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CONGENITAL HEART DISEASE

IMAGING VIGNETTE: CLINICAL VIGNETTE

Computed Fluid Dynamics Analysis for SVC-to-RPA Anastomosis With Antegrade Pulmonary Flow

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ABSTRACT

We report an infant case after superior vena cava -to-right pulmonary artery anastomosis with antegrade pulmonary flow in which computational fluid dynamics analysis showed that restriction of antegrade blood flow by the remaining right pulmonary stenosis resulted in reduced shear stress and energy loss in the superior vena cava. (J Am Coll Cardiol Case Rep 2024;29:102263) © 2024 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Superior vena cava (SVC)-to-right pulmonary artery (RPA) anastomosis with antegrade pulmonary artery (PA) flow is a common method in a one-and-a-half ventricular repair, and the restriction of antegrade PA flow can reduce the SVC pressure, leading to the prevention of subsequent facial swelling and SVC aneurysm.[1] However, its detailed hemodynamics have not been fully uncovered.

CLINICAL VIGNETTE

A 1-year-old male diagnosed with ventricular septal defect, atrial septal defect, hypoplastic tricuspid valve, and small right ventricle with 50% of normal size underwent SVC-to-RPA anastomosis, closure of ventricular septal defect and atrial septal defect, and PA de-banding. The proximal RPA stenosis due to prior PA banding was left to avoid competition between SVC flow and antegrade PA flow.

Ten months after surgery, computational fluid dynamics (CFD) analysis, a method described in previous studies and Supplemental Appendix,[2,3] was performed to evaluate detailed hemodynamics (**Figure 1**, Videos 1 and 2). The streamline of blood flow revealed a turbulent flow in the main pulmonary artery (MPA), left pulmonary artery (LPA), and proximal RPA, whereas a smooth laminar flow was observed in the SVC and distal RPA (**Figure 1A**, Video 1). Relatively high wall shear stress (WSS) (**Figure 1B**) was detected in the MPA, LPA, and proximal RPA, whereas almost no WSS was observed in the SVC and distal RPA. In the systole phase (**Figure 1C**, Video 2), the MPA blood (pink) flowed to the bilateral PAs, whereas the SVC blood (yellow) flowed only to the RPA, resulting in no competitive flow in the SVC from the MPA. In the diastole phase (**Figure 1D**), the balance of the pulmonary blood flow supply was observed to flow from the MPA only to the LPA and from the SVC to the bilateral PAs. The calculated mean blood flows in the right and left PAs were 625 and 694 mL/min, respectively. **Figure 1E** shows the stagnation of blood flow, defined as a flow velocity of <0.01 m/s, revealing no significant

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stagnation in the SVC and RPA. Figure 1F shows the energy loss of blood flow, indicating that the SVC and distal RPA had less energy loss than the MPA and LPAs.

