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THE "SYSTOLIC VOLUME BALANCE METHOD" FOR THE NON-INVASIVE ESTIMATION OF CARDIAC OUTPUT BASED ON PRESSURE WAVE ANALYSIS

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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INTRODUCTION

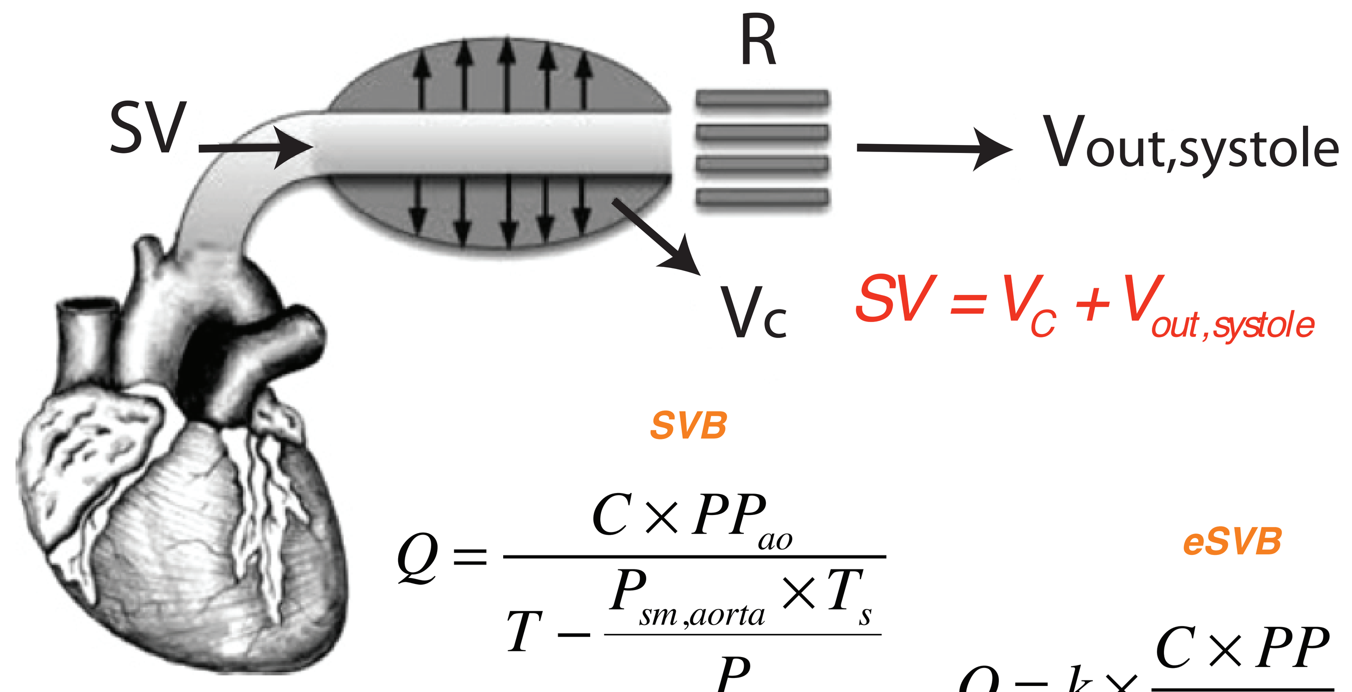
Monitoring of cardiac output (CO) is essential for the optimal management of patients. Either intraoperatively or in the settings of an intensive care unit, CO provides valuable insight for systemic O_2 delivery and global tissue perfusion. Furthermore, monitoring of SV variation provides important information for the optimisation of diagnosis and treatment [1].

MOTIVATION

Widely used "pulse contour CO" (PCCO) methods are still based on invasive recording of arterial pressure waves or require invasive hemodynamic measurements for calibration purposes [2,3].

AIMS

- Develop a simple method for monitoring CO that requires only non-invasive tonometry measurements
- Compare CO trend estimation versus a commercial device (Nexfin, Edwards Lifesciences)



