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Commentary: Advanced assessments of flow velocity to optimize surgical repair and clinical outcomes in single-ventricle congenital heart disease

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Schäfer and colleagues¹ share findings from their single-center four-dimensional magnetic resonance imaging (4D-MRI) evaluation of 26 patients with palliated hypoplastic left heart syndrome investigating the influence of neo-aortic arch tapering on flow-mediated viscous energy loss and the correlation between flow-geometry and single-ventricle power generation. They found that patients with higher degree of neo-aortic arch tapering experienced more than 2-fold greater viscous energy loss. Although this represents irreversibly wasted power generated by the single ventricle, a situation that should clearly be avoided, viscous energy loss accounted for only 0.7% and 0.3% of generated ventricular power in patients with high and low degrees of aortic arch tapering, respectively.

This innovative study adds to the current body of literature highlighting the potentially negative consequences of oversized ascending aortas following Norwood palliation: increased pulse wave velocity, altered reflections in distal vasculature, and increased aortic stiffness have been negatively associated with ventricular performance. Schäfer and colleagues' ¹ study is the first to comprehensively explore fluid dynamics in altered neo-aortic morphologies following Norwood palliation using 4D-MRI. The

William Harvey (1578-1657), the English physician credited with recognizing human circulation.

CENTRAL MESSAGE

4D-MRI evaluation of ascending aortic flow after Norwood palliation identifies higher viscous energy loss with greater degree of neo-aortic tapering.

application of this method, which allows for true in vivo determination of flow velocities, rather than relying on simplified flow velocity measurements obtained from traditional MRI or echocardiography, has the potential to significantly change our approach to assessing the hemodynamic consequences of inherent or residual cardiac lesions. The technique has found applications in adult patients with arterial, venous, and cardiac valve pathology assessments.²⁻⁵ In children with congenital heart disease, 4D-MRI has been used to assess proximal aortic flow dynamics following aortic valve surgery, tetralogy of Fallot repair, and the Fontan procedure.⁶⁻¹² Beyond assessment of a patient's current hemodynamic state, 4D-MRI may also be applied to preoperative hemodynamic modeling of expected velocities and pressure gradients, although several limitations to these simulations remain.^{13,14} As with any new technology, population-specific limitations, technical considerations, inter- and intrarater reproducibility, and cost-effectiveness considerations deserve consideration. Technical aspects in particular play an important role in the appropriate acquisition of both 4D-MRI data and its interpretation.¹⁵ As is often the case, these limitations and considerations are less well defined in children with congenital heart disease. Ultimately, the importance of any new medical technology is measured by its influence on clinical care. Given the persistent clinical vulnerability of patients with single-ventricle congenital heart disease,

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4D-MRI has the potential for significant influence on their outcomes.

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