Bidirectional Dynamic Change in Shunt Flow Across a Small Ventricular Septal Defect in a Patient With a Left Ventricular Assist Device

Tasuku Sato, MS,a Toru Hashimoto, MD, PhD,b,c Yusuke Ishikawa, MD,b Takeo Fujino, MD, PhD, b Ichiro Sakamoto, MD,b Taiki Higo, MD, b Akira Shiose, MD, PhD,a,d and Hiroyuki Tsutsui, MD, PhDb

a Echocardiography Laboratory, Kyushu University Hospital Heart Center, Fukuoka, Japan
b Department of Cardiovascular Medicine, Kyushu University Hospital Heart Center, Fukuoka, Japan
c Department of Advanced Cardiopulmonary Failure, Faculty of Medical Sciences, Kyushu University, Fukuoka, Japan
d Department of Cardiovascular Surgery, Kyushu University Hospital Heart Center, Fukuoka, Japan

A 50-year-old man implanted with a durable left ventricular assist device (LVAD; HeartMate 3, Abbott Laboratories, Chicago, IL) for idiopathic dilated cardiomyopathy was transferred to our hospital for further follow-up. He had not been diagnosed with any intracardiac shunts before LVAD implantation. On admission, echocardiography revealed a small left-to-right (L-R) shunt flow across the interventricular septum, indicating muscular ventricular septal defect (VSD). As the pump speed was raised during an echocardiographic ramp test for LVAD optimization, the L-R shunt flow at low pump speed (Fig. 1, A and D) gradually changed to a to-and-fro flow (Fig. 1, B and E), and finally to a continuous right-to-left (R-L) shunt flow at high pump speed (Fig. 1, C and F). Oxygen saturation simultaneously declined from 99% to 92% as the shunt flow changed from L-R to R-L. The LVAD pump speed was set at the point at which a balanced biventricular chamber size and L-R dominant shunt flow without oxygen desaturation were observed. Repair of the VSD was not considered, as the R-L shunt flow at rest could be avoided by optimization of the LVAD pump speed, and the patient had no clinical history of paradoxical thromboembolism. If systemic hypoxia due to R-L shunt manifests in the future, surgical repair will be necessary, as the position of the LVAD inflow cannula is close to the VSD, and percutaneous closure will be technically difficult.

Defects within atrial or ventricular septa theoretically can be sources of significant R-L shunt and hypoxemia after LVAD implantation. It is known that patent foramen ovale causes oxygen desaturation and paradoxical thromboembolism due to R-L shunt in patients with an LVAD.1-3 Our patient did not have prior evidence of interventricular communication. Elevated right heart filling pressure due to secondary pulmonary hypertension might have masked as shunt flow before LVAD implantation in the present case. In fact, the patient showed severe isolated post-capillary pulmonary hypertension; mean pulmonary arterial pressure before LVAD implantation was high at 34 mm Hg, even under support with continuous infusion of dobutamine and an intra-aortic balloon pump. To-and-fro or R-L shunt flow in diastole have been documented in cases of large VSD or VSD with severe pulmonary hypertension.4,5 The finding of continuous R-L shunt across a morphologically small VSD without advanced pulmonary hypertension might be unique to patients with an LVAD.

Novel Teaching Points
- Bidirectional shunt flow across a small VSD is inducible by pump speed settings in patients with an LVAD.
- Optimization of LVAD pump speed is important to avoid hypoxemia and paradoxical thromboembolism due to R-L shunt in cases of residual intracardiac shunt, even if it is small.

Received for publication February 26, 2021. Accepted March 9, 2021.

Ethics Statement: The case we reported here has adhered to the relevant ethical guidelines.

Corresponding author: Dr Toru Hashimoto, Department of Cardiovascular Medicine, Kyushu University Hospital, 3-1-1 Maidashi, Higashi-ku, Fukuoka, 812-8582, Japan. Tel.: +81-92-642-5360; fax: +81-92-642-5374. E-mail: torten79@cardiol.med.kyushu-u.ac.jp
See page 985 for disclosure information.

https://doi.org/10.1016/j.cjco.2021.03.004
2589-790X/© 2021 The Authors. Published by Elsevier Inc. on behalf of Canadian Cardiovascular Society. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Changes of VSD shunt direction associated with LVAD pump speed adjustment in the present case demonstrate the risk of R-L shunt and hypoxemia at high pump speed under residual intracardiac shunt.

**Funding Sources**

This work was supported by the Japan Society for the Promotion of Science (JSPS) KAKENHI Grant JP19K17567 awarded to Toru Hashimoto.

**Disclosures**

The authors have no conflicts of interest to disclose.

**References**

1. Bartoli CR, McCants KC, Birks EJ, Flaherty MP, Slaughter MS. Percutaneous closure of a patent foramen ovale to prevent paradoxical thromboembolism in a patient with a continuous-flow LVAD. J Invasive Cardiol 2013;25:154–6.

2. Fischer Q, Kirsch M, Brochet E, Juliard JM. Bailout transcatheter closure of patent foramen ovale for refractory hypoxaemia after left ventricular assist device implantation. Interact Cardiovasc Thorac Surg 2015;21:246–8.

3. Srinivas CV, Collins N, Borger MA, Horlick E, Murphy PM. Hypoxemia complicating LVAD insertion: novel application of the Amplatzer PFO occlusion device. J Card Surg 2007;22:156–8.

4. Zeve B, Keren G, Sherer J, et al. Bidirectional flow in congenital ventricular septal defect: a Doppler echocardiographic study. Clin Cardiol 1987;10:143–6.

5. Stojnic B, Pavlovic P, Ponomarev D, Aleksandrov R, Pirovic M. Bidirectional shunt flow across a ventricular septal defect: pulsed Doppler echocardiographic analysis. Pediatr Cardiol 1995;16:6–11.