$$SV = V_C + V_{out,systole}$$

SVB

$$Q = \frac{C \times PP_{ao}}{T - \frac{P_{sm,aorta} \times T_s}{P_m}}$$

eSVB

$$Q = k \times \frac{C \times PP}{T}$$

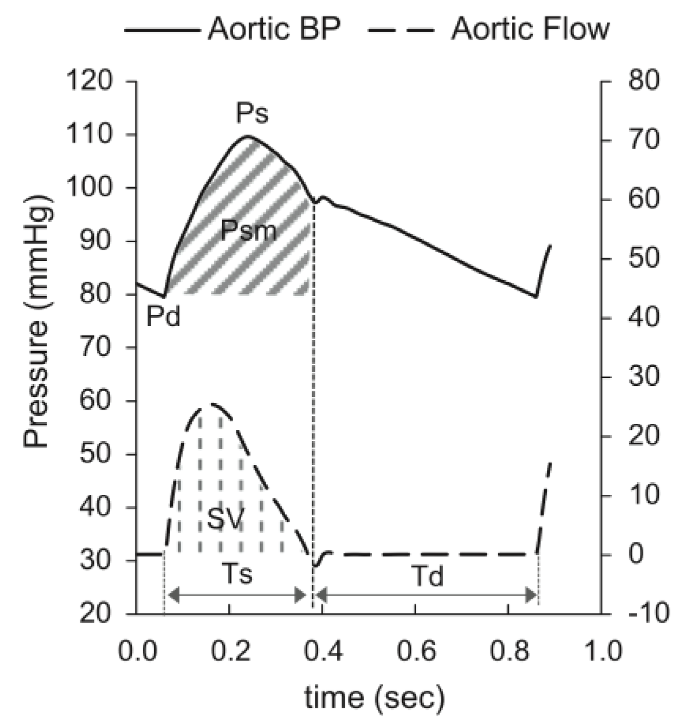


Figure 1. SVB definition and main parameters determined by pulse wave analysis.

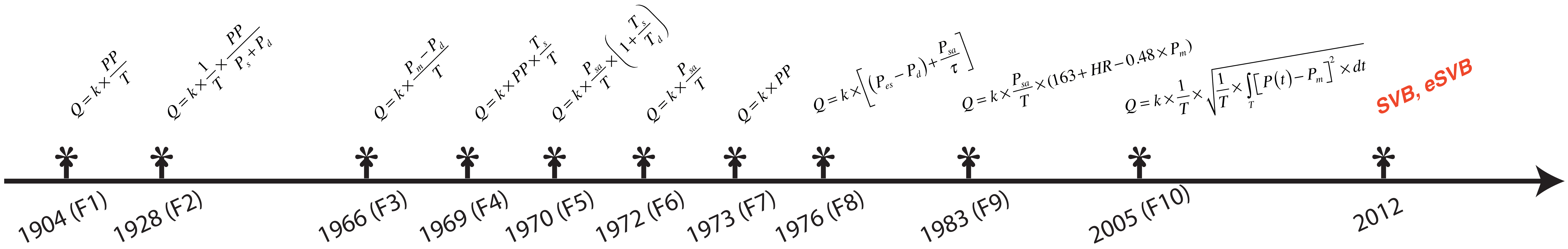


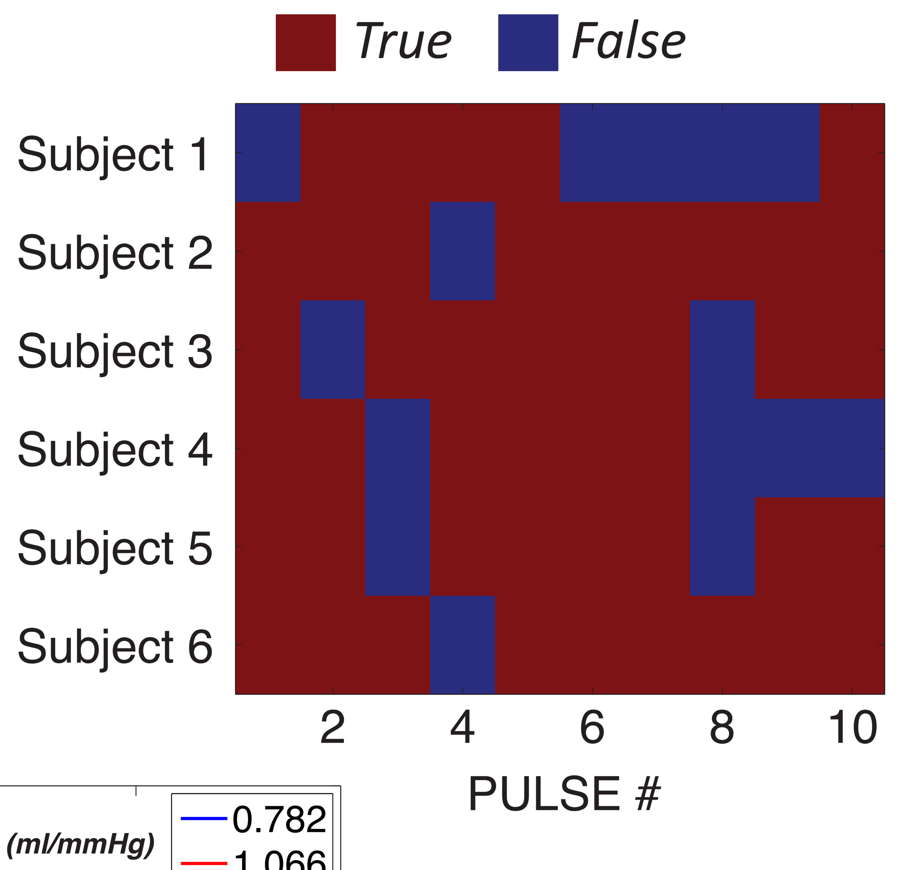
Figure 2. Timeline with the evolution of PCCO formulation over the last century. F1: Erlanger and Hooker, F2: Liljestrand and Zander, F3: Herd et al., F4: Harley et al., F5: Kouchoukos et al., F6:Wesseling et al., F7: Erlanger et al., F8: Bourgeois et al., F9: Wesseling et al., F10: AC power method, SVB and eSVB.

