

A modeling study of palliations used for refractory pulmonary hypertension

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Abstract

Several surgical interventions are currently being used for treating refractory pulmonary hypertension, including the creation of pre- and post-tricuspid shunts. A goal of these interventions is to establish a right-to-left shunt to reduce the load on the failing right ventricle. These shunts are created at the expense of decreased oxygen saturation. We hypothesize that mathematical models can help evaluate the effectiveness of ASD, VSD, and Potts shunts in the context of this disease. The aim of this study is to develop compartmental models of the human circulatory system that describe blood flow and oxygen transport through the two sides of the heart and the systemic and pulmonary tissues.

Models and Methods

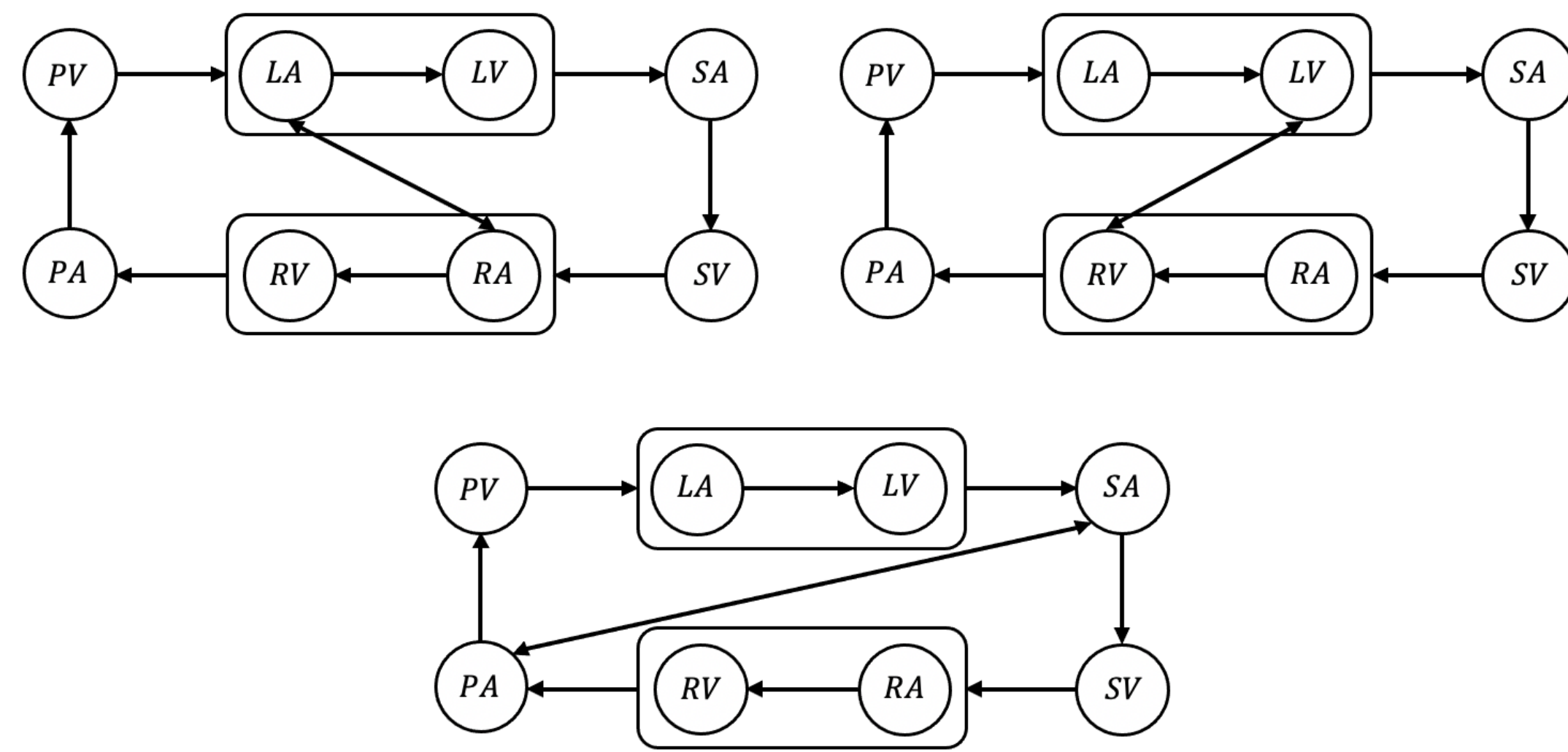


Figure 1: Schematics for our model palliations. The ASD is top left, the VSD is top right, and the Potts shunt is on the bottom.

