Blood flow dynamics in the total cavopulmonary connection long-term after Fontan completion

Rijnberg, F.M.

CHAPTER 6C

Tornado-like flow in the Fontan circulation: insights from quantification and visualization of viscous energy loss rate using 4D flow MRI

Friso M Rijnberg, Hans C van Assen, Mark G Hazekamp, Arno A W Roest

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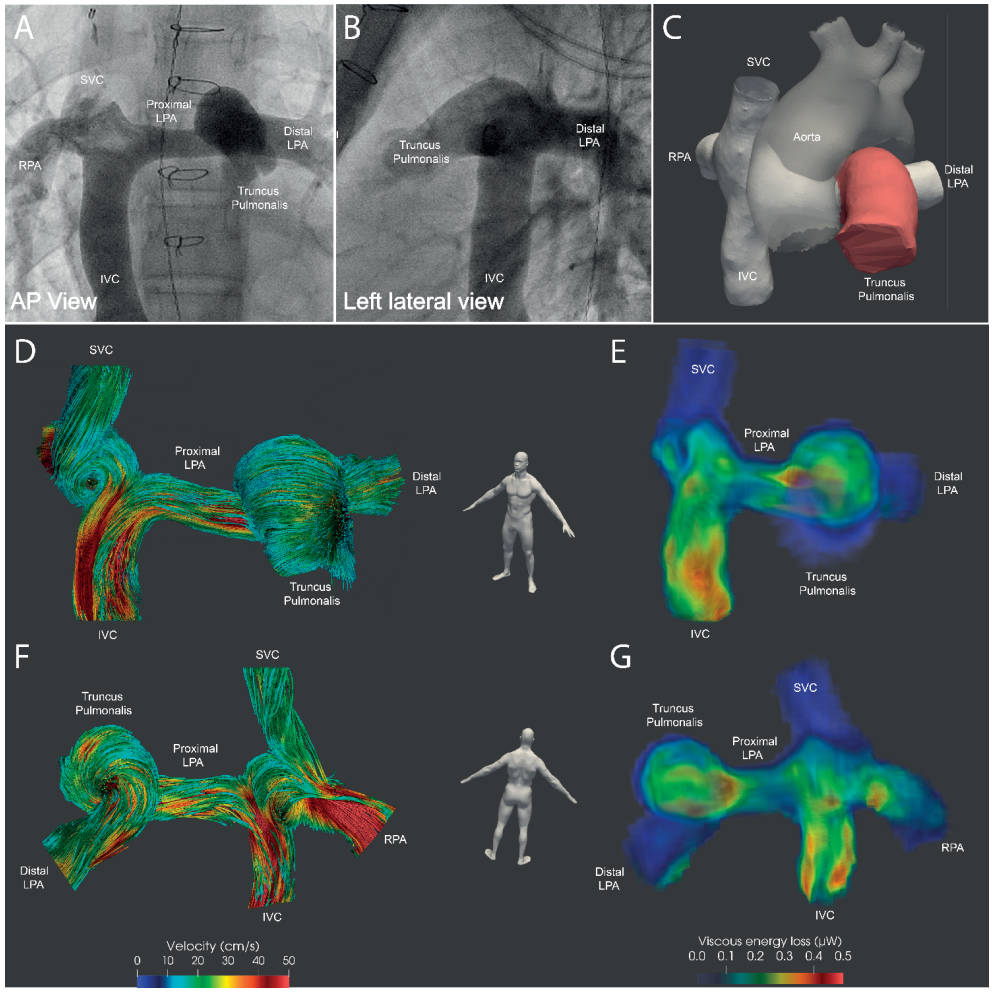

IVC, inferior vena cava; LPA, left pulmonary artery; RPA, right pulmonary artery; SVC, superior vena cava.

A female patient with tricuspid and pulmonary atresia underwent total cavopulmonary connection (TCPC) completion with a 16mm extracardiac conduit, without detachment of the pulmonary trunk at 4 years. At 17 years, the patient underwent a catheterization procedure to close veno-venous collaterals. Angiographic TCPC assessment showed the presence of a blind-ending, dilated pulmonary trunk (Panels A–C, segmented with CAAS MR Solutions v5.1, Pie Medical Imaging. red: pulmonary trunk, Supplementary material online, Videos S1 and S2). The significance of this observation, however, was unclear at that time. The following year, a magnetic resonance imaging (MRI) examination, including 4D flow MRI, was performed as part of routine follow-up. Visualization of flow patterns within the TCPC revealed a Tornado-like helical flow pattern inside the dilated pulmonary trunk (Panels D and F, Supplementary material online, Video S3). To evaluate the haemodynamic impact of this flow pattern, peak viscous energy loss rate (EL), a novel energetic marker representing kinetic energy loss due to friction, was calculated. Thirty-four percent of total viscous EL in the TCPC occurred in the pulmonary trunk (0.35 mW and 0.12 mW, respectively). Colour-coded visualization of the spatial distribution of viscous EL revealed the primary locations of increased EL (Panels E and G, Supplementary material online, Video S4). This case illustrates the complementary role of 4D flow MRI by allowing visualization of flow patterns and flow-related energetic parameters, thereby revealing locations of increased EL within the TCPC. In these patients, minimal EL in the TCPC is important to maximally conserve the reduced energy present in the Fontan circulation. Furthermore, to ensure a smooth pulmonary artery, detachment of the pulmonary trunk should be considered in univentricular patients with pulmonary atresia to avoid distorted, energy-consuming blood flow.