Mathematical model of the fluid status after intravenous fluid infusion

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Introduction

Finding the optimal fluid balance in surgical patients is complex due to the lack of information on circulatory and interstitial volume through direct measurements.

Figure 1: Clinical decision support workflow, with the addition of a mathematical laboratory

Mathematical models describing underlying physics and physiology, might be able to assist in determining the optimal fluid administration protocol for individual patients, by translating available measurements into quantitative information on the fluid status (figure 1).

Aim

In this study we present and test a pilot model for clinical decision support in fluid administration.

Methods

The model (figure 2) combines a cycle-averaged cardiovascular module including baroreflex control, with a fluid exchange module, driven by hydrostatic and osmotic pressure as described by Starling^{2,3}. Urine flow is linearly related to plasma volume.

Figure 2: Schematic overview of the mathematical model

We fitted and tested the model by simulating an experiment in which 2.3 L of saline was infused over 23 minutes in volunteers⁴.

Results

In agreement with the experimental data, in the model initially (30-60 min) a substantial part of the infused fluid enters the interstitial space, and eventually (60-180 min) leaves the body as urine.

Figure 3: Experimental data⁴ compared to model results

Discussion

This general fluid exchange model is able to qualitatively capture the physiological changes in healthy volunteers after fluid infusion.

Outlook

This is the first step in exploring the potential of mathematical decision support tools for fluid administration. Next steps include performing a sensitivity analysis to find unique solutions, modelling the effect of anesthesia, and testing on different patient datasets.

Acknowledgements

This work was performed within the IMPULS II perioperative monitoring framework

References

1. Brandstrup et al. (2005)
2. Jongen et al. (2016)
3. Xie et al. (1995)
4. Watenpugh et al. (1992)