PULMONARY ARTERY SIZE AT THE TIME OF BIDIRECTIONAL CAVOPULMONARY SHUNT AND FONTAN SURGERY INFLUENCES LONG-TERM OUTCOMES

To the Editor:

We were delighted to read the excellent article of Itatani and associates¹ published in the July 2011 issue of this *Journal*, which demonstrated that a small pulmonary artery index at the time of the Fontan operation resulted in suboptimal hemodynamics. This finding comes at a time when the impact of pulmonary artery size on outcome after Fontan surgery remains controversial.² Baek and colleagues³ have recently stated that pulmonary artery index does not influence late outcomes in Fontan survivors, so much so that intermediate procedures aimed at augmenting the pulmonary arteries between the bidirectional cavopulmonary shunt (BCPS) and Fontan operation are not justified. Currently, data on the minimum acceptable pulmonary artery size before the Fontan procedure are limited. The most likely reason for this is that in most centers, pulmonary artery index is not routinely measured before BCPS and Fontan. Further, current studies focus only on short-term or intermediate-term outcomes. We⁴ have previously demonstrated that BCPS serves as a selection process for Fontan surgery and it is likely that patients are no longer offered Fontan surgery if their

TABLE 1. Patient characteristics

Characteristic	N = 33
Dominant diagnosis, n (%)	
Tricuspid atresia	5 (15)
Double-inlet left ventricle	4 (12)
Complete atrioventricular canal	5 (15)
Pulmonary atresia with intact ventricular septum	2 (6)
Hypoplastic left heart syndrome	14 (43)
Complex	3 (9)
Predominant ventricular morphology, n (%)	
Left	12 (36)
Right	20 (61)
Biventricular	1 (3)

pulmonary arteries are too small. While Itatani and colleagues¹ determined that a Nakata index of less than 110 mm²/m² was associated with a poor hemodynamic profile during exercise, it is likely that with additional years of follow-up, a higher cutoff could be identified. We recently examined the correlation between Nakata index before BCPS and before Fontan surgery in 33 consecutive patients who underwent serial angiography at the Royal Children's Hospital Melbourne between January 2004 and December 2009 (Table 1). Mean time between angiographic studies was 3.4 ± 1.3 years. Mean Nakata index before BCPS was 253.5 ± 129.2,

and mean Nakata index before Fontan was 268.0 ± 126.7. We found no significant increase in Nakata index between the time of BCPS and Fontan ($P = .27$ using the paired Student *t* test) (Figure 1). This finding confirms that no significant pulmonary growth is achieved once a cavopulmonary circulation has been instituted. It is therefore possible that pulmonary artery augmentation between the time of BCPS and Fontan is still warranted. However, we acknowledge that more evidence is required. Therefore, we strongly advocate the routine measurement of pulmonary artery index before BCPS and before Fontan surgery.

FIGURE 1. Correlation of Nakata index before BCPS and before Fontan. BCPS, Bidirectional cavopulmonary shunt.

The Editor welcomes submissions for possible publication in the Letters to the Editor section that consist of commentary on an article published in the *Journal* or other relevant issues. Authors should: • Include no more than 500 words of text, three authors, and five references. • Type with double-spacing. • See <http://jtcvs.ctsnetjournals.org/misc/fora.shtml> for detailed submission instructions. • Submit the letter electronically via jtcvs.editorialmanager.com. Letters commenting on an article published in the *JTCVS* will be considered if they are received within 6 weeks of the time the article was published. Authors of the article being commented on will be given an opportunity of offer a timely response (2 weeks) to the letter. Authors of letters will be notified that the letter has been received. Unpublished letters cannot be returned.

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Reply to the Editor:

We appreciate the letter by Xu and colleagues regarding our article, and we are delighted with their thoughtful insights into our results.¹ They insist on the importance of routine measurement of pulmonary artery index (PAI) or Nakata index before bidirectional cavopulmonary shunt (BCPS) and Fontan operation, based on their clinical evidence that no significant pulmonary arterial growth can be expected after BCPS. Although there have been several reports that small pulmonary arterial size does not affect midterm results after Fontan,² there have not been sufficient clinical data about patients with PAI around 100 mm²/m² or

smaller; therefore, it is difficult to define lower limit of the PAI based only on statistics or on clinical experiences. We created numerical models of extremely small pulmonary arterial size and discussed the lower limit from a hemodynamic point of view.

As they describe, the cutoff value could be higher with the increase in the patient's body size if the pulmonary arterial size would not change once a cavopulmonary circulation has been instituted. Our cutoff value 110 mm²/m² was derived using the computational fluid dynamic (CFD) models based on 17 Fontan patients whose ages were 36.0 ± 32.0 months old and body surface areas 0.53 ± 0.16 m².¹ Because it is difficult to consider body growth or tissue generation in CFD models, cutoff value estimation in older patients requires additional models of larger body size. However, as Xu and colleagues pointed out, if pulmonary arterial size will not change drastically after BCPS, and because conduit size does not change, the shape of the anastomosis site would not change other than superior vena cava (SVC) diameter, and hemodynamics will depend on the total venous flow amount and flow distribution between the SVC and inferior vena cava (IVC). From our results, drastic increase of the venous pressure and energy loss was observed if the PAI dropped lower than 100 mm²/m², and this tendency did not change even if IVC flow increased exercise models.¹ We could conclude that the patient with a PAI less than 120 to 140 mm²/m² at the time of Fontan procedure would be problematic in long-term follow-up periods.

As Tan and colleagues³ pointed out, BCPS represents a selection process in the Fontan pathway, and small pulmonary arterial size would be paid attention to, despite the recent controversial evidences to PAI.² Surgical strategies to patients with extremely small pulmonary arteries (PAI under 100 mm²/m²), including complete pulmonary arterial augmentation

to the right and left pulmonary upper lobe branches with patch material,² or interstage additional flow for the purpose of pulmonary arterial augmentation warrants further study.

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THE SELECTED SEGMENTAL INFLATION TECHNIQUE FOR PULMONARY SEGMENTECTOMY: PROS AND CONS

To the Editor:

We read with interest the article titled, "Extremely rare but potential complication of diffuse brain edema due to air embolism during lung segmentectomy with selected segmental inflation technique by syringe needle during video-assisted thoracoscopic surgery," by Otsuka and colleagues¹ in the November issue of the *Journal of Thoracic and Cardiovascular Surgery*. We are interested in their experience and would like to make some comments.

We have been using the selected segmental inflation technique with a butterfly needle.² Japanese authors have written articles on identifying the intersegmental plane. Interestingly, the

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