Pulse Wave Transit Time for Non-invasive Monitoring of Pulmonary Artery Pressure: Respiratory Gating Improves Correlation

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Background and Goal of Study: Pulse wave transit time (PWTT) shortens as pulmonary artery pressure (PAP) increases and was therefore suggested as a potential non-invasive surrogate for PAP (1). Pulmonary hypertension (PH) is a condition associated with right and global heart failure and high one-year mortality (2) and therefore needs non-invasive methods for follow-up (3-4). The state of lung filling is also known to affect PWTT independently of PAP (5). The aim of this retrospective analysis was to test whether respiratory gating improved correlation between PWTT and PAP.

Materials and Methods: Two high fidelity pressure catheters were placed in each one of five anesthetized and mechanically ventilated pigs: One directly behind the pulmonary valve and the second one in a distal branch of the pulmonary artery (Fig. 1). PAP was raised using the thromboxane A2 analogue U46619 and animals were pressure-controlled ventilated (I:E ratio 1:2, respiratory rate 12/min, tidal volume of 6 ml/kg). The arrival of the pulse wave at each catheter tip was determined using a MATLAB-based modified hyperbolic tangent algorithm and PWTT calculated as the time interval between these arrivals (Fig. 2). Linear regression analysis was performed with the least square method by Pearson (mean ± SD).

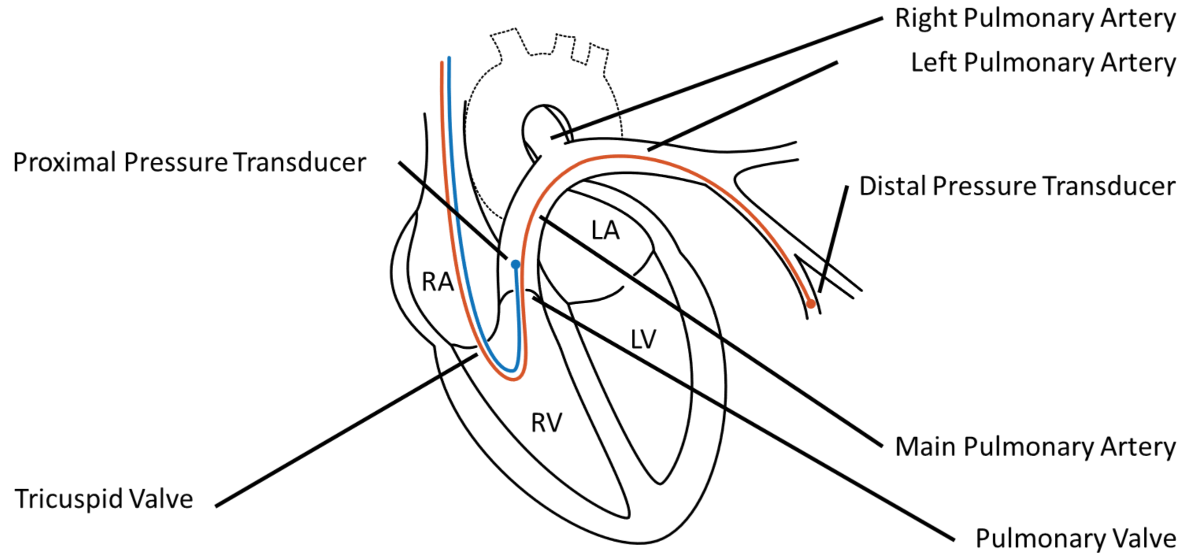

Figure 1: *Schematic drawing of the heart with placement of the pressure transducers. The proximal pressure transducer (blue) was placed directly behind the pulmonary valve and the distal one (red) in a distal branch of the left pulmonary artery.*

