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Respiratory stroke volume variation assessed by oesophageal Doppler monitoring predicts fluid responsiveness during laparoscopy

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Editor's key points

- This study demonstrates that stroke volume respiratory variation measured by oesophageal Doppler monitoring accurately predicts fluid responsiveness during laparoscopy with a grey zone ranging between 13 and 15%.
- The respiratory variation of the peak velocity was less predictive of fluid responsiveness.
- The corrected flow time was unable to accurately predict fluid responsiveness.

Background. This study was designed to assess the ability of the stroke volume respiratory variation (ΔrespSV) determined by oesophageal Doppler monitoring (ODM) to predict the response to volume expansion (VE) during pneumoperitoneum. The predictive value of ΔrespSV was evaluated according to the concept of the 'grey zone'.

Methods. Patients operated on laparoscopy and monitored by ODM were prospectively included. The exclusion criteria were frequent ectopic beats or preoperative arrhythmia, right ventricular failure, and spontaneous breathing. Haemodynamic parameters and oesophageal Doppler indices [stroke volume (SV), peak velocity (PV), cardiac output (CO), corrected flow time (FTc), respiratory variation of PV (ΔrespPV) and SV (ΔrespSV)] were collected before and after VE. Responders were defined as a $\geq$15% increase in SV after VE.

Results. Thirty-eight (64%) of the 59 patients were responders. A cut-off of $>$14% ΔrespSV predicted fluid responsiveness with an area under the ROC curve (AUC) of 0.92 [95% confidence interval (CI): 0.82–0.98, $P<0.0001$]. The grey zone of ΔrespSV ranged between 13 and 15%. With an AUC of 0.71 (95% CI: 0.56–0.83, $P=0.005$), ΔrespPV fairly accurately predicted fluid responsiveness. FTc was unable to accurately predict fluid responsiveness.

Conclusions. ΔrespSV and ΔrespPV predicted fluid responsiveness during laparoscopy under strict physiological conditions. FTc was not predictive of fluid responsiveness during laparoscopy.

Keywords: anaesthesia; Doppler, intraoperative; laparoscopy; monitoring; stroke volume

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Oesophageal Doppler monitoring (ODM) allows non-invasive continuous monitoring of cardiac output (CO) during surgery.[1] Dynamic preload indicators based on interactions between circulatory and respiratory functions under positive mechanical ventilation, such as respiratory variation of stroke volume (ΔrespSV) and respiratory variation of pulse pressure (ΔrespPP), predict fluid responsiveness during surgery and in intensive care unit (ICU).[2–5] We have recently shown the ability of ΔrespSV measured by ODM to predict fluid responsiveness in a mixed population of surgical patients.[6] However, some studies have highlighted the effect of intra-abdominal pressure (IAP) on the reliability of these indices.[7–9] Elevation of IAP up to 30 mm Hg can affect the accuracy and cut-off values of dynamic preload indices.[8] [9] In the surgical setting, these results may be affected by the fact that IAP is maintained lower than values usually observed during intra-abdominal hypertension. A recent study investigated the effect of pneumoperitoneum during laparoscopy on dynamic preload indices.[7] Using an uncalibrated pressure waveform device, these authors established that ΔrespPP and ΔrespSV did not change during laparoscopy, but had a relatively poor capacity to predict fluid responsiveness. However, haemodynamic changes associated with increased IAP may have affected the validity of the CO monitor used in this study.[10] To the best of our knowledge, ODM respiratory indices have not been studied during laparoscopy. We hypothesized that ΔrespSV measured by ODM would be a good indicator of fluid responsiveness during laparoscopy with pneumoperitoneum.

The primary objective of this study was to demonstrate that ΔrespSV monitored by ODM can accurately predict fluid responsiveness during laparoscopy. We also assessed the capacity of ΔrespPV and corrected flow time (FTc) to predict fluid responsiveness.

Methods

Ethics

This study was approved by the Institutional Review Board (IRB) for human subjects. Informed consent was waived, as the IRB considered the protocol to be part of routine clinical practice.

Patients

A prospective, observational study was conducted in Amiens University Hospital. Patients over the age of 18 yr monitored by ODM during laparoscopic surgery in whom the anaesthetist decided to perform volume expansion (VE) were included. Indications for VE were: optimization of CO, arterial hypotension, or haemorrhage. Patients with frequent ectopic beats or pre-operative arrhythmia, right ventricular dysfunction, spontaneous ventilation, and contraindications to ODM probe insertion were excluded.

