Supplemental methods

Parameter estimation for the fetal cardiovascular system. The following provides explicit documentation of how numerical values for specific fetal model parameters, listed in Table 1, were obtained.

Heart chambers

Ménigault et al. (1) present parameter values for the maximum (systolic) elastance and unstressed volume of the left and right ventricles (ELVMAX, ERVMAX, VLVU, and VRVU). These authors also present an end-diastolic cardiac volume of 10.5 ml and an end-diastolic pressure of 3 mmHg, obtained in human fetuses. Assuming both ventricles have the same end-diastolic volume, we can calculate the minimum (diastolic) elastance of the left and right ventricles (ELVMIN and ERVMIN) using equation (A7) from Goodwin et al. (2). Note that the average intrathoracic pressure (PTH) was assumed to be 0 mmHg (assumed value further explained below).

Numerical values for atrial parameters are not as easily encountered as for the ventricles. Pennati et al. (3) and Huikeshoven et al. (4) present values for fixed atrial elastances (ranging between 0.33 mmHg.ml⁻¹ and 1 mmHg.ml⁻¹). We set the atrial diastolic elastances (ELAMIN and ERAMIN) to the lowest value and the maximum atrial elastances (ELAMAX and ERAMAX) to the highest value. The unstressed volumes (VLAU and VRAU) were assumed to be zero.

For the resistances of the heart valves (RLAOUT, RLV, RRAOUT and RRV) we used the values proposed by Huikeshoven et al. (4).

Heart rate (HR) is set to the mean value presented by Mielke and Benda (5) for term human fetus.

Blood volumes

Total fetal-placental blood volume for a term fetus is approximately 125 ml/kg (6). The blood volume in the fetal body accounts for an average of 78 ml/kg and in the placenta for an average of 45 ml/kg (6). These values were necessary for the model initialization.

Huikeshoven et al. (4) give values for the unstressed volumes of the vascular compartments. For the placenta (VPLU) and the pulmonary arteries and veins (VPAU and VPVU) we directly used the reported values. (Total) venous and arterial unstressed volumes were obtained from Huikeshoven et al. (4) and distributed over the intrathoracic and extrathoracic compartments of our model (VITHAU, VETHAU, VETHVU, and VITHVU) in the same proportion as the neonatal parameters presented in Sá Couto et al. (7).
Resistances

Huikeshoven et al. (4, 8) present values for fetal hemodynamic resistances. For the resistances of the ductus arteriosus (RDA), placental inflow and outflow (RPLIN and RPLOUT), foramen ovale (RFO), and the left atrium inflow rate (RLAIN), we directly used the proposed values. As for the unstressed volumes, the (total) arterial and venous systemic resistances were obtained from Huikeshoven et al. (4) and distributed over the arterial and venous systemic compartments of our model, in the same proportion as the neonatal parameters presented in Sá Couto et al. (7). To obtain pulmonary peripheral resistance (RPP), we used the ratio RPP/RSP ratio of 3.4 for term human fetuses, presented by Rasanen et al. (9). The resulting RPP is in the same range as the one obtained by Assali et al. (10) in term fetal lambs.

Elastances, Inertia and Intrathoracic pressure

Huikeshoven et al. (4) present values for the elastances of the vascular compartments. We use these values for the venous elastances (EETHV, EITHV, EPL and EPV). The values for the arterial elastances proposed by Pennati et al. (3) were distributed over the systemic and pulmonary arterial compartments of our model (EITHA, EETHA and EPA).

A value for blood flow inertia in the ductus arteriosus (LDA) is presented by Huikeshoven et al. (4). For the inertia in the systemic arteries (LETHA) we use the value proposed by Pennati et al. (3).

The average intrathoracic pressure (PTH) was set to 0 mmHg (for lungs filled with fluid) (11, 12).
REFERENCES


