

Direct Left Atrial Pressure Measurement with Pressure Sensing Wires in Complex Univentricular Heart Disease

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Abstract

In congenital heart disease, pressure-sensing wires provide an alternative method of obtaining important hemodynamic information when it cannot be obtained with traditional fluid-filled catheters. Here, we illustrate how pressure-sensing wires are vital for patients with univentricular heart physiology and an atrial stent *in situ* to prove candidacy for bidirectional cavopulmonary anastomosis.

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Key Words

Pressure wire • Congenital heart disease • Pediatric cardiology

Introduction

Pressure-sensing wires are guidewires, typically 0.014 inches in diameter, with high fidelity tip sensor technology for pressure measurement. In adult cardiology, their use has become routine for functional assessment of atherosclerotic coronary artery lesions by calculating fractional flow reserve [1]. This technique has also been described in pediatric patients with Kawasaki disease [2], but few reports have been published on the use of pressure wires for pediatric patients with congenital heart disease.

In children with single ventricle physiology, the accurate measurement of pulmonary vascular resistance (PVR) is critical for assessing the suitability of bidirec-

tional cavopulmonary anastomosis. Occasionally, the sequelae of previous interventions may preclude the use of traditional fluid-filled catheters to obtain this critical hemodynamic data. Pressure wires provide an alternative method of obtaining this information. Here, we present two cases in which the use of pressure wires allowed an accurate pre-surgical assessment and successful outcome where the absence of such data may have precluded surgical care.

Case Presentation

Two infants with complex univentricular heart disease and atrial septal stents *in situ* were taken to the catheterization laboratory for pre-bidirectional cavopulmonary anastomosis evaluation. We used a standard technique for pressure-sensing wire (St. Jude Medical pressure wire FFR Aeris Agile Tip 0.36mm in width, 175cm in length, St. Paul, MN) measurement [3]. An end-hole guiding catheter (Terumo 4/5-F) was placed proximal to the area of interest. A standard fluid-filled pressure transducer was attached to the catheter system. The sensor of the pressure wire was set to zero *ex vivo*. The wire was then inserted into the guide catheter until the tip extended just beyond the end of the catheter (still in the same vascular structure). In this position, we equalized the pressures registered by both the pressure wire and catheter. The pressure wire was advanced to the area of interest, and pressure was measured. Following measurement, with



the pressure wire back at the tip of the catheter, we confirmed equal pressure signals from the wire and catheter to ensure no significant drift. Values used for predicted oxygen consumption ($\text{ml}/\text{min}/\text{m}^2$) when calculating pulmonary blood flow were taken from tables created by Seckeler et al. using a new predictive equation [4].

Patient 1 had a diagnosis of double inlet left ventricle with atrioventricular and ventriculoarterial discordance and a hypoplastic left-sided right ventricle. A pulmonary artery band was placed at 1 month of age. At 2.5 months of age, he underwent atrial septal stent implant (8×18 mm Genesis, Cordis, Ireland) for

a restrictive atrial septum in the context of increasing stenosis of the left atrioventricular valve. At 6 months of age, pre-bidirectional cavopulmonary anastomosis cardiac catheterization demonstrated an elevated mean pulmonary pressure of 23 mmHg. Left ventricular end diastolic pressure was 4 mmHg, and right atrial pressure was 4 mmHg. We obtained a mean pulmonary capillary wedge pressure of 12 mmHg and decided to proceed with obtaining direct left atrial pressure given the importance of an accurate determination of PVR. The obtuse angulation of the atrial stent prevented a fluid-filled hemodynamic catheter from passing into the left atrium (Figure 1A-C). Using a pressure wire,

