Intraoperative assessment of pulmonary artery pressure using transesophageal echocardiography in patients undergoing cardiac surgery

John F. Zaki, MD^a, Muaz Ajjazi, MD^b , Michael A. Wong, DO^a, Warren Choi, MD^a , Ovidiu L. Moise, MD^a, Stephanie F. Tran, MD^a, Timothy R. Pawelek, MD^a, Shao F. Zhou, MD^a, Roy Sheinbaum, MD^a, Alexandra C. Fonseca, BS^b, and Travis Markham, MD^a

^aDivision of Cardiovascular and Thoracic Anesthesiology, Department of Anesthesiology, The University of Texas Health Science Center at Houston (UTHealth), McGovern Medical School, Houston, Texas; ^bThe University of Texas Health Science Center at Houston (UTHealth) McGovern Medical School, Houston, Texas

ABSTRACT

We performed a retrospective chart review to investigate a potential relation between pulmonary artery (PA) diameter as measured by intraoperative transesophageal echocardiography and PA pressures measured by PA catheter with the aim of determining whether main PA diameter can aid clinicians in the diagnosis of PA hypertension. A total of 82 adult patients undergoing cardiac surgery were included in our study. Main PA diameter showed a moderate correlation with systolic and diastolic pressures, $r = 0.576$ (95% confidence interval [CI], 0.407–0.703), $P < 0.001$, and $r = 0.504$ (95% CI, 0.319–0.648), $P < 0.001$, respectively. The authors believe that although a moderate correlation exists between main PA diameter and PA pressure, confounding hemodynamic variables prevent main PA diameter from being an accurate and reliable means of diagnosing PA hypertension.

KEYWORDS Pulmonary artery diameter; pulmonary artery hypertension; pulmonary artery pressure; transesophageal echocardiography

Although right-sided heart catheterization remains the gold standard for the diagnosis of pulmonary hypertension, it is an invasive procedure, posing a risk of morbidity (1.1%) and mortality (0.06%) to patients.¹ As such, additional diagnostic methods have been investigated as alternative means to identify and assess this patient population. Doppler echocardiography with transesophageal echocardiography (TEE) is one such method that is used as an initial screening tool to obtain estimates of pulmonary artery (PA) pressures. As a noninvasive technique, it poses fewer risks to patients while being both inexpensive and widely available.² Doppler echocardiography can be utilized to measure PA diameter, which is worth investigating due to the possibility of a correlation between PA diameter and PA pressure. To this effect, we present a retrospective chart review of 82 patients investigating a potential relation between PA diameter and PA pressure as obtained via TEE.

METHODS

A retrospective chart review was performed of 82 patients undergoing cardiac surgery at a large academic medical center. Patients were included in the study if they were at least 18 years old and underwent cardiac procedures in which both a PA catheter and a TEE were utilized. We excluded patients diagnosed with acute mitral regurgitation to avoid the possibility of acutely elevated PA pressure leading to potentially confounding results.

Patient gender, age, height, and weight were recorded. After placement of the TEE probe, the main PA diameter in the midesophageal ascending aortic short-axis view was measured just proximal to the main PA bifurcation. If significant changes in PA pressures were observed, the same measurement was repeated after the bypass procedure. The right PA diameter was also recorded immediately above the bifurcation site as standard procedure in our institution. A leading

Corresponding author: Muaz Ajjazi, MD, University of Texas Health Science Center at Houston McGovern Medical School, 7000 Fannin Street, #1200, Houston, TX 77030 (e-mail: muazajz@gmail.com)

Received March 18, 2018; Revised April 19, 2018; Accepted April 23, 2018.

edge-to-leading edge measurement was taken in the midesophageal ascending aorta (short-axis view). Two to three measurements were taken per patient, and the data were recorded by eight faculty members. Each TEE was reviewed by a second faculty member intraoperatively.

A PA catheter was placed in every patient as standard of care. TEE was utilized to confirm placement of the distal PA catheter within the distal main PA. PA pressures as recorded by our electronic medical record were correlated with the time the TEE PA diameter measurements were performed. The time stamps from the TEE device and the electronic medical record were then synchronized.

Statistical analysis was performed using Stata 13.0 software. Pearson's correlation coefficient and simple linear regression were used to evaluate the relationship between PA pressure (systolic, diastolic, and mean) and PA diameter.

RESULTS

Of the 82 patients included, 55 (67%) were men and 27 (33%) were women. The mean age of the patients was 59 years (SD = 14.12), and their mean body mass index was 29.77 kg/m² (SD = 6.50). *Table 1* presents the summary of patient demographic characteristics and mean PA pressures along with mean PA diameters measured. *Table 2* depicts the calculated Pearson correlation coefficients. The main PA diameter had a moderate correlation with systolic and diastolic pressures, with coefficients of 0.576 (95% confidence

interval [CI], 0.407–0.703), *P* < 0.001, and 0.504 (95% CI, 0.319–0.648), *P* < 0.001. However, the right PA diameter had a weak correlation with PA pressures (0.250 and 0.184).

DISCUSSION

The results of our study demonstrate that main PA diameter, as determined by intraoperative TEE, may have a moderate correlation with the systolic and diastolic PA pressure as measured by PA catheterization. No such correlation was observed between right PA diameter and PA catheter pressures.

