CMR, newer imaging adjuncts, such as feature-tracking to measure ventricular strain, have been added to the armamentarium for predicting optimal timing of pulmonary valve replacement.⁹ We congratulate the authors for their contribution to this expanding field of imaging in patients of rTOF.

References

1. Smith CA, McCracken C, Thomas AS, Spector LG, St Louis JD, Oster ME, et al. Long-term outcomes of tetralogy of Fallot: a study from the pediatric cardiac care consortium. *JAMA Cardiol.* 2019;4:34-41.
2. Geva T. Repaired tetralogy of Fallot: the roles of cardiovascular magnetic resonance in evaluating pathophysiology and for pulmonary valve replacement decision support. *J Cardiovasc Magn Reson.* 2011;13:9.
3. Heng EL, Gatzoulis MA, Uebing A, Sethia B, Uemura H, Smith GC, et al. Immediate and midterm cardiac remodeling after surgical pulmonary valve replacement in adults with repaired tetralogy of Fallot: a prospective cardiovascular magnetic resonance and clinical study. *Circulation.* 2017;136:1703-13.
4. Oosterhof T, van Straten A, Vliegen HW, Meijboom FJ, van Dijk AP, Spijkerboer AM, et al. Preoperative thresholds for pulmonary valve replacement in patients with corrected tetralogy of Fallot using cardiovascular magnetic resonance. *Circulation.* 2007;116:545-51.
5. He F, Feng Z, Chen Q, Jiao Y, Hua Z, Zhang H, et al. Whether pulmonary valve replacement in asymptomatic patients with moderate or severe regurgitation after tetralogy of Fallot repair is appropriate: a case-control study. *J Am Heart Assoc.* 2019;8:e010689.
6. Shen W-C, Chen C-A, Chang C-I, Chen Y-S, Huang S-C, Wu M-H, et al. Outflow tract geometries are associated with adverse outcome indicators in repaired tetralogy of Fallot. *J Thorac Cardiovasc Surg.* 2021;162:196-205.
7. Vonder Muhll IF. Timing and results of pulmonary valve replacement for pulmonary regurgitation in repaired tetralogy of Fallot: a challenge for evidence-based medicine. *Can J Cardiol.* 2019;35:1620-2.
8. Bokma JP, Geva T, Sleeper LA, Babu Narayan SV, Wald R, Hickey K, et al. A propensity score-adjusted analysis of clinical outcomes after pulmonary valve replacement in tetralogy of Fallot. *Heart.* 2018;104:738-44.
9. Inage A, Kishiki K, Suzuki R, Mizuno N. Identification of optimal timing for pulmonary valve replacement in asymptomatic repaired tetralogy of Fallot using feature tracking. *Circulation.* 2019;140:A16016.

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Commentary: “If it ain’t pretty, it ain’t going to work pretty”

Tain-Yen Hsia, MD

“If it ain’t pretty, it ain’t going to work pretty”

—Levi Watkins, Jr, MD
(June 13, 1944-April 11, 2015)

Levi Watkins, Jr was a trailblazer. Born in Kansas but raised in Alabama during the birth of the civil rights movement, Watkins was 11 years old when he joined his family pastor, Reverend Dr Martin Luther King, Jr, in the Montgomery bus boycott that followed Rosa Parks’ arrest for refusing to give up her seat to a white passenger. Later, Watkins was the first African American to study

Levi Watkins, Jr reminding the author, “if it ain’t pretty, it ain’t going to work pretty.”

CENTRAL MESSAGE

Unique shapes of the reconstructed right ventricular outflow tract following tetralogy of Fallot repair are associated with worse late outcomes.

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Disclosures: The author reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

Received for publication Nov 13, 2020; revisions received Nov 13, 2020; accepted for publication Nov 16, 2020; available ahead of print Nov 23, 2020.