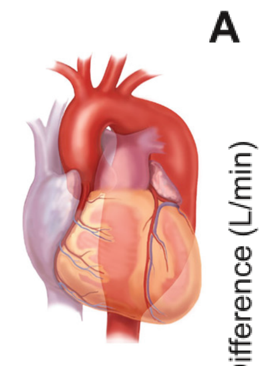
1D ARTERIAL TREE MODEL

The SVB and eSVB methods were tested along with the rest reported formulations via the arterial tree model previously developed by Reymond et al. [4]. Compliance, resistance and heart rate were varied resulting in a large variety of flow and pressure waveforms.

IN VIVO COMPARISON

- 6 healthy volunteers (10 pulses)
- Supine position
- Tonometry in the carotid
- Brachial Sphygomanometry
- SPT 301 tonometer (Millar)
- Nexfin monitor (Edwards)
- AD instruments Powerlab





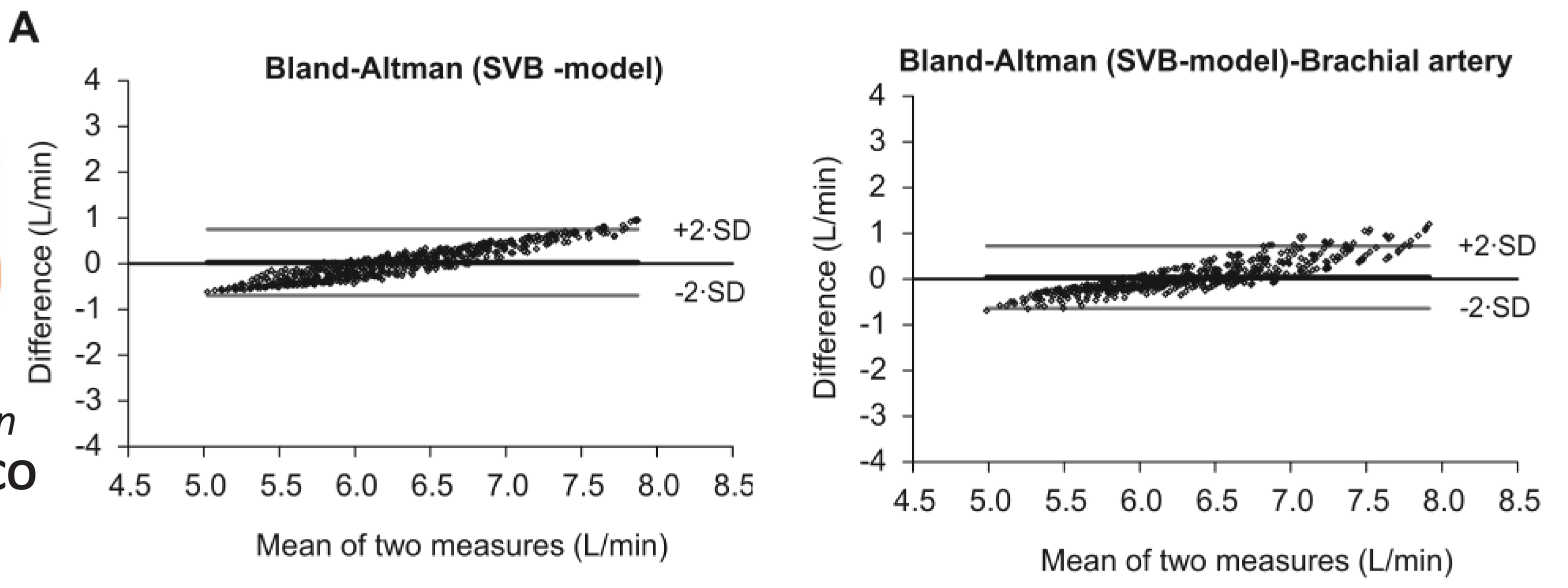
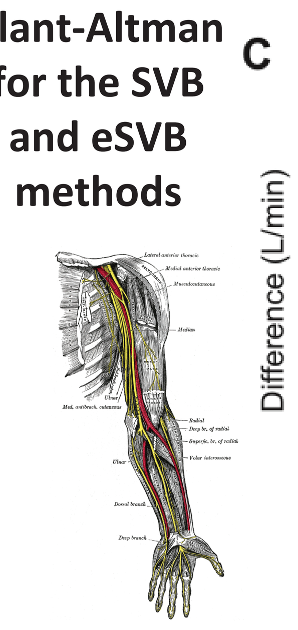
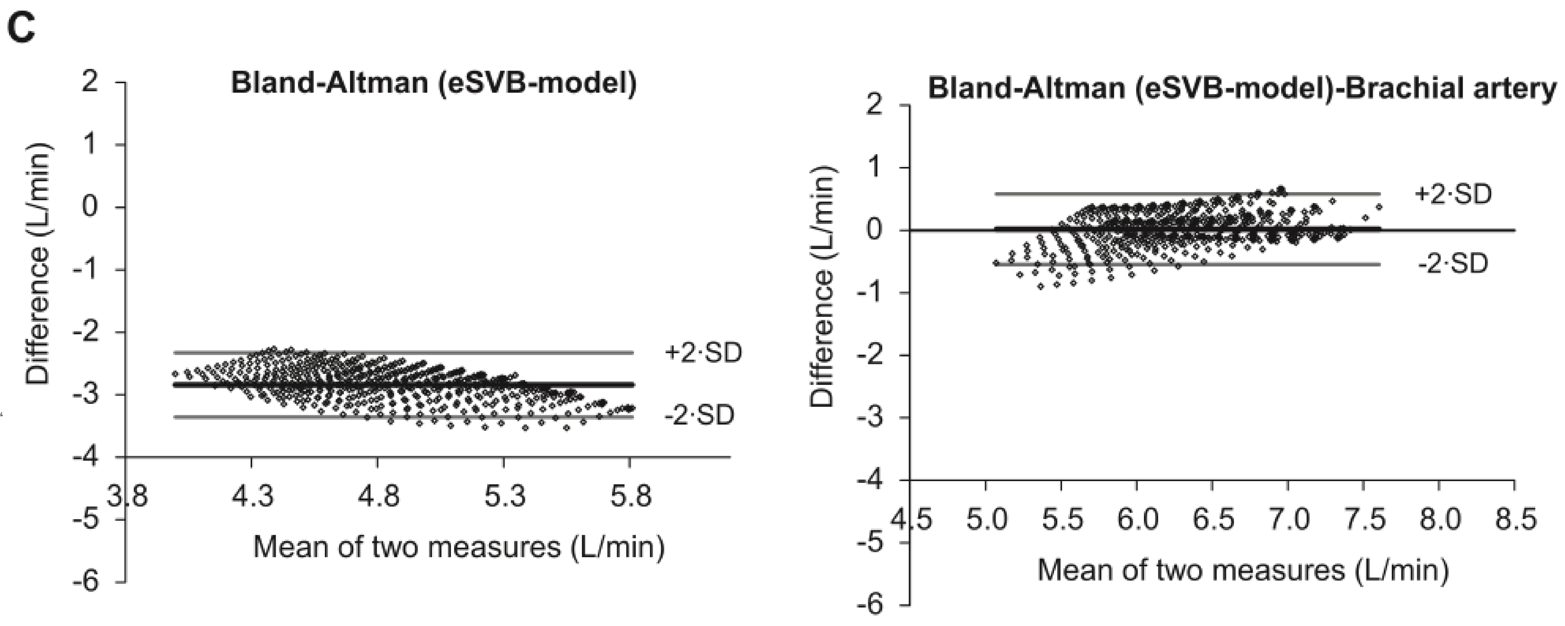
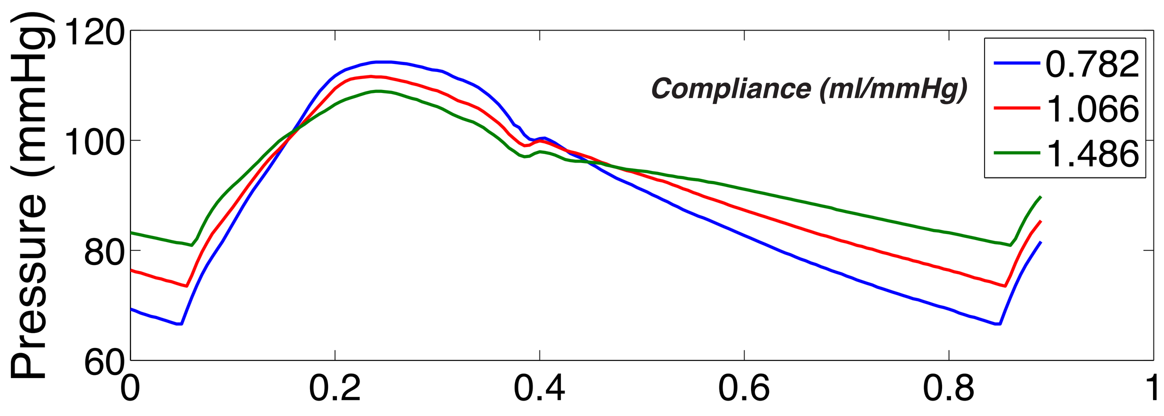