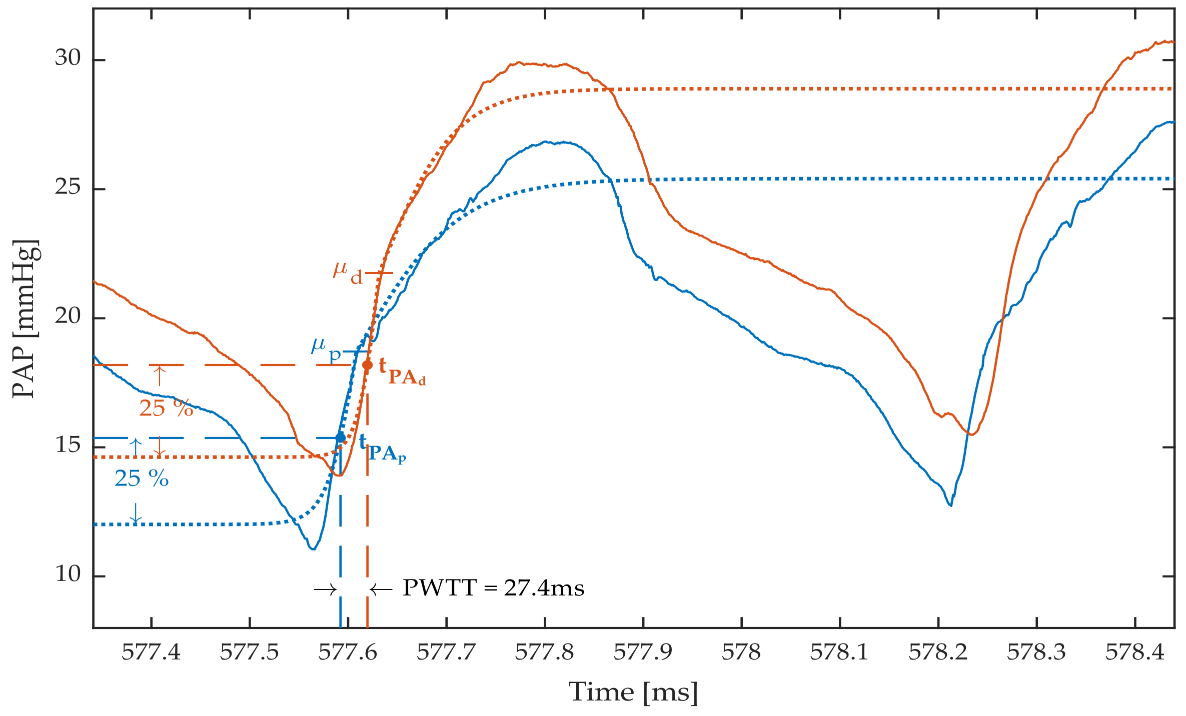

Figure 2: *Pulse wave transit time (PWTT) between the proximal and distal pulmonary artery. The proximal pressure curve is shown in blue, the distal one in red. Solid lines represent the respective pulmonary artery pressures in mmHg. Local pulse arrivals were determined by the inflection points of the fitted hyperbolic tangent (dotted lines) and marked by dots, respectively. Pulse wave transit time (PWTT) was calculated as the time difference between the selected pulse arrival times.*

Results: Visualization of the timing of each heartbeat within the respiratory cycle in blue (inspiration) and red (expiration) revealed a respiratory dependence of PWTT (Fig. 3) with a correlation coefficient for PWTT and mPAP of r = 0.932. This correlation increased dramatically when heartbeats were selected (i.e. gated) at end-inspiration (r = 0.978) or end-expiration (r = 0.985). Table 1 gives an overview as well for sPAP and dPAP.

