Chapter 13

The Respiratory Systolic Variation Test to predict fluid loading responsiveness

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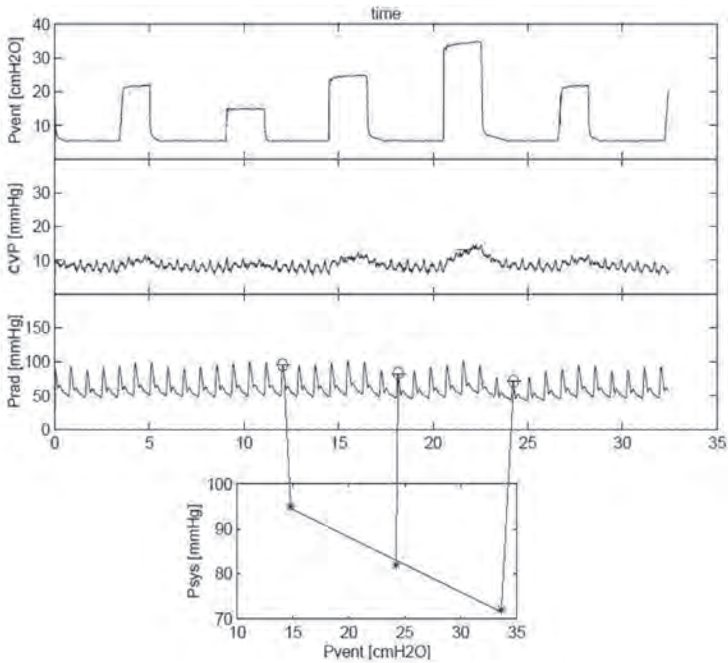
Especially in cardiac surgery patients, unnecessary fluid loading can lead to general and pulmonary oedema, and prolong hospitalization [1]. Several traditional and dynamic parameters have been studied for the predictive value to fluid loading responsiveness (FLR, i.e. an increase in CO) but no gold standard exists.
Preisman and colleagues studied a Respiratory Systolic Variation Test (RSVT) in 18 mechanically-ventilated patients undergoing cardiac surgery to predict FLR with a increase in CO of at least 15% after 250 ml fluid loading [2]. The RSVT consists of three successive incremental-pressure-controlled inspiratory breaths (10, 20 and 30 cmH_2O) of 1.5 seconds [2]. The lowest systolic blood pressure for each breath is plotted against their respective airway pressure, Figure 1. The slope of this plot is the RSVT-value, and is suggested to increase with hypovolaemia and decrease with fluid loading [2,3]. RSVT is reported to predict FLR with high sensitivity and specificity [2]. However, the RSVT were applied manually and no control group was used. We developed a semi-automated RSVT procedure and tested transferability of the RSVT with a threshold of 0.51 $mmHg \cdot cmH_2O^{-1}$ in independent group of patients to predict FLR.

Methods

Fourteen patients undergoing elective-cardiac surgery were included after approval of the institutional ethics committee and personal informed consent was obtained. Prior to surgery, each patient received a pulmonary artery catheter (Intellicath; Edwards Lifesciences; Irvine, CA, USA) to measure CO and CVP, and a 20 G radial artery catheter to measure arterial pressure (Prad).
Patient's anaesthesia was continued with propofol-target-control infusion and sufentanil in the ICU. The lungs were mechanically ventilated (Draeger, Evita 4, Lubeck, Germany) in a pressure-control mode with standard settings (12 $breaths \cdot min^{-1}$, tidal volume 8-10 $ml \cdot kg^{-1} \cdot min^{-1}$, FiO_2 40%, PEEP 5 cmH_2O). To perform the RSVT semi-automatic we putted the ventilator under computer control. Airway pressure (Paw) was measured at the proximal end of the endotracheal tube.
The radial artery pressure (Prad) was analysed with the Modelflow program (FMS, Amsterdam, the Netherlands) to provide beat-to-beat values of systolic blood pressure (Psys), MAP, HR and to determine pulse pressure variation (PPV) over 30 second intervals [4]. Thermodilution cardiac output (COtd) was obtained as averaged value of three thermodilution measurements performed equally spread over the ventilatory cycle [5].
During the observation period the patients maintained the supine position. Use of sedative and vascular medication remained unchanged. No fluids were administered during the observation period outside the study protocol.
The 1.5 second RSVT procedure and COtd, MAP, Psys, PPV, HR and CVP measurements

were semi-automatically performed before and five minutes after a 500 ml administration of colloid in 15 minutes. Responders were characterized by a ≥10% increase in COtd with 500 ml fluid loading five minutes after fluid was administered.
Statistical analyses were performed with a Kolmogorov-Smirnov test and (un)paired t-test. Reliability to predict fluid loading responsiveness was assessed using the threshold of 0.51 for RSVT from the report of Preisman and co-workers [2]. Study size was similar to the study of Preisman and co-workers. The accuracy of the test is unknown hence no power analysis was performed.