Figure 3. Left: *In vivo* **results for CO trend, Right: Blant-Altman for the SVB and eSVB methods**







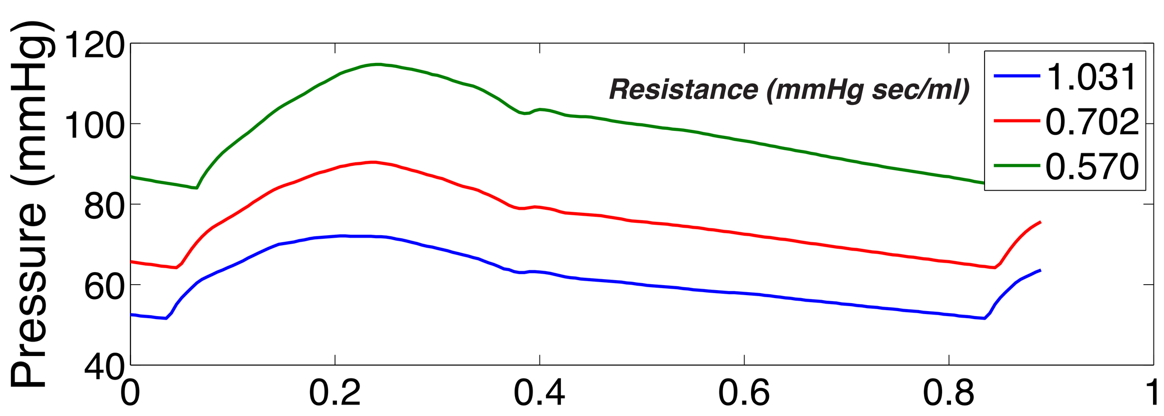


Figure 4. A diagram of the simulated arterial tree and different aortic pressure waveforms with varying arterial compliance (up) and varying terminal restistance (down).

RESULTS

The SVB and eSVB methods presented the highest correlation and agreement and resulted in the lowest variation and error bias when compared with the "real" CO computed by the model. In all subjects the SVB presented good agreement in detecting CO trends versus Nexfin. The mean value of trend agreement was 75%.

DISCUSSION AND CONCLUSIONS

The proposed SVB method and the simplified eSVB presented good accuracy and were superior when compared against other methods with *in silico* waveforms. The CO-trend estimation of the SVB correlated well with the CO trends reported by the Nexfin device for 6 in vivo data acquisitions. Further in vivo validation studies remain to be conducted in order to validate the performance of these methods in the clinical enviroment.

[1] Garcia X, Pinsky MR. Clinical applicability of functional hemodynamic monitoring. Ann Intens Care 1: 35, 2011.
[2] Schwann NM, Hillel Z, Hoeft A, Barash P, et al. Lack of effectiveness of the pulmonary artery catheter in cardiac surgery. An, 2011
[3] Cholley BP, Payen D. Noninvasive techniques for measurements of cardiac output. Curr Opin Crit Care 11: 424–429, 2005.
[4] Reymond, P., F. Merenda, F. Perren, D. Rufenacht, and N. Stergiopulos. Validation of a one-dimensional model of the systemic arterial tree. ajp