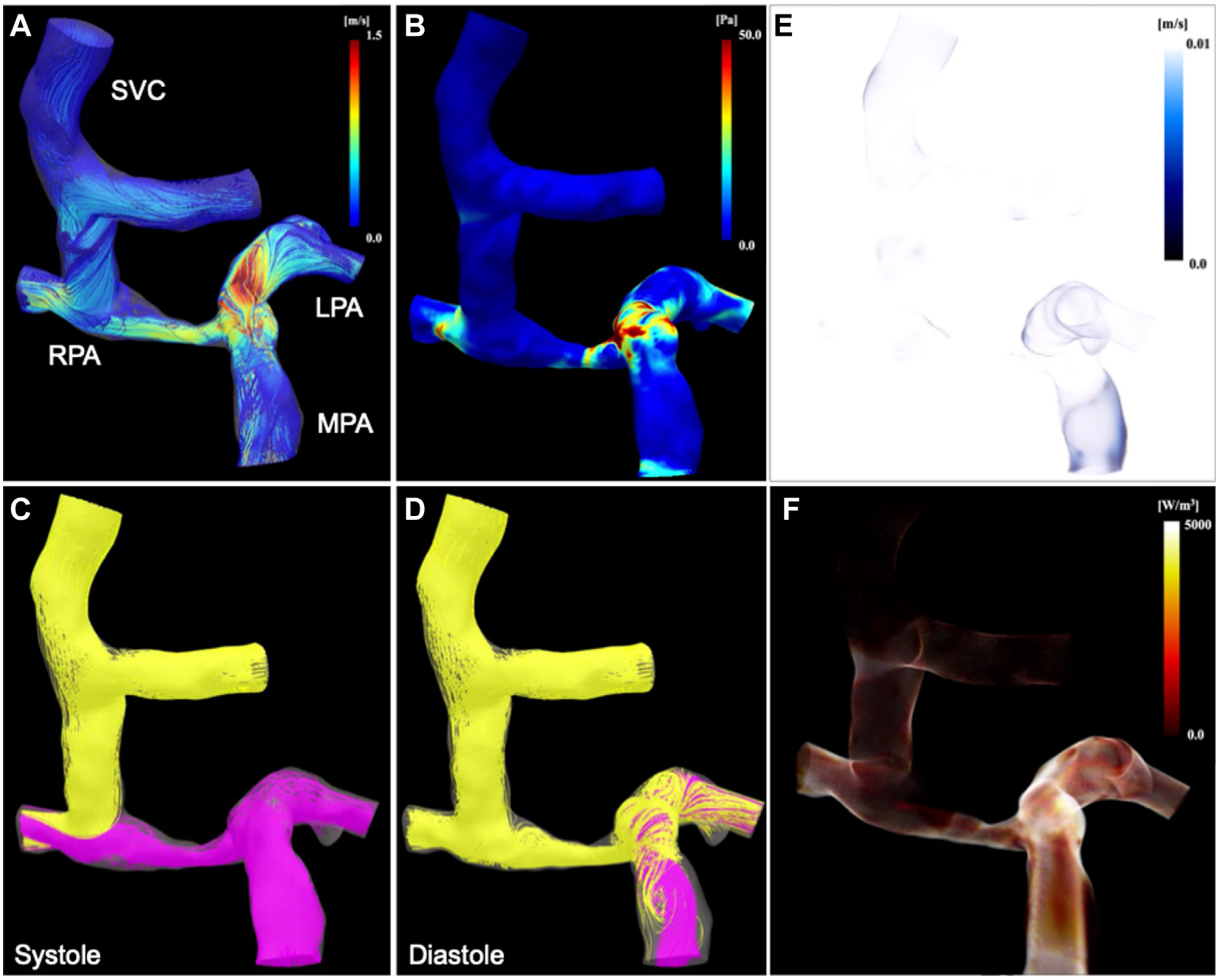
In our case, CFD analysis successfully showed the hemodynamics of SVC-to-RPA anastomosis with restricted antegrade PA flow. First, blood flow in the SVC and distal RPA showed smooth flow, low WSS, little stagnation, and low energy loss. Second, blood flow from the lower body is distributed to both lungs. These results suggest that left RPA stenosis plays an important role in avoiding competition between SVC flow and antegrade PA flow while maintaining hepatic flow to both lungs, likely leading to the prevention of SVC aneurysm and pulmonary arteriovenous malformation.

Because the current analysis was performed with a supine position and sedated condition, it may not reflect the hemodynamics in an upright position or on an exercise condition. The patient's inspiration or expiration condition was also not considered in this analysis. Therefore, they should be noted as a limitation.

ABBREVIATIONS AND ACRONYMS

CFD = computational fluid dynamics
LPA = left pulmonary artery
MPA = main pulmonary artery
PA = pulmonary artery
RPA = right pulmonary artery
SVC = superior vena cava

FIGURE 1 Computational Fluid Dynamics Analysis for Superior Vena Cava to Right Pulmonary Artery Anastomosis With Antegrade Pulmonary Blood Flow in an Infant



(A) Streamline of blood flow in the pulmonary artery (PA) and superior vena cava (SVC). (B) Wall shear stress is less in the SVC and distal right PA (RPA). (C, D) Blood flow of the SVC (yellow) and main PA (pink) in (C) systole and (D) diastole. (E) Blood flow stagnation. (F) Energy loss is less in the SVC and the distal RPA than in the main and left PAs. LPA = left pulmonary artery; MPA = main pulmonary artery.

In conclusion, CFD analysis can provide us the information on 4-dimensional visualized pulmonary blood flow as well as the detailed evaluation of sheer stress and energy loss of blood flow in SVC-to-RPA anastomosis with restricted antegrade PA flow hemodynamics, even in infants, and it would be possible to use for predicting risk of hemodynamic complications.

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KEY WORDS children, congenital heart defect, one-and-a-half ventricular repair

APPENDIX For the method of computational fluid dynamics analysis and supplemental videos, please see the online version of this paper.