Anaesthesia

Each patient was monitored by pulse oximetry, non-invasive arterial pressure monitoring, and 3-lead electrocardiogram and underwent general anaesthesia. All patients received a tracheal intubation and were ventilated in volume-controlled mode. The choice of drugs was left to the anaesthetist's discretion and comprised either propofol or etomidate and remifentanil or sufentanil. Anaesthesia was maintained with either an inhaled hypnotic (desflurane or sevofurane) or propofol and the same opioid used for induction. Neuromuscular block was systematically induced by rocuronium (0.6 mg kg^{-1}) or cisatracurium (0.15 mg kg^{-1}). Tidal volume was adjusted to ideal body weight to obtain 7–9 ml kg^{-1} and the ventilatory rate was adapted to maintain end-tidal CO_2 at 3.99–4.7 kPa; a positive end-expiratory pressure (PEEP) of 0.74–1.24 kPa was applied.

Measurements

The ventilator parameters (end-expiratory pressure, plateau pressure, and tidal volume) were recorded at baseline. Pneumoperitoneum using insufflated intra-abdominal carbon dioxide was maintained with a preset IAP of <15 mm Hg. The IAP was the average of three measured IAP values.

Oesophageal Doppler monitoring

The oesophageal Doppler probe (CardioQ™, Deltex Medical, Gamida, France) was positioned to obtain the optimum signal for descending aorta blood velocity. To avoid artifacts related to the precise distinction of the beginning and end of aortic flow with each ventricular beat that may be distorted by wall thump and run-off, respectively, laminar flow was ensured with a narrow frequency range (blunt velocity profile). Stroke volume (SV), FTc, and peak velocity (PV) were recorded continuously by the ODM software (beat by beat) from aortic blood flow velocity, and their mean values were calculated over 10 s. Respiratory variations (Δresp) of ODM values were obtained as previously described, regardless of the respiratory cycle.[6] The respiratory variation of SV (ΔrespSV) was calculated as $\Delta respSV = \{(SV_{max} - SV_{min})/[(SV_{max} + SV_{min})/2]\} \times 100$, where SV_{min} and SV_{max} are the minimum and maximum SV values over one respiratory cycle, respectively. The same method was used to calculate the respiratory variation of PV (ΔrespPV). All values represented the mean of three measurements. All measurements were analysed off-line using a video sequence of the monitor. ODM is routinely used to monitor surgical patients in our centre with good inter-observer variability.[7]

Study protocol

Each patient was included after intra-abdominal insufflation and stabilization of haemodynamic parameters in the absence of any drug injection or changes in ventilatory parameters. The first VE consisted of infusion of 500 ml Ringer lactate over 10 min and was the only volume challenge recorded for the study. Two sets of measurements [IAP, diastolic arterial pressure (DAP), mean arterial pressure (MAP), systolic arterial pressure (SAP), heart rate (HR), ΔrespPV, ΔrespSV, PV, FTc, and SV] were performed before and immediately after the fluid challenge.

Statistics

At least, 40 patients would be sufficient to demonstrate that ΔrespSV can predict fluid responsiveness with an area under the ROC curve (AUC) of >0.90, for a power of 80%, an alpha risk of 0.05, and a beta risk of 0.2. The distribution of variables was assessed using the D'Agostino–Pearson test. Taking into account the exclusion criteria and possible loss of ODM signal during pneumoperitoneum, 61 patients were recruited over a 6-month period. Data are expressed as proportion (percentage) or mean [standard deviation (SD)], as appropriate. Non-responders and responders were defined by the SV variation (expressed as a percentage) after VE. A positive response was defined as a ≥15% increase in SV.[5 6] A Student's paired *t*-test was used to compare within-group changes in haemodynamic variables. Differences between responders and non-responders were compared by a Student's *t*-test. Linear correlations were tested by the Pearson-rank method. A receiver-operating characteristic curve (ROC) was established for ΔrespSV, FTc, and ΔrespPV. ROC curves were generated by averaging 1000 bootstrapped samples (sampling with replacement) from the original study population. The test previously described by DeLong and colleagues.[11] was used to compare AUC for each variable. The predictive value of ΔrespSV was evaluated by using a grey zone approach, as previously described.[5 12] The grey zone approach indicated two cut-offs between which the prediction of fluid responsiveness remained uncertain. In these cases, the physician must confirm fluid responsiveness by additional information. Differences with a *P*-value of <0.05 were considered statistically significant. IBM® SPSS® Statistics 18 (IBM) was used to perform statistical analysis.

Results

Sixty-one patients undergoing laparoscopic surgery were included. Two were excluded because of ODM failure. No