$$V_i = (V_d)_i + C_i P_i \quad (\text{volume-pressure relations for compliance chambers})$$

$$\frac{d}{dt}(C_i P_i) = \sum_{j=1}^N (S_{ij} G_{ij} + S_{ji} G_{ji})(P_j - P_i) \quad (\text{equations for pressure within each compliance chamber})$$

$$R_{\text{shunt}} = R_{\text{visc}} + \frac{\rho}{2A_0^2} |Q| \quad (\text{shunt resistance from the Gorlin equation})$$

$$\frac{d}{dt}([O_2]_i V_i) = \sum_{j=1}^N ([O_2]_j Q_{ji} - [O_2]_i Q_{ij} + M_{ji}) \quad (\text{equations for oxygen transport})$$

Results for Pressures

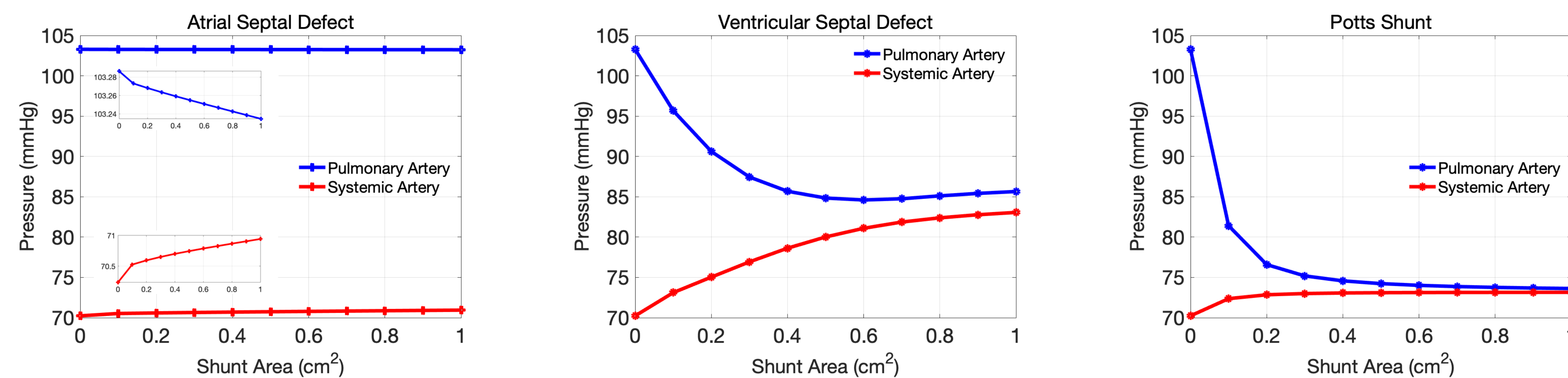


Figure 2: Systemic (red) and pulmonary (blue) artery pressures as functions of the shunt area.

