,510 grams. Neonatal echocardiography demonstrated hypoplasia of the transverse aortic arch and descending aorta. The posterior infolding of the aortic arch, also known as “contraductal shelf”, coincided with the tortuous section of the aortic arch visualized by prenatal B-flow imaging.

DISCUSSION

The “contraductal shelf” is a sonographic finding described in neonates with coarctation of aorta.¹ This congenital heart disease is characterized by a narrowing of the distal aortic arch, and occurs in 0.2–0.62 per 1,000 live births.¹ The shelf has been proposed to represent residual fibrous tissue derived from the ductus arteriosus.² This obstructive lesion may reduce the blood flow in the aortic arch leading to arch hypoplasia.¹ However, in less severe cases, the aortic narrowing may only be clinically evident after birth, when the arterial ductus closes, or even years later.¹

In neonates, the media layer of the aortic arch has regularly spaced elastic lamella.² In the aortic isthmus, which is the aortic segment between the left subclavian artery and the ductus arteriosus,³ the elastic lamellae is more condensed.² In contrast, the ductus arteriosus lacks the regularly spaced elastic lamellae, being essentially a muscular artery.² Indeed, its media is mainly composed of loosely arranged smooth muscle fibers in a connective tissue matrix that contains very fine elastic fibers.² In neonates without heart defects, the elastic lamellae of the ductus arteriosus stops at the junction with the aorta. In contrast, in those with aortic coarctation, ectopic ductal tissue may contribute to the narrowing of the aortic arch.² The morphology of this ectopic ductal tissue in the aortic arch has been described as: 1) a sling along the luminal surface of the aorta in cases of tubular hypoplasia; 2) diaphragmatic-like structure at the entrance of the isthmus; or 3) a tongue-like obliterative lesion in aortic imperforation at the level of the ductal junction. Based on these histologic findings, Ho et al² proposed that the obstructive lesion should not be described as a shelf, but as a diaphragm originating from the ductal insertion into the aortic arch.

Aortic coarctations have been classified as preductal or postductal according to the location of the aortic narrowing. However, Hutchins et al⁴ studied 310 surgical specimens and reported that all coarctations were located opposite to the ductal entrance to the aorta. The authors proposed that during early development a higher blood flow from the ductus arteriosus (than that from the aortic arch) may separate the ductal blood flow into proximal and distal streams which, in turn, may produce a “branch-point” lesion (localized obstruction) opposite to the junction of the ductal arch and the aorta.⁴ However, this proposed mechanism may not explain the formation of tubular narrowings of the aortic arch. In half of the cases with aortic coarctation, there is a combination of diffuse tubular narrowing of the aorta and obstructive lesions.² Thus, some investigators have proposed that the term “coarctation” should be used to refer only to the localized constriction of the aorta (ridge or shelf), as the word “coarctation” (from the Latin “coartare”) means constriction or stricture,⁵ whereas the term “tubular hypoplasia” should be used to describe a long narrow segment.⁶

Multipanar imaging in three-dimensional (3D) and 4D ultrasonography is a novel display modality that allows for the simultaneous visualization of three orthogonal anatomic planes (transverse, sagittal and coronal) (Figure 3). An imaging tool, referred to as the “reference dot”, can be used to identify anatomic structures in these orthogonal planes. For example, placement of the reference dot at the entrance of the ductus arteriosus in the aorta (panel A, figure 3), allowed the visualization of the contraductal shelf in the sagittal view of the aortic arch displayed on panel B. In this panel, the reference dot is located inferior to the shelf confirming that this obstructive lesion is at the aortic-ductal junction. The shelf can be proximal to, opposite to, or distal to the aortic-ductal junction.²

While 2D sonography traditionally relies on standard anatomic planes for a thorough examination of the fetal heart, 3D and 4D sonography can facilitate the visualization of these planes, further simplify the examination of the fetal heart, and can potentially reduce

operator dependency that is characteristic of 2D fetal echocardiography. By reslicing *volume* datasets of the fetal heart (which can only be obtained with 3D and 4D sonography), sonographic planes can be easily obtained. Indeed, using a combination of Spatio-Temporal Image Correlation (STIC) and Tomographic Ultrasound Imaging (TUI), standard transverse planes commonly used to examine the fetal heart can be automatically displayed with TUI.^{7,8} The development of new algorithms which are designed to facilitate examination of the fetal heart can potentially increase the detection rates of congenital heart diseases and reduce the perinatal morbidity and mortality associated with them. The 3-vessel and trachea view, 4-chamber view, and both outflow tracts can be simultaneously visualized using a novel algorithm combining STIC and TUI.⁹ This algorithm allowed for visualization of the standard planes for fetal echocardiography in most fetuses with and without heart defects.