A recent prospective study by Rich et al sought to investigate the accuracy of PA systolic pressure measured by Doppler echocardiography compared to right heart catheterization. Their results showed a moderate correlation between PA systolic pressure from right-sided heart catheterization and Doppler echocardiography with an *r* value of 0.68 (*P* < 0.001), but Doppler estimates were found to be inaccurate 51% of the time. Both underestimations and overestimations of PA systolic pressure were observed, with a tendency toward underestimated values.³ Performing both measurements simultaneously did not alter these findings, suggesting that variations in hemodynamics did not account for the measured inaccuracy. A prospective study performed by Fisher et al demonstrated similar results, with inaccurate measurements in 48% of cases. This study included 65 patients with varying degrees of pulmonary hypertension and obtained Doppler measurements within 1 hour of right-sided heart catheterization to eliminate changes in hemodynamic status.⁴

The situation being investigated is nuanced, and despite the strategic measures taken, our study has limitations. First, patient factors including volume status and hemodynamic variables likely influenced the diameters that were recorded, and these variations were not accounted for in the data analysis. Pulmonary vasodilatation caused by general anesthesia may partially account for the lack of a stronger correlation that may be seen under normal physiological conditions. We also did not account for right ventricular functional status. Degree of right ventricular dysfunction may be an important factor influencing hemodynamics, which in turn affect PA diameter measurements.

Because of our study's retrospective nature, it was not possible to perform interventions (i.e., administration of vasoactive medications or fluids) and assess their effects on PA pressure/PA diameter. Therefore, we are unable to state whether the correlation between PA diameter and PA pressure is truly dynamic. Additionally, TEE and the resulting measurements of main PA diameter were recorded by various cardiac anesthesiologists, inevitably leading to some operator-dependent variations despite our double-check verification system. Poor image acquisition windows may have influenced the ability to obtain accurate measurements in some patients, causing us to exclude images of poor quality that could have potentially provided unreliable data. Diameter measurements were also taken at end systole, and variations from this standard may alter data interpretation. Finally, we

Table 1. Summary statistics for continuous variables

	Mean (SD)
Age (years)	59 ± 14
Men	55 (67%)
Body mass index (kg/m ²)	29.8 ± 6.5
PA systolic pressure (mm Hg)	33 ± 11
PA diastolic pressure (mm Hg)	18 ± 7
Main PA diameter (cm)	2.6 ± 0.4
Right PA diameter (cm)	2 ± 0.5

PA indicates pulmonary artery.

Table 2. Pearson correlation coefficients

Diameter	Pressure (mm Hg)	<i>r</i>	95% CI	<i>P</i> value
Main PA	PA systolic	0.576	0.407 to 0.703	<0.001
	PA diastolic	0.504	0.319 to 0.648	<0.001
Right PA	PA systolic	0.250	−0.009 to 0.474	0.056
	PA diastolic	0.184	−0.077 to 0.419	0.163

CI indicates confidence interval; PA, pulmonary artery.

believe that status of pulmonary hypertension with regards to chronicity needs to be taken into account when correlating PA diameter to pressure, because there may be a degree of vascular compensation with significant impact on our results.

Future studies would be better served dividing patients into groups according to current pulmonary hypertension status (normal, mild, moderate, or severe pulmonary hypertension), as well as specific indications for surgery and current severity of disease. Extent of disease is especially important in the context of right ventricular function. We believe that the PA pulsatility index is another metric to be considered. A prospective study would also allow for measuring the impact that different interventions (e.g., fluids, vasoactive medications) potentially have on PA diameter, which would lend insight into what is a dynamic situation. Until these limitations are addressed appropriately, intraoperative TEE cannot be relied on to diagnose and ultimately manage pulmonary hypertension in the operating room.

ORCID

Muaz Aijazi <http://orcid.org/0000-0003-1629-8895>

Warren Choi <http://orcid.org/0000-0003-1147-2006>

1. Hoeper MM, Lee SH, Voswinckel R, et al. Complications of right heart catheterization procedures in patients with pulmonary hypertension in experienced centers. *J Am Coll Cardiol*. 2006;48:2546–2552. doi:10.1016/j.jacc.2006.07.061. PMID: 17174196.
2. Janda S, Shahidi N, Gin K, Swiston J. Diagnostic accuracy of echocardiography for pulmonary hypertension: a systematic review and meta-analysis. *Heart (British Cardiac Society)*. 2011;97(8):612–622. doi:10.1378/chest.9930.
3. Rich JD, Shah SJ, Swamy RS, Kamp A, Rich S. Inaccuracy of Doppler echocardiographic estimates of PA pressures in patients with pulmonary hypertension: implications for clinical practice. *Chest*. 2011;139:988–993. doi:10.1378/chest.10-1269. PMID: 20864617.
4. Fisher MR, Forfia PR, Chamera E, et al. Accuracy of Doppler echocardiography in the hemodynamic assessment of pulmonary hypertension. *Am J Respir Crit Care Med*. 2009;179:615–621. doi:10.1164/rccm.200811-1691OC.