Figure 1 An example of the Respiratory Systolic Variation Test (RSVT). Upper graph; three successive 1.5 seconds incremental-pressure-controlled inspiratory breaths of 10, 20 and 30 cmH_2O are applied with a PEEP of 5 cmH_2O (Pvent is airway pressure). Second graph; a linear transfer of Pvent to central venous pressure (CVP) can be observed. Third graph; radial artery pressure (Prad) is plotted and lowest systolic blood pressure (Psys) for each RSVT breath is indicated. Lower graph; Psys against Pvent is given. The slope of this plot is the RSVT value.



Results

Fourteen patients (10 male) of 63 ± 10 years, 86 ± 15 kg and 175 ± 9 cm were included. Eleven patients received straightforward CABG and three received single valve repair with or without CABG.

Data was normally distributed. CO, CVP and MAP increased due to fluid administration. HR did not change and PPV and RSVT-values decreased (Table 1). CO increased with 34% in responders (n=9) and did not change in non-responders (n=5). An RSVT with a threshold of 0.51 predicted responders and non-responders correctly in 78% of the patients (sensitivity 78%, specificity 60%, positive predictive value 78%, and negative predictive value 60%). A PPV of 10% (conform Preisman's 9.4%) would have missed one responder; sensitivity 90%, specificity 100%, positive predictive value 100% and negative predictive value 80%.

Table 1 Changes in hemodynamic parameters from baseline to after 500 ml fluid loading for all patients, responders and non-responders.

Parameters	All patients			Responders			Non-responders		
	Baseline	500 ml	*P value*	Baseline	500 ml	*P value*	Baseline	500 ml	*P value*
COtd ($L \cdot min^{-1}$)	5.6 ± 1.5	6.8 ± 1.6	0.002	5.3 ± 1.1	7.0 ± 1.4	0.001	6.3 ± 1.9	6.4 ± 2.1	0.384
MAP (mmHg)	84.1 ± 22.3	94.3 ± 18.1	0.021	86.0 ± 27.0	97.3 ± 21.1	0.074	80.7 ± 11.7	89.0 ± 10.6	0.187
HR (min^{-1})	81 ± 16	78 ± 14	0.075	86 ± 16	82 ± 12	0.120	72 ± 14	71 ± 15	0.313
CVP (mmHg)	9.2 ± 3.2	11.4 ± 2.8	0.001	9.6 ± 1.8	11.6 ± 1.6	0.007	8.4 ± 5.0	11.0 ± 4.4	0.107
RSVT ($mmHg \cdot cmH_2O^{-1}$)	0.96 ± 1.02	0.57 ± 0.80	0.003	0.86 ± 0.47	0.41 ± 0.33	0.007	1.15 ± 1.69	0.86 ± 1.30	0.229
PPV (%)	14.8 ± 9.2	7.2 ± 4.9	0.004	17.4 ± 8.5	7.0 ± 3.4	0.007	10.0 ± 9.3	7.6 ± 7.4	0.136

Thermodilution cardiac output (COtd), mean arterial pressure (MAP), heart rate (HR), central venous pressure (CVP), Respiratory Systolic Variation Test (RSVT) and pulse pressure variation (PPV).

Discussion

In response to earlier publications of Preisman and co-workers [2], we evaluated the RSVT in an independent group of post cardiac surgery patients and found RSVT with a threshold of 0.51 reliable in predicting responders and non-responders. To perform semi-automated RSVT manoeuvres we put the ventilator under computer control. Preisman and colleague's characterized responders by a ≥15% change in CO after 250 ml of fluid loading [2]. We used 500 ml since this is more broadly used in FLR research [6-9]. Apparently, this difference in characterizing responders has no impact on the RSVT threshold of 0.51.

Several considerations have to be mentioned. First, RSVTs can only be measured in patients on mechanical ventilation with an arterial catheter and without arrhythmias [10]. Second, it is not unimaginable that pathologic states of the lung like COPD or ARDS influence the reliability of the test because the change in lung compliance may have an impact on the transmission of alveolar to intra-thoracic pressure [11]. Third, changes in vasomotor tone during progression of sepsis, brain injury and peripheral vascular disease could influence clinical use of the RSVT as a hemodynamic monitoring tool. Fourth, one can imagine that during very low cardiac output states application of an RSVT can cause a brief reduction in venous return and hence further reduce CO. Fifth, only a small number of patients have been studied. The RSVT technique has to be further evaluated in other subgroups.

Conclusions

We showed that the RSVT procedure is transferable and feasible to predict fluid loading responsiveness. The advantage of the RSVT is that it is not affected by tidal volume and breathing frequency like PVV.

References

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