Pulmonary Artery Acceleration Time in Cardiac Surgical Patients

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Objectives: **To examine the potential for using pulmonary Doppler to assess the hydraulic forces opposing right ventricular ejection in a perioperative setting.**

Design: **A prospective, observational study.**

Setting: **A university hospital tertiary-care center.**

Participants: **Participants included 74 patients: 62 undergoing coronary artery bypass grafting and 12 undergoing mitral valve surgery.**

Interventions: **None.**

Measurements and Main Results: **After induction of anesthesia, a pulmonary artery catheter was used to assess pulmonary artery pressures, cardiac output, and pulmonary vascular resistance. Transesophageal echocardiography was performed to measure pulsed-wave Doppler-derived acceleration time (AT) in 3 locations: the right ventricular outflow tract, the main pulmonary artery, and the right pulmonary artery. Flow reversal was observed in the main pulmonary artery in 96% of patients and possibly was responsible for the shorter ATs seen in this location. The best correlations between AT and pulmonary hemodynamic parameters were found in the right pulmonary artery. The relationships were strengthened in a subgroup of patients with elevated pulmonary capillary wedge pressure (PCWP). An acceleration time of 90 ms was associated with elevated pulmonary artery pressure and pulmonary vascular resistance.**

Conclusions: **Flow reversal occurred frequently in the main pulmonary artery. AT in the right pulmonary artery yielded the best correlation with invasive hemodynamic parameters that were strengthened in patients with elevated PCWP. The addition of a PCWP measurement improved the reliability of AT in this patient population.**

KEY WORDS: pulmonary Doppler, acceleration time, pulmonary artery pressure, pulmonary vascular resistance, cardiac surgery

IN THE ABSENCE of invasive monitoring, pulmonary artery pressure (PAP) may be assessed using Doppler interrogation of the tricuspid regurgitant jet.[1,2] However, when using transesophageal echocardiography (TEE), the tricuspid regurgitant jet may prove difficult to interrogate by Doppler. The pulmonary artery Doppler flow contour may be helpful in assessment of the vascular forces opposing right ventricular ejection.[3,4] When measured using transthoracic echocardiography, the pulmonary acceleration time (AT), defined as the time interval from onset to peak pulmonary flow (Fig 1A), has been correlated with PAP and pulmonary vascular resistance (PVR).[5–10] A shorter AT suggests elevated PAP and PVR and, consequently, a larger hydraulic burden on right ventricular ejection. Pulmonary AT may offer an intraoperative alternative in the assessment of pulmonary vascular constraints.

The perioperative measurement of AT using TEE has not been investigated. Pulmonary AT traditionally has been measured using transthoracic echocardiography by placing a pulsed-wave Doppler sample volume in the right ventricular outflow tract (RVOT) near the pulmonary valve. When using TEE, multiple pulmonary artery sampling areas are possible; the easiest is found in the midesophageal ascending aortic short-axis view. However, sampling near the pulmonary valve is problematic when using TEE because views designed to interrogate near the pulmonary valve sometimes are difficult to obtain.

The purpose of this study was to compare pulmonary AT measured in 3 different locations in the pulmonary artery using TEE in a perioperative setting. The authors also assessed whether the AT measured using TEE at each location correlated with invasively determined PAP and PVR.

METHODS

Study Population

This study was approved by the institutional review board before patient enrollment, and written informed consent was obtained from all patients before surgery. Patients scheduled to undergo elective coronary artery bypass grafting or mitral valve surgery were prospectively recruited. Patients were excluded from the study if they were not in sinus rhythm, were unstable, required a balloon pump, required inotropic or vasopressor support, or had contraindications to TEE.

Measurements

After induction of anesthesia (sufentanil, midazolam, rocuronium) and insertion of a pulmonary artery catheter (7.5F Paceport; Edwards Lifesciences, Irvine, CA), an omniplane TEE probe was introduced, and echocardiography was performed using a GE Vivid 7 ultrasound system (GE Healthcare, Wauwatosa, WI). Patients did not receive volatile anesthetics or vasoactive agents during the study period. Patients were mechanically ventilated without positive end-expiratory pressure. A respiratory trace was used to facilitate Doppler measurements at end-expiration.

Echocardiographic Measurements

Pulmonary artery pulsed-wave Doppler was performed by placing a 4-mm sample volume in 3 locations: (1) in the main pulmonary artery (MPA) near the medial border, midway between the pulmonary valve and the bifurcation using a midesophageal ascending aortic short-axis view (Fig 2A); (2) in the right pulmonary artery (RPA) distal to the bifurcation (Fig 2B); and (3) in the RVOT proximal to the pulmonary valve using a transgastric right ventricular inflow (outflow) view optimized for the outflow tract (Fig 2C). AT was measured from the onset of forward pulmonary flow to peak

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1053-0770/2601-0001$36.00/0
http://dx.doi.org/10.1053/j.jvca.2015.04.004

