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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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2 published cases^{1,3} with air embolism have something in common: an S8 segmentectomy. At present, we have no idea what this means. Is the anatomy of the vascular structures a risk factor?

We also considered air embolism, and our article,² which stated, "Potential pitfalls include anomalous bronchial anatomy and air embolism if the pulmonary artery branch is inadvertently punctured," warned of this. We have performed anatomic segmentectomies in 53 patients as of September 2011 and have never experienced an air embolism.⁴ We might have just been lucky. However, we take the following steps to avoid air embolism:

- The targeted vessels are divided first.
- When we are certain that the targeted bronchus has been identified, we always divide the bronchus first, hoist the bronchial stump with a string or forceps, and then try to insert the needle into the bronchial stump in the direction of the long axis of the bronchus.
- We always use 100% oxygen gas and a 23-gauge butterfly needle, which is a relatively thin needle.
- The instillation of oxygen into the bronchus is limited to 0.5 to 1.5 L, and the oxygen flow rate is no greater than needed, which prevents excessive air flow into the pulmonary parenchyma.
- If vessel puncture is of particular concern, a thin catheter with a balloon is used instead of a butterfly needle.

We would like to ask Otsuka and associates the following questions:

- What is the direction of puncture of the targeted bronchus?
- What flow rate or air pressure is used?
- Why do you use an 18-gauge needle; is the stump too thick for insertion of a B8?
- Although it was confirmed that there was no blood regurgitation, was air reflux confirmed?

- It is odd that air was not confirmed in the target area after the air was blown into the tube. We postulate that the needle was inserted into the pulmonary parenchyma. If air were to be instilled into the pulmonary parenchyma, an air embolism would not be unusual, as seen with the computed tomography-guided marking technique.⁵

Would you please comment on the last point and elaborate on our questions?

No matter how careful we are, problems can occur, and this may serve to heighten our caution. Finally, we thank Otsuka and associates for providing important information on the pros and cons of the selected segmental inflation technique.

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Reply to the Editor:

We thank Kamiyoshihara, Nagashima, and Igai for their comments on our article¹ and are pleased to reply.

Pulmonary segmentectomy with video-assisted thoracic surgery procedures has been one of the common methods for lung cancer as smaller tumors have begun to be identified. The selected segmental inflation technique is frequently used in Japan for detecting the intersegmental plane.^{2,3} We also used the technique with an 18-gauge needle, as we mentioned.¹ We punctured the bronchus longitudinally just as Kamiyoshihara, Kakegawa, and Morishita² described. To puncture a bronchus, we use a relatively thick needle, which is less resistant while air is being blown. The punctured stump of the B8 on this occasion was more than 5 mm across. There was no thickening of the bronchial wall, which we did not find difficult to puncture. We used air, not oxygen, to inflate the selected segment to avoid explosion. Air was blown at a pressure of 0.1 MPa by using a regulator. No blood regurgitation was confirmed under atmospheric pressure when the inner needle was removed after the syringe needle punctured the bronchus. Inasmuch as negative pressure was not applied by using a syringe, air regurgitation was not confirmed.

As Kamiyoshihara, Nagashima, and Igai, pointed out, it is odd that air was not confirmed in the target area after the air was blown into the tube. We would like to suggest 2 possible reasons for this. First, as the authors suggested, air blown into the lung parenchyma via the tip of the needle caused air embolism at the end. The other possible reason is that the tip of the needle moved accidentally into the vein, which allowed air to be blown directly into it, causing air embolism. It is hard to ascertain which mechanism caused the complication this time. There would be less risk of air embolism if we adopted the technique that Kamiyoshihara has used.