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Haemodynamic monitors in laparoscopy

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ABSTRACT

Laparoscopic procedures are often performed on high risk surgical patients that could benefit from close haemodynamic monitoring and goal directed fluid therapy. Pneumoperitoneum has been shown to influence haemodynamic variables and alter arterial pressure waveform upon which many minimally invasive haemodynamic monitors rely. There are a few individual studies verifying various less invasive haemodynamic devices. With the possible exception of oesophageal Doppler, their measurements under pneumoperitoneum conditions are less reliable. Besides modifying reliability of monitors, pneumoperitoneum possibly also exerts independent influence on haemodynamic variables, such as lowering predictive value of pulse pressure variation for fluid responsiveness.

Keywords: pneumoperitoneum, laparoscopy, haemodynamic monitoring

INTRODUCTION

Laparoscopic procedures are gaining in frequency of use due to the advantages they possess over classic laparotomy. Laparoscopy is namely associated with reduced inflammatory response, reduced surgical site infection rate, earlier mobilisation, reduced postoperative pain, reduced length of stay and better cosmetic outcome (1–3). Despite failing to prove beneficial in individual studies, goal-directed therapy (GDT) continues to show reduced morbidity when we pool data in meta-analyses (4–6). GDT has also been associated with reduced mortality, but the effect seems to be limited to high risk surgical patients (7). These are the patients that are increasingly receiving laparoscopic treatment due to the above-mentioned advantages of such procedures.

Use of advanced haemodynamic monitoring is thus necessary also during laparoscopic procedures and the reliability of haemodynamic monitors in this setting needs to be determined.

PNEUMOPERITONEUM

Pneumoperitoneum is established with carbon dioxide and automatically held during surgery at 10 – 15 mmHg. This increased intra-abdominal pressure causes an increase in mean arterial pressure (MAP) and systemic vascular resistance (SVR); cardiac output (CO) is usually reduced (8–10). Myocardial contractility appears to remain the same (11) and the reduction of CO is probably due to increased afterload. Pneumoperitoneum also results in significant increases in plasma catecholamine levels that further influence vascular tone (12).

HAEMODYNAMIC MONIORING TECHNIQUES

For anaesthesia practice it is important to know whether a haemodynamic monitor reliably determines CO (that drives oxygen delivery) and whether it can predict fluid responsiveness. Predicting fluid responsiveness largely falls onto respiratory induced variations of pulse pressure (pulse pressure variation, PPV), stroke volume (stroke volume variation, SVV) and sometimes others, i.e. systolic pressure.

Intermittent CO measurements with thermodilution or lithium dilution are reliable techniques, but they are just that – intermittent. What an anaesthesia provider needs is a continuous measurement of haemodynamic variables. Stroke volume (SV) needs to be determined beat-to-beat to enable calculation of SVV.

Minimally invasive haemodynamic monitors estimate SV from the arterial pressure waveform using different algorithms. Modified arterial pressure waveform in changed vascular tone due to vasopressor therapy has been shown to reduce reliability of minimally invasive haemodynamic measurements (13). Altered vascular tone in pneumoperitoneum could have the same effect. But what is the evidence?

Oesophageal Doppler

Oesophageal Doppler (OD) is a minimally invasive haemodynamic device, but it does not use arterial pressure waveform to derive CO measurements. Its reliability during pneumoperitoneum has been compared to the pulmonary artery catheter, widely recognised as the gold standard of haemodynamic measurements and to transthoracic ultrasound (14). It has proven to be a very reliable measurement of CO. In terms of reliability of predicting responsiveness to fluids, Guinot et al. tested the usefulness of SVV measured with OD (15). SVV was shown to be a very accurate predictor of fluid responsiveness with an area under the ROC curve (AUROC) of 0.92 in this study.

Pulse contour methods

Pulse contour devices relate the contour of the arterial pressure waveform to SV and SVR. Høiseth et al. used the 3rd generation of FloTrac™ (Edwards Lifesciences, Irvine, USA), a pulse contour device, to record haemodynamic measurements during pneumoperitoneum (16). Oesophageal Doppler was also used simultaneously. Interestingly, after establishing pnemoperitoneum, OD recorded a fall in CO as expected, but FloTrac™ recorded an increase, which could be explained with distribution of blood flow to upper body parts (FloTrac™ used a radial arterial line signal). Both methods performed well in recording a change of CO to fluids. SVV, measured with FloTrac™, however, was found to be a moderately good predictor of fluid responsiveness with AUROC of 0.74.

As already discussed, vascular tone can be significantly altered in pneumoperitoneum. Changes in vascular tone in turn modify arterial pressure waveform upon which the pulse contour methods rely and

can thus severely influence the reliability of haemodynamic measurements. There is evidence to support this with 3rd generation of FloTrac™ mentioned above (13) and a 4th generation was introduced and is believed to be more reliable (17), however it has not been tested during laparoscopy.
PiCCO™ (Pulsion, Munich, Germany) also uses the pulse contour method to obtain continuous CO values and should face similar limitations. Additional concern is the femoral positioning of the arterial cannula for arterial pressure recording, which could be influenced by flow redistribution. Some data using PiCCO™ in animals and humans during pneumoperitoneum exist, but all CO measurements were performed with thermodilution and not estimated by the pulse contour, so the method has not really been tested in this setting (18,19).

Pulse power method

Pulse power method is used by the PulseCO™ algorithm in LiDCO™ devices (LiDCO Ltd, Cambridge, UK). It uses the assumption of conservation of mass/power and that following correction for aortic compliance, net power has a linear relationship to net flow. Because of this it is less influenced by changes in arterial pressure waveform and is believed to be reliable with changes in vascular tone (20). However, until recently it has not been tested in pneumoperitoneum. We conducted a study using LiDCORapid™ during laparoscopy (21). The device was able to track changes in intravascular volume. SVV predicted fluid responsiveness with AUROC 0.8, but with lower sensitivity (63%).

Non-invasive monitors

Lately, completely non-invasive devices are being introduced to measure haemodynamic parameters. There are some reports that they might remain useful during laparoscopy (22), but more data is needed to confirm these findings.

VALIDATION DILEMMAS

Assessing accuracy of CO measurements with different haemodynamic devices is difficult for several reasons. There needs to be a gold standard and it is widely accepted that this should be the pulmonary artery (PA) catheter. The PA catheter has a relatively high complication rate and failed to reduce mortality in intensive care (23) and its use has declined to only a few indications. Also, declaring a CO measurement as accurate or not depends largely on the method described originally by Critchley and Critchley (24), but this method too has been questioned as the most appropriate (25). In the absence of a widely used gold standard and a reliable methodology, it is difficult to design validation studies.

CONCLUSION

Pneumoperitoneum clearly limits the use of less invasive haemodynamic monitors because it influences haemodynamic measurements and reduces their reliability. Oesophageal Doppler seems to be the most reliable for measuring CO and SVV in this setting, probably because it does not rely on the arterial pressure waveform. However, PPV, measured by different means, has consistently performed worse than SVV in pneumoperitoneum conditions (15,16,21). This is possibly an influence of pneumoperitoneum on this haemodynamic variable that is independent of the measuring technique, rendering it a less reliable predictor of fluid responsiveness.
Minimally invasive monitors remain useful tools during laparoscopy, but the measurements should be interpreted with caution. More data is needed to enable more exact conclusions.

CONFLICTS OF INTEREST

The author has acted as a lecturer for Edwards Lifesciences.

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