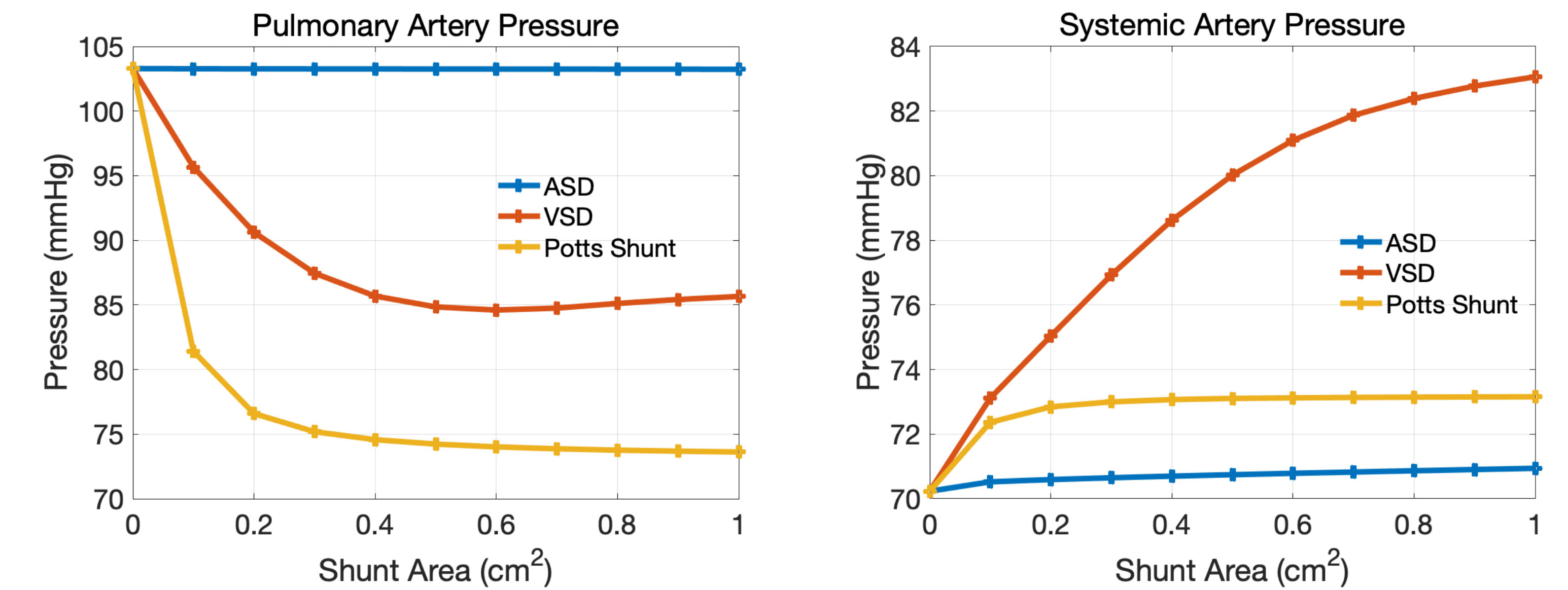


Figure 3: Comparing pressures between the interventions; pulmonary artery pressure on the left, systemic artery pressure on the right.

Results for Flows and Oxygen Saturations

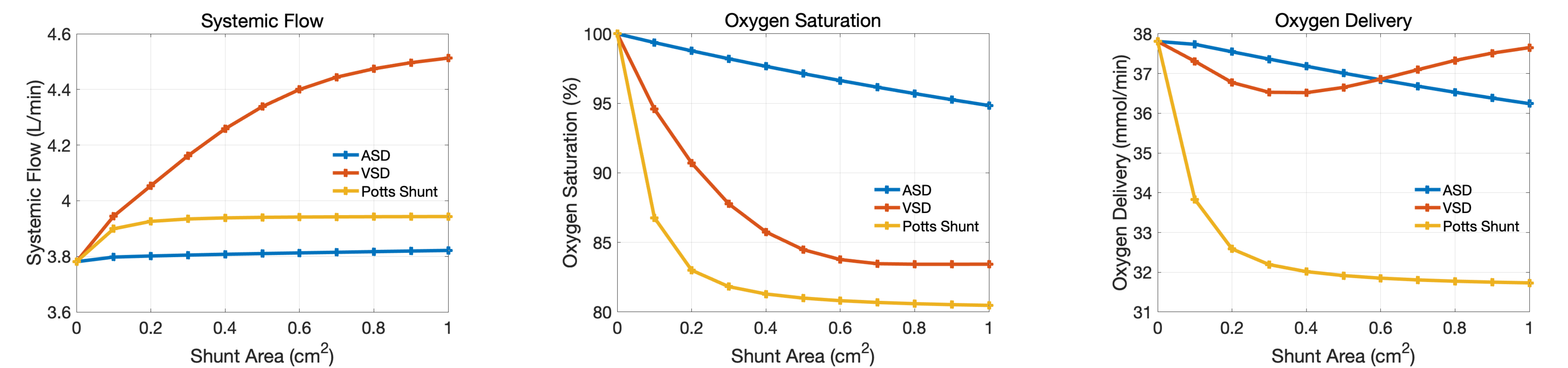


Figure 4: Comparing systemic flow, oxygen saturation, and oxygen delivery between the interventions.