B-flow is a new display modality in 4D ultrasound that digitally enhances signals from weak blood reflectors from vessels and, at the same time, suppresses strong signals from surrounding tissues.^{10–12} This technology does not rely on Doppler methods to display blood flow; thus, it is angle-independent and does not interfere with the frame rate. This feature of B-flow imaging is potentially advantageous over color or power Doppler imaging when used in conjunction with STIC, for the evaluation of the fetal vasculature. In B-flow imaging, echoes from the tissue and that of the blood flow can be displayed with high resolution and without the overlay that characterizes color Doppler imaging.¹³ Moreover, B-flow may have less signal drop out when the ultrasound beam is perpendicular to the vessel. For example, B-flow imaging is able to distinguish the anterior cerebral arteries as 2 parallel vessels, a feature that has not been reported previously with the use of color or power Doppler.¹⁰ The use of B-flow in the case presented herein, demonstrates that this imaging modality provides important insight into the location and nature of arch abnormalities in fetuses with coarctation of aorta. Indeed, B-flow allowed for a clear visualization of a thin and tortuous aortic arch, as well as its spatial relationships with the fetal heart and other vascular structures (see Figures 2a, 2b and video clips 1 and 2).

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Reference List

1. Hornberg, L. Aortic Arch Abnormalities. In: Allan, L.; Hornberg, L.; Sharland, GK., editors. Textbook of Fetal Cardiology. Greenwich Medical Media; London: 2000. p. 305-22.
2. Ho SY, Anderson RH. Coarctation, tubular hypoplasia, and the ductus arteriosus. Histological study of 35 specimens. Br.Heart J. 1979; 41:268–74. [PubMed: 426975]
3. Fouron JC, Zarelli M, Drblik P, Lessard M. Flow velocity profile of the fetal aortic isthmus through normal gestation. Am J Cardiol. 1994; 74:483–86. [PubMed: 8059730]
4. Hutchins GM. Coarctation of the aorta explained as a branch-point of the ductus arteriosus. Am J Pathol. 1971; 63:203–14. [PubMed: 5090637]
5. Stedman's Medical Dictionary. Williams & Wilkins; Baltimore: 1995.
6. Elzenga NJ, Gittenberger-de Groot AC. Localised coarctation of the aorta. An age dependent spectrum. Br.Heart J. 1983; 49:317–23. [PubMed: 6830664]
7. Devore GR, Polanko B. Tomographic ultrasound imaging of the fetal heart: a new technique for identifying normal and abnormal cardiac anatomy. J Ultrasound Med. 2005; 24:1685–96. [PubMed: 16301725]

8. Goncalves LF, Espinoza J, Romero R, et al. Four-dimensional ultrasonography of the fetal heart using a novel Tomographic Ultrasound Imaging display. *J Perinat.Med.* 2006; 34:39–55. [PubMed: 16489885]
9. Espinoza J, Kusanovic JP, Goncalves LF, et al. A novel algorithm for comprehensive fetal echocardiography using 4-dimensional ultrasonography and tomographic imaging. *J Ultrasound Med.* 2006; 25:947–56. [PubMed: 16870887]
10. Pooh RK. New application of B-flow sono-angiography in perinatology. *Ultrasound Obstet.Gynecol.* 2000; 15:163. [PubMed: 10776004]
11. Deane C. Extended field-of-view and B-flow ultrasound: fashion or future? *Ultrasound Obstet.Gynecol.* 2000; 15:96–97. [PubMed: 10775988]
12. Devore GR. Three-dimensional and four-dimensional fetal echocardiography: a new frontier. *Curr.Opin.Pediatr.* 2005; 17:592–604. [PubMed: 16160533]
13. Wipro GE Healthcare. Ultrasound Technical Tutorials: B-flow. 2003 Ref Type: Internet Communication.

Figure 1. Posterior infolding of the aortic arch (contraductal shelf) wall at the level of ductal insertion is noted in the sagittal view of the aortic arch. CS: contraductal shelf; D Ao: descending aorta; LV: left ventricle

Figure 2. Figures 2a and 2b display the B-flow imaging of a narrow and tortuous aortic arch and its relationship with the heart and other vascular structures as seen from the left and right,

respectively. Ao arch: aortic arch; PA: pulmonary artery; BT: brachiocephalic trunk; LPA: left pulmonary artery; D Ao: descending aorta; IVC: inferior vena cava; SVC: superior vena cava; HV: hepatic vein.

Figure 3.

Multiplanar display of the aortic arch. Panel A displays the three vessel view of the heart, where a disproportion between the width of the aorta and the pulmonary artery can be observed. The reference dot was placed at the junction of ductus arteriosus and aorta. Panel B displays the narrow aortic arch in the sagittal view. The reference dot is just inferior to the shelf indicating that this obstructive lesion is located at the level of aortic-ductal junction. Panel C displays the coronal view of the descending aorta. Ao: aorta; SVC: superior vena cava; PA: pulmonary artery; DA: ductus arteriosus; LV: left ventricle; A Ao: ascending aorta; CS: contraductal shelf; D Ao: descending aorta.