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J Thorac Cardiovasc Surg 2021;162:207-20

0022-5223/\$36.00

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<http://dx.doi.org/10.1016/j.jtcvs.2020.11.053>

medicine at Vanderbilt University and was the sole African American by the time he graduated. He entered surgical training as an intern at Johns Hopkins Hospital in 1971 and survived its notoriously difficult pyramidal scheme to become its first African American Chief Resident in Cardiac Surgery. Just 7 months after completing training, as a

junior staff cardiac surgeon at Hopkins, Watkins performed the first human implantation of an automatic defibrillator. His greatest legacy was his lifelong advocacy for inclusion, equity and opportunity in medicine, opening medical school doors for hundreds of minority and women students. By 1983, 4 years after he joined the Admissions Committee at Johns Hopkins Medical School, African American enrollment had increased from 8 to 40.¹ The minority recruitment and retention model that he helped to create at Hopkins was adopted at numerous other institutions. However, for a generation of cardiac surgery residents at Johns Hopkins who trained under Watkins, the sound of his deep Southern Baptist voice repeating the words “if it ain’t pretty, it ain’t going to work pretty [big man]” will forever resonate in their minds and in their hearts.

In reconstructive cardiac surgery, form and function are interrelated. It is not always clear whether form follows function or function follows form, but an awareness is emerging that shape (ie, the appearance of a reconstruction) can affect how blood flows and impact clinical outcomes independent of hemodynamic perturbations. Applying advanced statistical shape analysis of 3-dimensional (3D) cardiac magnetic resonance (CMR) images, the group at Great Ormond Street has demonstrated that even in patients with no residual stenosis or obstruction, variations in the 3D shape of the aortic arch following either Norwood-type reconstruction or isolated aortic coarctation repair are associated with different long-term ventricular performance and clinical outcomes.^{2,3} Therefore, the assumption that everything is fine as long as there is no significant pressure gradient postoperatively is no longer valid.

How this concept applies to the right ventricular outflow tract (RVOT) reconstruction during tetralogy of Fallot (TOF) repair is less obvious. The obligatory free pulmonary insufficiency and the odd-looking oversized patch notwithstanding, the underpinning principle—at least the way many of us were taught—has been to create a generous RVOT that leaves minimal residual pressure gradient. However, because many of these patients return with significant latent right ventricular (RV) dilatation and dysfunction, often requiring pulmonary valve replacement and concomitant RVOT reduction, we are beginning to realize that the shape and size of the initial RVOT reconstruction carries important long-term ramifications.⁴ Recognizing this early, Marc de Leval in London often preached limiting the size of the transannular patch to produce “just the right amount of stenosis and regurgitation,” defined by a residual RV systolic pressure that is up to two-thirds of the systemic pressure. But reproducibly fashioning the patch at the time of surgery

to achieve the correct balance remains an art. Furthermore, there has not been a study with adequate follow-up to conclusively show that this strategy leads to better outcomes.

In this issue of the *Journal*, the highly regarded group at National Taiwan University in Taipei attempts to shed light on the relationship between RVOT shape and outcome following TOF repair.⁵ In an impressive study of 206 patients that includes detailed 3D CMR and exercise testing at more than 10 years after TOF repair, the authors report that distinct RVOT shapes are associated with differential late RV function. Specifically, an RVOT shaped like a pyramid (wide proximally and slender distally) is correlated with worse RV dilatation, while one that resembled an “inverted trapezoid” (narrowest at the subvalvular RVOT) had the smallest RV end-diastolic volume and pulmonary annulus. However, the best peak oxygen consumption was seen in patients with an hourglass-like RVOT. Moreover, in the 25% of patients whose left pulmonary arteries were markedly smaller than the right (ie, pulmonary artery discrepancy), their exercise capacity was worse. Despite the arbitrary nature of categorizing 206 RVOT shapes into 4 types, the curious use of 2-dimensional measurements to define the 3D RVOT when 3D imaging data were available, and the missed opportunity to apply statistical shape analysis tools developed specifically to examine complex 3D structures, the study does add to our current understanding. In addition to reaffirming de Leval’s proposition that we should limit the size of the transannular patch to avoid exaggerated RVOT augmentation, the authors’ clear message is: RVOT appearance matters.

In 1966, Levi Watkins, Jr learned that he had been admitted to Vanderbilt Medical School from a newspaper headline. Suffering from repeated racist insults and attacks, he was forced to take up housing off-campus, away from his classmates. Watkins often reflected that his time as a medical student was “lonely.” Thus, it was heartening to know that when he suffered a fatal heart attack at a recruitment dinner for cardiac surgery trainee candidates, he was surrounded by his beloved residents.

