Pulmonary Arterial Hypertension: First-Pass Contrast Bolus Kinetics Contain Information on RV Function, Remodeling, and Lung Resistance

J. Vogel-Claussen[1,2], J. Skrok[2], M. Shehata[2], D. A. Bluemke[3], R. Girgis[2], and P. M. Hassoun[2]

[1]Tübingen University, Tübingen, BW, Germany, [2]Johns Hopkins University, Baltimore, MD, United States, [3]National Institutes of Health

Purpose

Blood flow through the lungs is affected by cardiac function, pulmonary pressure, and resistance. In pulmonary arterial hypertension (PAH), vascular resistance and pressure are increased, causing right ventricular (RV) dysfunction, leading to right heart failure and death. Predictors of patient survival include RV cardiac index (RVCI), mean pulmonary arterial pressure (mPAP), and pulmonary vascular resistance (PVR). Our hypothesis was that first-pass contrast bolus kinetics, such as cardiopulmonary transit time (PTT), left ventricular (LV) full-width-half-maximum (FWHM), and LV time-to-peak were directly related to these parameters. We used magnetic resonance imaging (MRI) to evaluate first-pass contrast bolus kinetics in relation to biventricular function and invasive pulmonary hemodynamic measurements in patients undergoing right heart catheterization (RHC) for known or suspected PAH.
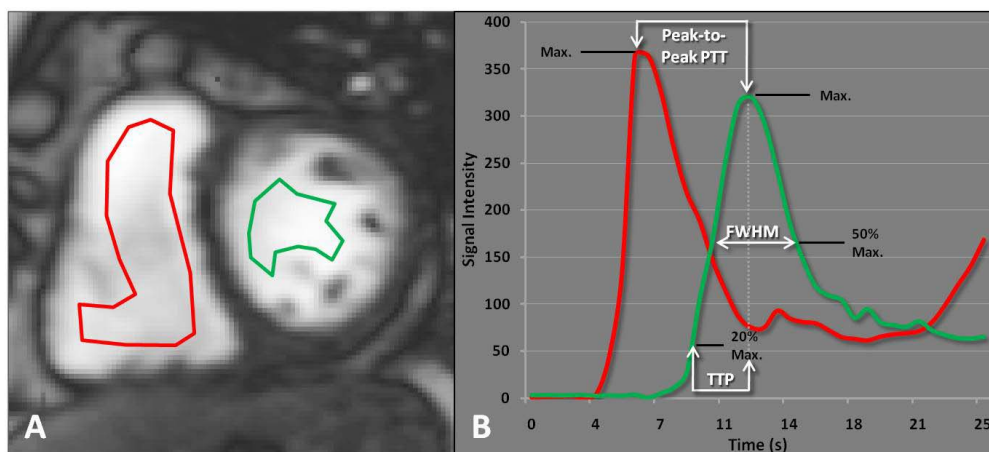
Outline of Content

61 subjects were enrolled: 32 PAH patients (mPAP 40 [29-49] mmHg) and 11 scleroderma patients without PAH (mPAP 17 [15-20] mmHg) underwent RHC and 3T cardiac MRI on the sane day. 18 volunteers underwent MRI only. For evaluation of bolus kinetics, a 1:10 diluted bolus (0.0025mmol/kg) of gadopentetate dimeglumine was administered intravenously at 4cc/sec, and a single short-axis saturation-recovery GRE (TR /TE: 2.1/1.05 msec, 12° flip angle, a minimal field of view, 192 x 116 matrix, slice thickness 10mm, GRAPPA 2) slice was acquired in the basal third of both ventricles over 40 heartbeats at one image per beat. For analysis, two regions of interest were drawn in the right and left ventricular cavities, and time-intensity curves were generated. From these curves, PTT, FWHM, and time-to-peak were calculated (Figure 1).

RV-to-LV PTT, LV FWHM, and LV time-to-peak in PAH patients (8.2s, 8.2s, 4.8s) were significantly higher than in non-PAH patients (6.5s, p=0.006; 5.0s, p=0.01; 3.6s, p=0.01) and control subjects (6.4s, p=0.0003; 5.2s, p=0.0004; 3.2s, p<0.0001) (Table 1). There were significant correlations of bolus kinetics with pulmonary hemodynamics and biventricular function and structure. In linear regression analysis, including PVRI, ventricular mass index (VMI), and RVCI as covariates, PTT was predicted by RVCI and VMI; FWHM and time-to-peak were predicted by PVRI. In receiver operator characteristics (ROC) analysis for transit time to distinguish between PAH patients with and without right heart failure (RVCI <2.2L/min/m^2) the area under the ROC curve was 0.82 with a sensitivity of 100% and specificity of 63.6% for a threshold of 8.1s.

Figure 1. ROI Placement and Time-Intensity Curves

Short-axis saturation-recovery GRE image (A) demonstrates regions of interest placed in the right (red) and left (green) ventricular cavities. Time-intensity curves (B) illustrate the passage of the contrast bolus through the regions of interest and signify the calculated parameters: peak-to-peak cardiopulmonary transit time, full-width-half-maximum (FWHM), and time-to-peak (TTP).

Summary

In patients with known or suspected PAH, first-pass bolus kinetics are closely related to pulmonary hemodynamics and RV dysfunction. Right-to-left-ventricular PTT is mainly predicted by RV cardiac function and biventricular remodeling; time-to-peak and FWHM are associated with pulmonary vascular resistance. Their predictive value regarding patient prognosis warrants further investigation.

Table 1.

	PAH	SSc non-PAH	Controls	p
Peak Transit Time (s)	8.2††‡‡ [6.9-9.9]	6.5†† [5.6-7.0]	6.4‡‡ [5.7-7.1]	0.0003*
FWHM LV (s)	8.2††‡‡ [5.7-11.4]	5.0†† [4.0-7.3]	5.2‡‡ [4.1-6.1]	0.0006*
Time-to-Peak LV (s)	4.8††‡‡ [3.9-6.5]	3.6†† [2.7-4.0]	3.2‡‡ [2.8-3.8]	0.0001*

Data are presented as median and 25th-75th percentile. Peak-to-peak cardiopulmonary transit time, left ventricular full-width-half-maximum (FWHM) and time-to-peak measurements were significantly longer for PAH patients than for non-PAH patients and healthy controls. Mann-Whitney *U* test was used for comparison of all three groups: *p<0.01. Wilcoxon rank-sum test was used for individual group comparisons: PAH vs. non-PAH: †p<0.05, ††p<0.01; PAH vs. controls: ‡p<0.05, ‡‡p<0.01