Mean systemic filling pressure

From Guyton to the ICU, and back again

Akademisk avhandling

Som för avläggande av medicine doktorsexamen vid Sahlgrenska akademin, Göteborgs universitet, kommer att offentligen försvaras i lokal Arvid Carlsson, Academicum, Medicinaregatan 3, fredagen den 1:e mars 2019, klockan 09:00

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Avhandlingen baseras på följande delarbeten

I. Berger D., Möller P.W., Weber A., Bloch A., Blöchlinger S., Hänggi M., Søndergaard S., Jakob S., Magder S., Takala J. (2016). **Effect of PEEP, blood volume, and inspiratory hold maneuvers on venous return.** *American Journal of Physiology. Heart and Circulatory Physiology, 311*(3), H794-H806.

II. Möller P.W., Winkler B., Hurni S., Heinisch P.P., Bloch A., Søndergaard S., Jakob S., Takala J., Berger D. (2017). **Right atrial pressure and venous return during cardiopulmonary bypass.** *American Journal of Physiology. Heart and Circulatory Physiology, 313*(2), H408-H420.

III. Möller P.W., Hana A., Heinisch P.P., Liu S., Djafarzadeh S., Hänggi M., Bloch A., Takala J., Jakob S., Berger D. (2018). **The effects of vasoconstriction and volume expansion on veno-arterial ECMO Flow.** *SHOCK. E-published ahead of print. Received 3 May; accepted in final form 24 May 2018. DOI: 10.1097/SHK.0000000000001197.*

IV. Möller P.W., Søndergaard S., Jakob S., Takala J., Berger D. **Effect of volume status on the estimation of mean systemic filling pressure.** *Submitted.*

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Abstract

Mean systemic filling pressure (MSFP) is the equilibrated vascular pressure at zero flow. Venous return (VR) driving pressure (VRdP) is the difference between MSFP and right atrial pressure (RAP). In clinical research, MSFP can be estimated: $MSFP_{insp\_hold}$ is the zero-flow extrapolation of RAP-cardiac output data-pairs from inspiratory hold maneuvers; $MSFP_a$ is a dynamic analogue computed from clinically available hemodynamics. However, results are controversial and fundamental concepts of VR physiology are questioned. We aimed to test experimentally the concept of VRdP in dynamic conditions and validate estimates of MSFP against zero-flow measurements.

We compared estimates of MSFP against zero-flow measurements from right atrial balloon occlusion ($MSFP_{RAO}$), or from intermittently paused venoarterial extracorporeal membrane oxygenation (ECMO), in three porcine models exposed to changing blood volumes and vasoconstriction.

Changes in RAP resulted in immediate and directionally opposite changes in VR. Temporary VR and ECMO flow imbalance resulted in dynamically changing VRdP and RAP. In euvolemia, MSFP was increased by increased airway pressure. A moderate increase in positive end-expiratory pressure increased RAP, $MSFP_{RAO}$ and VRdP. Resistance to VR did not change. Changing blood volume led to concordant changes in RAP, $MSFP_{RAO}$, VRdP and flow. Vasoconstriction and volume expansion increased MSFP and maximum achievable ECMO flow with similar effects on oxygen delivery. $MSFP_{insp\_hold}$ overestimated $MSFP_{RAO}$ in euvolemia due to flow restoration predominantly occurring in the inferior vena cava. Methods for MSFP estimation had an accuracy that was dependent on volume status. All methods tracked changes in the reference method concordantly, but with the possible exception of $MSFP_a$, the bias was clinically unacceptable.

If pressure effects from volume shifts are accounted for, the concept of VRdP is valid also during dynamic conditions. VR physiology can explain the responses of volume expansion and vasoconstriction on veno-arterial ECMO flow. Inspiratory hold maneuvers are unsuitable for the estimation of MSFP due to clinically significant bias.

Keywords: mean systemic filling pressure, venous return, right atrial pressure, positive pressure ventilation, extracorporeal membrane oxygenation

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