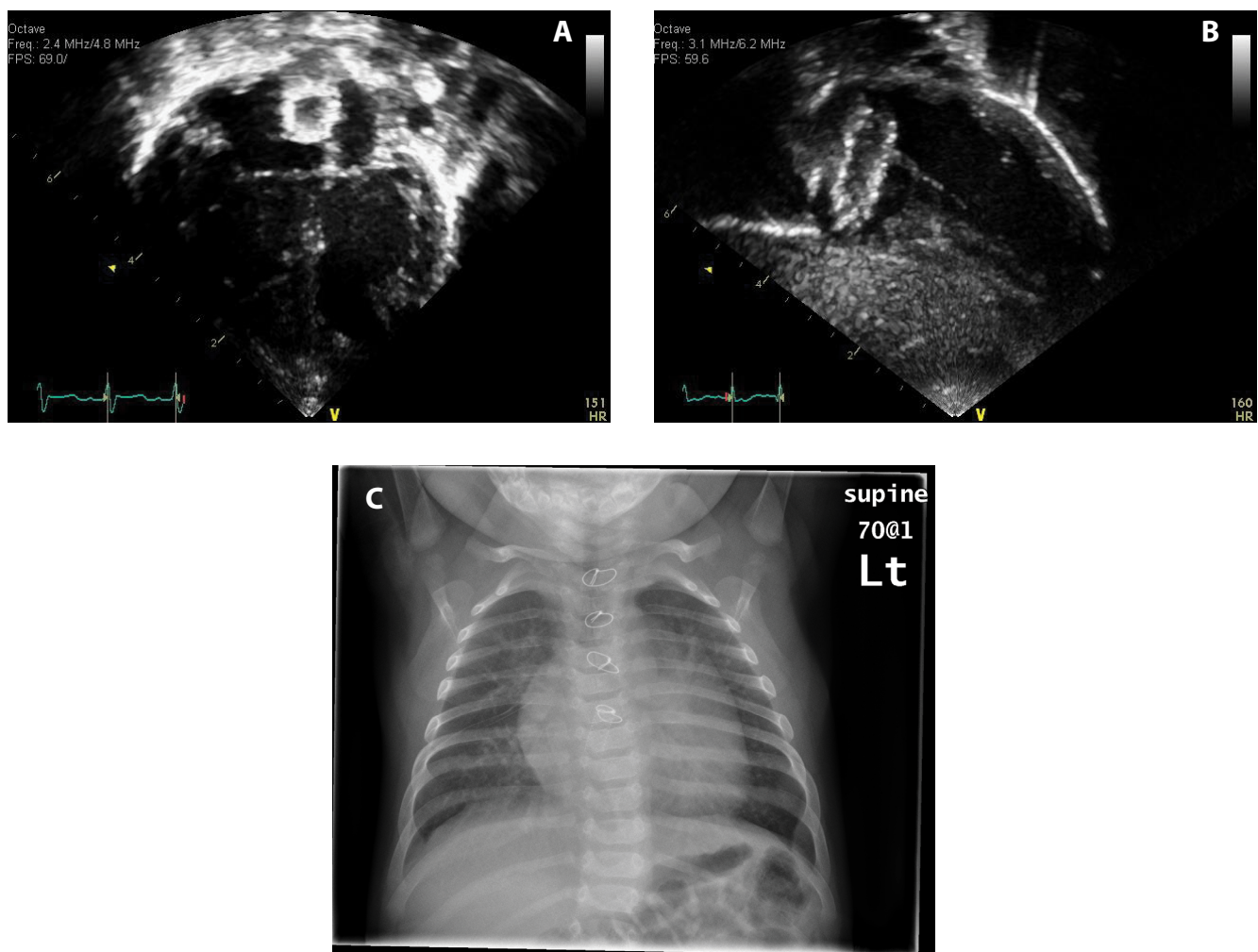


Figure 1. *Panel A.* Two-dimensional echocardiogram, four-chamber apical view. The atrial stent was seen lying in an almost horizontal anterior posterior position. *Panel B.* Two-dimensional echocardiogram, subcostal view directed at the atrial septum. The atrial stent protrudes 2/3:1/3 into the right atrial cavity, precluding passage of a fluid-filled catheter to the left atrium. *Panel C.* Anterior-posterior chest radiograph demonstrating atrial stent position.

