Catheter hemodynamics and pulse pressure in patent ductus arteriosus: Back to the basics

Fadi Bitar[1], Ziad Bulbul[1, 2]

[1]Department of Pediatrics and Adolescent Medicine, American University of Beirut, Beirut, Lebanon
[2]Children's Heart Center, American University of Beirut, Beirut, Lebanon

Related article
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Correspondence to:
Ziad Bulbul, MD,
Children's Heart Center,
And Department of Pediatrics and Adolescent Medicine,
American University of Beirut,
Beirut, Lebanon,
phone: +96 176 793 838,
e-mail: ziad.bulbul@aub.edu.lb

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In this issue of the *Polish Heart Journal*, Trębacz et al. [1] in their article titled "A new approach to evaluating aortic pressure changes during the transcatheter closure of patent ductus arteriosus (PDA) in pediatric patients" presented their data on invasive measurement of the aortic pressure in patients undergoing transcatheter closure of PDA. The study involved 50 children, in whom systolic blood pressure gradients were measured between the ascending and descending aortas before and after PDA closure. The results showed that while most patients experienced an "improvement" in pressure gradients, a considerable number did not. They concluded that simple pressure measurements could enhance understanding of hemodynamic changes during PDA closure and help assess the return to physiological conditions post-procedure. The authors recommended further studies to validate these observations and explore their clinical implications.

Pulse pressure (PP), defined as the difference between systolic blood pressure (SBP) and diastolic blood pressure, is influenced by arterial stiffness and flow pulsatility. It is well established that peripheral PP and SBP exceed the central pressures [2]. Simplistically, this phenomenon occurs due to the "amplification phenomenon", where the amplitude of a pressure wave is higher in peripheral than central arteries [3]. The aortic pressure waveform comprises two components: a forward pressure waveform and a backward pressure waveform. The forward wave is produced by the ejection of blood from the left ventricle while the backward wave results from the summation of pressure wave reflections. These reflections originate from discontinuities in the elastic properties of the arterial tree, where variations in arterial stiffness occur. In the normal aortic tree, the primary reflecting point, which represents the integrated pressure wave reflections, is in the region of the aortic bifurcation [4]. The reflected pressure wave reaches the descending aorta earlier in the cardiac cycle compared to the ascending aorta. Consequently, the PP of the composite pressure waveform at the descending aorta is greater than at the ascending aorta.

Aortic pressure augmentation increases with age, primarily due to changes in arterial stiffness. However, Shieh et al. [5] found that the pressure waveforms in infants and children resemble those of older adults. This phenomenon is attributed to differences in body length and the timing of wave reflection. In children, the reflection wave returns early not because of arterial stiffness or rapid pulse wave velocity, as seen in older individuals, but due to their shorter body length [6].

Murakami et al. [7] studied the PP in 54 patients under 15 years of age, none had aortic regurgitation or a shunt at the aortic level. The descending aortic SBP was higher, and the PP was wider than those in the ascending aorta. The PP difference between the descending aorta and the ascending aorta was 4.5 ± 2.7 mm Hg. The difference in the PP has a positive relationship with age and the mean arterial pressure [7].

The authors explain the "pathological" ΔP phenomenon by noting that a persistent PDA causes some blood to "leak" into the pulmonary circulation, reducing the blood volume below the duct, as noted by Talner [9]. Additionally, the volume of blood reaching the ascending aorta increases in the presence of a PDA. Bruckheimer et al. [10] reported that closing a PDA decreased the left ventricular outflow tract gradient in three patients due to reduced left ventricular preload. Similarly, Xie et al. [11] observed a 10 mm Hg decrease in the aortic valve gradient in eleven patients after PDA closure. The augmented flow across the LVOT extends to the ascending aorta and may be responsible for the rise in systolic blood pressure. Furthermore, the runoff into the pulmonary artery via the PDA could further decrease the systolic pressure in the descending aorta distal to the PDA orifice, widening the PP. The mean increase in systolic pressure in the ascending aorta was marginal in the series reported in this issue of the *Polish Heart Journal*. This could be explained by the relatively small pulmonary-to-systemic flow ratio, as evidenced by the reported narrow PP in the descending aorta.

While the authors in the current issue detailed the shape of the PDAs in their patients, they did not comment on the size and morphology of the aortic arch isthmus or whether there was any narrowing that might be exacerbated following closure. Masri et al. [8], using the same type of occluder as the device used in this series, reported that the position of the device in the aortic arch might cause immediate narrowing in the lumen. This might explain the increase in gradient across this area, as observed also by Trębacz et al. [1] in 30% of the cohort. The authors did not comment on whether the children with a persistent "pathological" ΔP had angiographic findings of device protrusion or narrowing following PDA closure. The explanation for lower blood pressure in the descending aorta may be due to either a narrowing of the arch at the site of the PDA insertion, a lower volume of circulating blood (stroke volume distal to PDA), or abnormal vessel wall elasticity.

Lastly, PDA closure has made remarkable progress, evolving from Porstmann's initial reports on older children and adults [12] to contemporary interventions in premature infants. Diagnostic and monitoring methodologies have likewise advanced. Early procedures relied on physical examination, hemodynamic assessment, and angiography within the cardiac catheterization laboratory. Recently, many centers have eschewed hemodynamic assessment, depending exclusively on echocardiography and angiography for diagnostic and procedural guidance. While this streamlined approach has been sufficient in most instances, conducting a meticulous hemodynamic assessment in the catheterization laboratory — encompassing evaluations of shunt magnitude, pulmonary artery pressure, and pressure gradients across the isthmus before and after closure — would offer a more comprehensive understanding in selected cases.

Article information

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