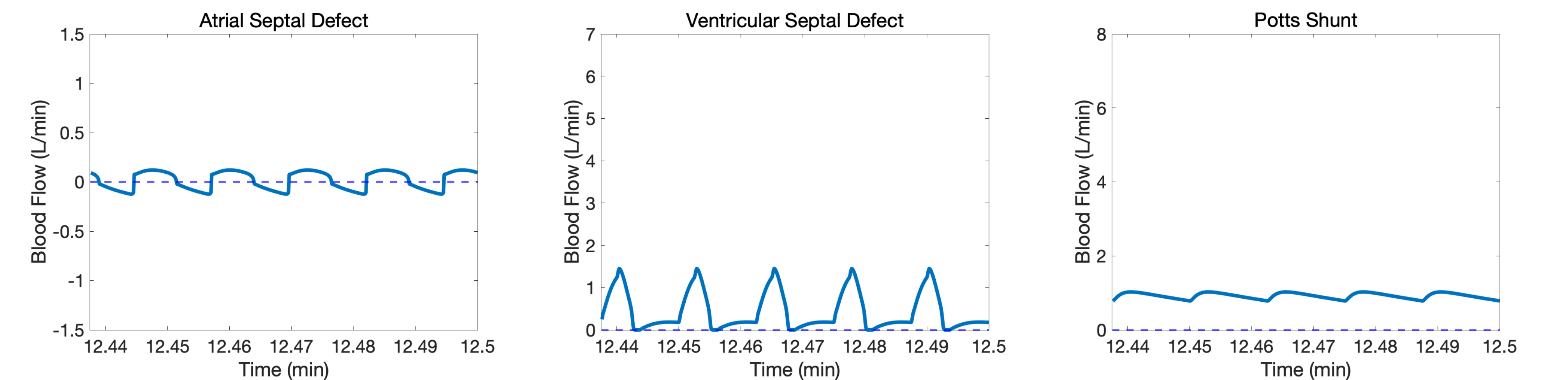


Figure 5: Shunt flow waveforms for ASD, VSD, and Potts, from left-to-right. The shunt area is 0.1 cm².

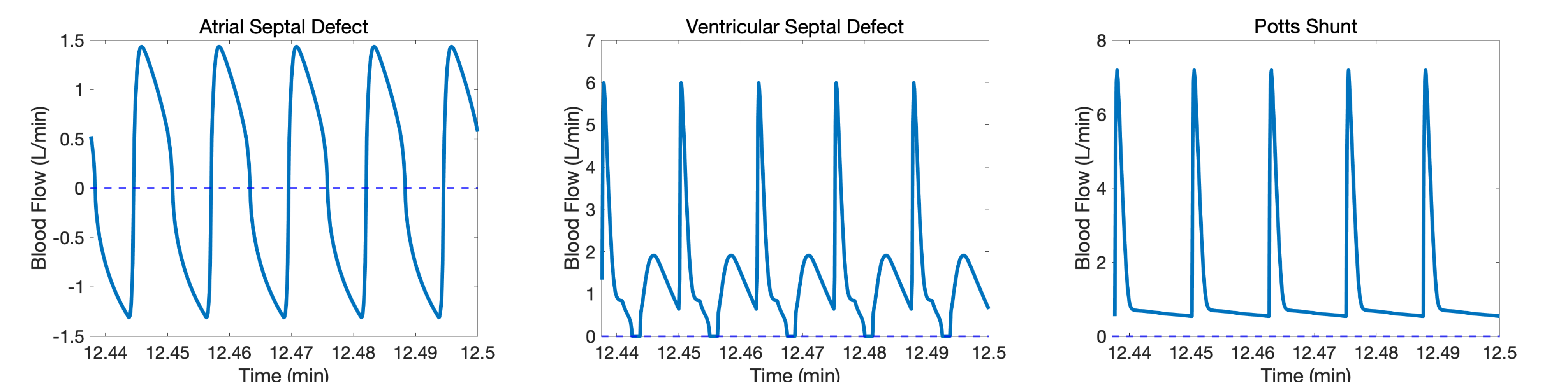


Figure 6: Shunt flow waveforms for ASD, VSD, and Potts, from left-to-right. The shunt area is 1 cm².