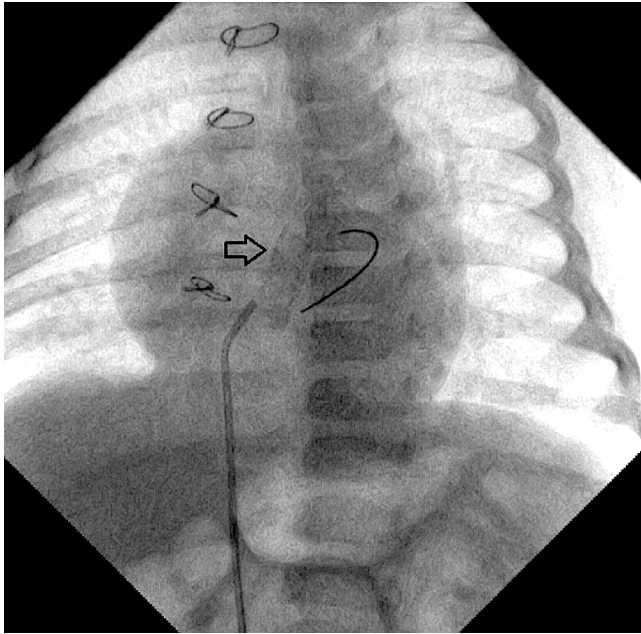


Figure 2. Left anterior oblique, 30°. 4-F terumo angle catheter in right atrium adjacent to a Genesis atrial stent (*open arrow*). Note the acute angulation of the stent compared with the atrial septum. The pressure wire was passed through the body of the stent with the radio-opaque end curled within the left atrium. The pressure sensor was located at the non-opaque-to-opaque junction of the wire.

which easily passed through the side cells of the stent and then traversed to the left atrium, we were able to measure the left atrial pressure at 12 mmHg with a right atrial pressure of 4 mmHg. Using left atrial pressure, the calculated PVR was 1.8 Wood units. As such, we determined that the patient was a satisfactory candidate for bidirectional cavopulmonary anastomosis.

Patient 2 had a diagnosis of atrioventricular and ventriculoarterial discordance, hypoplastic left-sided right ventricle, left atrioventricular valve atresia, and pulmonary atresia. At three days of age, he had a modified right Blalock-Taussig shunt and balloon atrial septostomy for a restrictive atrial septum. He went on to have an atrial septal stent (5 × 16 mm Liberte, Boston Scientific, Marlborough, Massachusetts) placed at six weeks of age. At 3.5 months of age, the patient's pre-bidirectional cavopulmonary anastomosis evaluation showed an elevated mean pulmonary artery pressure of 21 mmHg. Left ventricular end diastolic pressure was 7 mmHg. Similar to the case of Patient 1, a catheter could not be passed through the atrial

septal stent to the left atrium, but a pressure wire was successfully passed through a side cell of the stent into the left atrium, and a direct pressure measurement was obtained (Figure 2). Left atrial pressure was significantly elevated at 16 mmHg compared with a right atrial pressure of 5 mmHg. PVR was calculated as 1.5 Wood units, making the patient a suitable candidate for bidirectional cavopulmonary anastomosis.

Pulmonary pressures were elevated in both patients, but this was in the setting of left atrial hypertension secondary to a restrictive atrial septum (as the lumen of the previously placed stent was now too small for the size of the patient) with normal PVR. Both patients underwent bidirectional cavopulmonary anastomoses and had uneventful postoperative courses. The information obtained using pressure-sensing wires directly contributed to our management decisions and was instrumental in ensuring that the patients were not denied the appropriate next-stage palliative surgery.

Discussion

For children with single ventricle physiology, the accurate assessment of PVR is essential as part of the preoperative evaluation to determine suitability for surgical palliation. For patients in whom measured pulmonary pressure suggests that PVR may be elevated, the perioperative risk becomes difficult to accurately ascertain. The ability to directly measure left atrial pressure in these children to calculate PVR is critical for optimal surgical decision-making. Pulmonary capillary wedge pressure can be used as a surrogate for left atrial pressure. However, there is some error in predicting left atrial pressures using this technique, which can be amplified at higher wedge pressure measurements [5]. Given that such a discrepancy could result in an erroneously low PVR calculation, direct left atrial pressure measurement with a pressure-sensing wire may be more appropriate given the important clinical decision based on these measurements. Future evaluation of the relationship between the pulmonary capillary wedge pressure and left atrial pressure in children with elevated left atrial pressures would be useful.

There is a paucity of published reports of pressure wire use in children with congenital heart disease. However, pressure wires have been safely and successfully used to measure pulmonary artery pressure

via a central or Blalock-Taussig shunt [6]. Zampi et al. also described the role of pressure wires in the setting of hypoplastic left heart syndrome palliated with the hybrid stage 1 procedure [7]. Pressure wires were used to measure distal pulmonary artery pressure and subsequently assess the adequacy of pulmonary bands. Rates of re-operation for pulmonary artery band adjustment were less in the group in which pressure wires were used for this purpose. Pressure wire use has also been reported in the human fetus during aortic balloon valvuloplasty [8].

Pressure-sensing wires are feasible and safe to use in the pediatric setting. We demonstrated how

pressure-sensing wires can provide accurate hemodynamic data not otherwise obtainable with conventional catheters in the setting of complex univentricular congenital heart disease.

Conflict of Interest

The authors have no conflict of interest relevant to this publication.

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