See Article page 1529.

Commentary: Vis a tergo—a push from behind—is of paramount importance for the optimal function of a bidirectional cavopulmonary shunt

Thierry Carrel, MD

Thierry Carrel, MD

CENTRAL MESSAGE

Vis a tergo is a prerequisite for the optimal function of a bidirectional cavopulmonary shunt.

The hemodynamic success of the Fontan circulation is based on sufficient passive systemic venous blood flow through the lungs, whereas a subpulmonary ventricle is not compulsory for venous return to cross the pulmonary vascular bed. Pulmonary blood flow, and thus preload to the single ventricle, can be driven by moderately elevated central venous pressure when pulmonary vascular resistance is low enough to permit adequate forward flow.

Unrestricted passive systemic blood flow to the pulmonary artery is of paramount importance for the optimal function of a Fontan circulation. Among the original 10 commandments for a successful Fontan procedure (Table 1), at least 4 relate directly to unrestricted blood flow: normal systemic venous return, mean pulmonary artery (PA) pressure < 15 mm Hg, pulmonary vascular resistance <4 Woods units/m^2, and absence of PA distortion.[1] Adhering to these criteria ensures adequate venous blood flow and a sufficient pressure gradient between the systemic venous system and the pulmonary circulation, but it is clear from a historic perspective that total compliance with all criteria does not necessarily portend excellent long-term survival. Following the first step of a Fontan circulation, namely a superior vena cava (SVC) to PA anastomosis, standing position of the patient will increase the gravity force (and therefore the hydrostatic pressure), whereas the latter disappears when the patient is in a supine position. Following the second stage operation, the hydrostatic pressure adversely influences the passive venous return to the lung circulation but help is provided by the pump action of the lower extremities musculature. Ten years after the article by Choussat and colleagues,[1] Brawn and colleagues[2] found in their own series of 406 patients that 2 of the original 10 commandments carry significant weight for both early and late outcome over the Fontan procedure and that they are preoperative ventricular function and preoperative PA pressure >15 mm Hg.

Luo and colleagues[3] analyzed the preoperative SVC blood flow using cardiac magnetic resonance and found that the latter may predict physiology and clinical outcome after bidirectional cavopulmonary shunt (BCPS). Their hypothesis that low blood flow in the SVC may be among the most significant factor to determine the mid- to long-term functionality of a BCPS was confirmed because low preoperative SVC blood flow was associated with a higher probability of shunt takedown and death, the 2 worst events following BCPS. In that sense, adequate SVC blood flow might need to be added the list of commandments for a successful cavopulmonary anastomosis.

This additional knowledge raises 2 questions: What is the minimal SVC blood flow for the success of a BCPS? and, What are the most common reasons for too-low SVC blood flow: low cardiac output, systemic aortic valve regurgitation, or reduced function of the systemic ventricle? These are important points that should be investigated in future studies. In a placebo-controlled randomized trial in infants in a different setting of reduced SVC blood flow, Bravo and colleagues[4] demonstrate a tendency toward improved short-term clinical and biochemical perfusion variable outcomes in infants with low SVC flow treated with dobutamine.

From the Department of Cardiovascular Surgery, University Hospital and University of Bern, Bern, Switzerland.

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 April 26, 2020; revisions received April 26, 2020; accepted for publication April 27, 2020; available ahead of print May 11, 2020.

Address for reprints: Thierry Carrel, MD, Department of Cardiovascular Surgery, University Hospital and University of Bern, Freiburgstrasse, CH-3010 Bern, Switzerland (E-mail: thierry.carrel@insel.ch).

J Thorac Cardiovasc Surg 2020;160:1541-2
0022-5223/$36.00

https://doi.org/10.1016/j.jtcvs.2020.04.128

CONG

TABLE 1. Ten commandments for identifying an ideal Fontan candidate[1]

- Age older than 4 y
- Sinus rhythm
- Normal systemic venous return
- Normal right atrial volume
- Mean pulmonary arterial pressure <15 mm Hg
- Pulmonary vascular resistance <4 Woods units/m^2
- Pulmonary artery:aorta ratio >0.75
- Left ventricular ejection fraction >0.6
- Competent mitral valve
- Absence of pulmonary artery distortion

Among the most important strategy to increase SVC blood flow is probably the elimination of antegrade pulmonary blood flow that competes with SVC flow. This was performed in a large majority of the patients in this study. Another more theoretical option would be to drain the azygos vein with the SVC, but this is usually not indicated for an anatomic reason: The most complete mobilization of the SVC with division of the azygos vein represents the best way to achieve a tension-free anastomosis. A bilateral SVC to PA shunt that may provide a higher SVC flow was not found to be a beneficial factor for long-term functionality of a Fontan circulation.[5,6]

The authors described 4 patients who developed extensive postoperative SVC/PA thrombus, and 2 of these patients had pre-existing thrombosis in the upper venous system. This raises the question of the best possible preoperative imaging (magnetic resonance) and the potential consequences of finding thrombotic material in the upper body systemic venous circulation: Would this be considered a contraindication for BCPS? On the other side, the most adequate postoperative anticoagulation to avoid thrombotic occlusion of smaller anastomoses and/or cavopulmonary shunt with low flow conditions still have to be determined.

In this study, preoperative SVC blood flow positively correlated with early post-BCPS arterial saturation. The multivariable analysis, although performed in a relatively small number of patients, showed that SVC flow was the only factor associated with BCPS failure (hazard ratio, 0.186; $P = .04$). Surprisingly, among the predictors related to the pre-BCPS anatomy and physiology, neither PA pressure nor pulmonary vascular resistance was associated as an individual variable with adverse outcomes. A reason for that may be that the authors were highly selective in the indication for BCPS because patients who had borderline PA size or pressure were amply excluded for this procedure. For this reason, it would be interesting to know the exact exclusion criteria regarding PA pressure and size, the PA–aorta relationship, and PA branch sizes.

References

1. Choussat A, Fontan F, Besse P, Anderson RH, Shinebourne EA. Selection criteria for Fontan's procedure. *Pediatr Cardiol*. 1978;559-66.
2. Hosein RB, Clarke AJ, McGuirk SP, Griselli M, Stumper O, De Giovanni JV, et al. Factors influencing early and late outcome following the Fontan procedure in the current era. The 'Two Commandments'? *Eur J Cardiothorac Surg*. 2007;31:344-52.
3. Luo S, Haranal M, Deng MX, Varenbut J, Runeckles K, Fan CPS, et al. Low preoperative superior vena cava blood flow predicts bidirectional cavopulmonary shunt failure. *J Thorac Cardiovasc Surg*. 2020;160:1529-40.e4.
4. Bravo MC, Lopez-Ortego P, Sanchez L, Riera J, Madero R, Cabanas F, et al. Randomized, placebo-controlled trial of dobutamine for low superior vena cava flow in infants. *J Pediatr*. 2015;167:572-8.
5. Ono M, Burri M, Mayr B, Anderl L, Cleuziou J, Strbad M, et al. Flow Dynamics of bilateral superior cavopulomonary shunts influence outcomes after Fontan completion. *Pediatr Cardiol*. 2020;41:816-26.
6. Keizman E, Tejman-Yarden S, Mishali D, Levine S, Borik S, Pollak U, et al. The bilateral bidirectional Glenn operation as a risk factor prior to Fontan completion in complex congenital heart disease patients. *World J Pediatr Cong Heart Surg*. 2019;10:174-81.