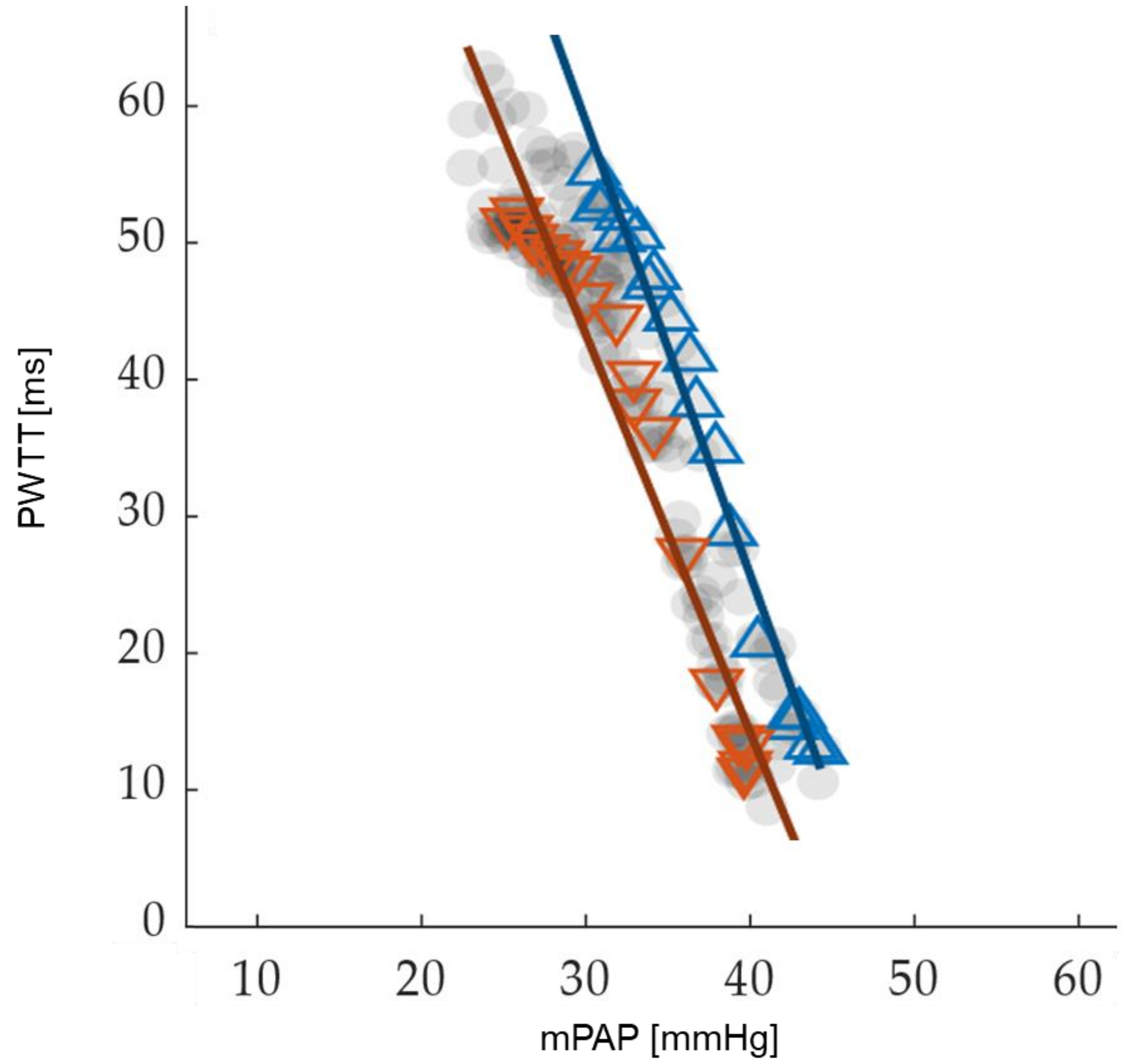

Figure 3: *Scatter plot showing the relation between mean PAP and PWTT. The last heartbeat of each inspiration is highlighted in blue (open triangle with tip upwards) and the last heartbeat of each expiration red (open triangle with tip downwards) while all other beats are grey colored dots.*

	sPAP	mPAP	dPAP
ungated	0.955 ± 0.056	0.932 ± 0.067	0.851 ± 0.173
end-expiratory	0.977 ± 0.127	0.985 ± 0.187*	0.970 ± 0.304*
end-inspiratory	0.973± 0.095	0.978 ± 0.068*	0.953 ± 0.090*

Table 1. *Mean linear regression analysis for correlation of pulse wave transit time with sPAP, mPAP and dPAP in thromboxane A2-induced pulmonary hypertension for all analyzed heartbeats (ungated), the last expiratory heartbeat (end-expiratory gating) and the last inspiratory heartbeat (end-inspiratory gating; mean ± SD, rmANOVA on Ranks, * p< 0.05).*

Discussion: Considering only the last cardiac cycle during inspiration or expiration increased the coherence and resulted in an almost linear relationship between PWTT and PAP. Whether this is due to stable intrathoracic pressures at the endpoints of the respiratory cycle can only be supposed. Interestingly the correlation coefficient was slightly better for end-expiratory gating than for end-inspiratory gating, but without reaching significance.

Conclusion: Respiratory gating should be considered when using PWTT as a surrogate for PAP. These results offer new insights into the mechanisms of heart-lung-interaction.

Literature:

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