References

1. Roberts S. Levi Watkins, 70, dies; pioneering heart surgeon pushed civil rights. *New York Times*. April 16, 2015.
2. Bruse JL, Cervi E, McLeod K, Biglino G, Sermesant M, Pennec X, et al. Looks do matter! Aortic arch shape following hypoplastic left heart syndrome palliation correlates with cavopulmonary outcomes. *Ann Thorac Surg*. 2017; 103:645-54.
3. Bruse JL, Khushnood A, McLeod K, Biglino G, Sermesant M, Pennec X, et al. How successful is successful? Aortic arch shape after successful aortic coarctation repair correlates with left ventricular function. *J Thorac Cardiovasc Surg*. 2017; 153:418-27.

4. Frigiola A, Hughes M, Turner M, Taylor A, Marek J, Giardini A, et al. Physiologic and phenotypic characteristics of late survivors of tetralogy of Fallot repair who are free from pulmonary valve replacement. *Circulation*. 2013;128:1861-8.

5. Shen W-C, Chen C-A, Chang C-I, Chen Y-S, Huang S-C, Wu M-H, et al. Outflow tract geometries are associated with adverse outcome indicators in repaired tetralogy of Fallot. *J Thorac Cardiovasc Surg*. 2021;162:196-205.

See Article page 196.

Commentary: The neglected chamber: Does the infundibulum make a difference in the long-term outcome of tetralogy of Fallot?

Alvise Guariento, MD, PhD, and
Christoph Haller, MD

Senac, the French father of cardiac pathology, misinterpreted the description of Aristotle's third ventricle as the right ventricular infundibulum.¹ The mystery around Aristotle's triventricular heart was elegantly resolved by Richard and Stella Van Praagh in 1983,² but the importance of the right ventricular infundibulum has long remained undervalued. Tetralogy of Fallot (ToF) is the congenital defect that best illustrates the role of the infundibulum, and Shen and colleagues³ add yet another twist to it.

The authors report an analysis of magnetic resonance imaging scans of patients after surgical correction of ToF with particular emphasis on the anatomy of the right ventricular outflow tract (RVOT) and pulmonary artery (PA). Measurements of lateral projections of the outflow tract were used to categorize 4 distinct geometries: tubular, with no significant stenosis along the RVOT and PA axis; pyramidal, with the narrowest segment at the distal main PA; hourglass, with the narrowest segment more proximal, but distal to the pulmonary valve annulus; and inverted trapezoid, with the narrowest segment within the RVOT. They conclude that RV remodeling was

Jean Senac (1693-1770). From Harvard Medical Library in the Francis A. Countway Library of Medicine.

CENTRAL MESSAGE

A functional infundibulum may preserve right ventricular dimensions after surgical correction of tetralogy of Fallot.

affected by RVOT geometry with the inverted trapezoid best preserving RV end-diastolic volume indices and QRS durations.

The most frequent surgical approach to ToF nowadays remains transannular patch (TAP) reconstruction. The use of a TAP causes progressive pulmonary insufficiency and chronic right ventricular volume overload, leading to RV dilation and dysfunction. This is associated with reduced functional capacity and inevitably leads to pulmonary valve replacement in adulthood. Techniques aiming at preservation of the pulmonary valve annulus and valve function have demonstrated excellent results with low re-intervention rates and reduced RV dilation compared to TAP.^{4,5}

The data presented by Shen and colleagues³ shed new light on the importance of the approach to the infundibulum in ToF. Although not well delineated in their article, the hourglass and especially the pyramidal geometry may represent patching of the RVOT—infundibular or transannular, respectively—leaving a large and supposedly non-contractile proximal infundibular segment followed by distal narrowing. An a- or dyskinetic infundibulum

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The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

Received for publication Oct 27, 2020; revisions received Oct 27, 2020; accepted for publication Oct 28, 2020; available ahead of print Nov 5, 2020.

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J Thorac Cardiovasc Surg 2021;162:209-10

0022-5223/\$36.00

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<http://dx.doi.org/10.1016/j.jtcvs.2020.10.113>