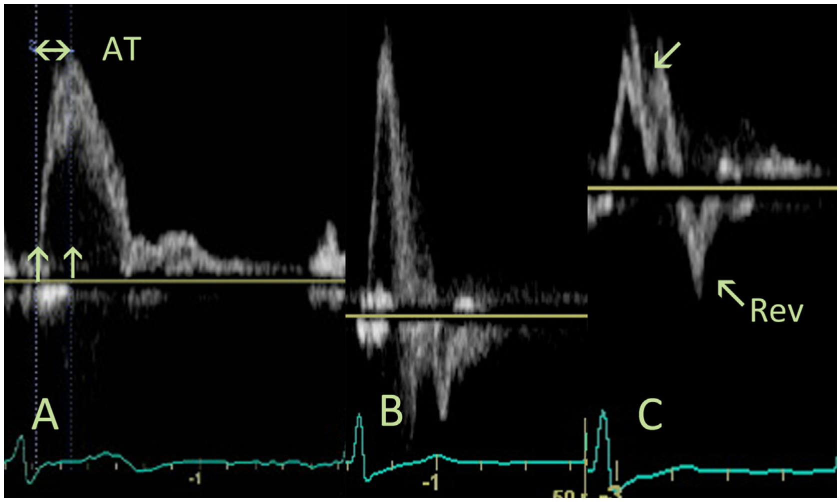

Fig 1. Pulmonary artery pulsed-wave Doppler profile as sampled in the main pulmonary artery. (A) Normal Doppler profile. Acceleration time (AT) is demonstrated by the interval between onset and peak flow (arrows). (B) Triangular-shaped pulmonary Doppler profile. (C) Notched pulmonary Doppler profile (arrow) with flow reversal (Rev) seen below baseline.

flow (Fig 1A) and averaged over 5 nonconsecutive beats at end-expiration. The tricuspid annular plane systolic excursion was measured using 2-D echocardiography in the midesophageal 4-chamber view and averaged over 3 consecutive beats. The left ventricular end-diastolic area and fractional area of change were measured in the transgastric short-axis view and averaged over 3 consecutive beats.

Hemodynamic Measurements

Hemodynamic measurements were performed after the echocardiographic examination to avoid Doppler noise as a result of the injection of normal saline for thermodilution cardiac output determination. Measurements included heart rate; systolic, diastolic, and mean systemic and pulmonary artery pressures; central venous pressure; and pulmonary capillary wedge pressure (PCWP). The transducers were calibrated at midchest level in the supine position. Thermodilution cardiac output measurements were made using the average of three 10-mL room temperature normal saline injections throughout the respiratory cycle. PVR was calculated using a standard formula and expressed in dynes/s/cm^5. Capacitance was calculated as stroke volume divided by pulse pressure and expressed in mL/mmHg.

Data Analysis and Statistical Methods

All images were analyzed offline on a reading station using EchoPAC software (GE Healthcare, Milwaukee, WI) at a later date by 1 observer who was blinded to the hemodynamic data. Continuous variables were tested for normality. Only patient data sets in which all 3 locations could be measured were included in the analysis of comparison of AT by location. Kruskal-Wallis analysis of variance was used to compare AT in the 3 sampling locations. Individual comparisons between locations were made using the Mann-Whitney *U*-test with Bonferroni correction. The degree of correlation between AT and hemodynamic variables was evaluated using linear regression. Linear regression also was used to assess the relationship between AT and the hemodynamic parameters in a subgroup of patients with elevated PCWP (>12 mmHg).

The AT data at each sampling location were separated into groups above and below the following hemodynamic thresholds: Mean PAP >25 mmHg and >30 mmHg, and PVR >240 dynes/s/cm^5. The 95% confidence interval was used to assess the differences in mean AT in each location between the groups with low and high hemodynamic parameters because the null hypothesis was not entertained.

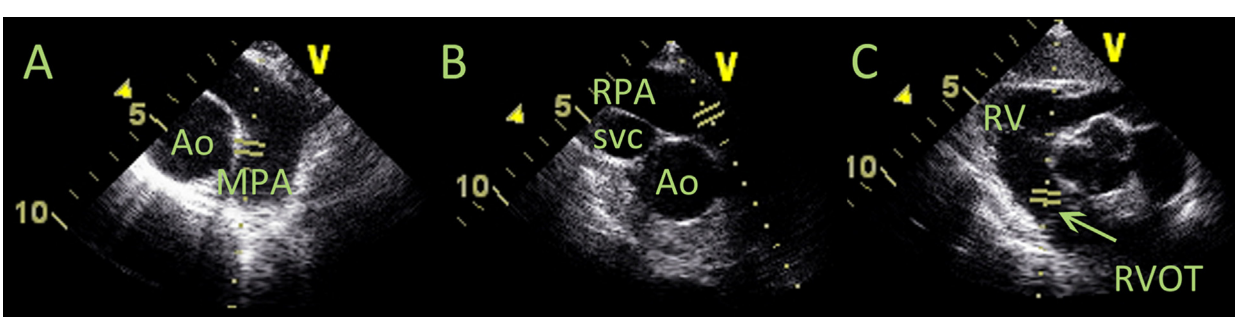

Fig 2. (A) Midesophageal aortic short-axis view with Doppler sample volume placed in the main pulmonary artery (MPA). (B) Midesophageal aortic short-axis view angled to align the right pulmonary artery (RPA) with the Doppler cursor. The sample volume is seen in the RPA. (C) Transgastric right ventricular (RV) inflow (outflow) view modified to view right ventricular outflow tract (RVOT). The sample volume is placed in the RVOT. Ao, aorta; SVC, superior vena cava.