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Effects of pneumoperitoneum and Trendelenburg position on intracranial pressure assessed using different non-invasive methods

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Abstract

Background. The laparoscopic approach is becoming increasingly frequent for many different surgical procedures. However, the combination of pneumoperitoneum and Trendelenburg positioning associated with this approach may increase the patient's risk for elevated intracranial pressure (ICP). Given that the gold standard for the measurement of ICP is invasive, little is known about the effect of these common procedures on ICP.

Methods. We prospectively studied 40 patients without any history of cerebral disease who were undergoing laparoscopic procedures. Three different methods were used for non-invasive estimation of ICP: ultrasonography of the optic nerve sheath diameter (ONSD); transcranial Doppler-based (TCD) pulsatility index (ICP_{PI}); and a method based on the diastolic component of the TCD cerebral blood flow velocity (ICP_{FVd}). The ONSD and TCD were measured immediately after induction of general anaesthesia, after pneumoperitoneum insufflation, after Trendelenburg positioning, and again at the end of the procedure.

Results. The ONSD, ICP_{FVd}, and ICP_{PI} increased significantly after the combination of pneumoperitoneum insufflation and Trendelenburg positioning. The ICP_{FVd} showed an area under the curve of 0.80 [95% confidence interval (CI) 0.70–0.90] to distinguish the stage associated with the application of pneumoperitoneum and Trendelenburg position; ONSD and ICP_{PI} showed an area under the curve of 0.75 (95% CI 0.65–0.86) and 0.70 (95% CI 0.58–0.81), respectively.

Conclusions. The concomitance of pneumoperitoneum and the Trendelenburg position can increase ICP as estimated with non-invasive methods. In high-risk patients undergoing laparoscopic procedures, non-invasive ICP monitoring through a combination of ONSD ultrasonography and TCD-derived ICP_{FVd} could be a valid option to assess the risk of increased ICP.

Key words: head-down tilt; intracranial pressure; optic nerve sheath diameter; pneumoperitoneum; transcranial Doppler

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Editor's key points

- Laparoscopic procedures are commonly performed with pneumoperitoneum and the patient in the Trendelenburg position.
- These procedures can both cause increases in intracranial pressure.
- The authors studied three non-invasive estimates of intracranial pressure in healthy patients undergoing laparoscopic surgery.
- Concordant increases of all three measures were found.

Laparoscopic surgery has become a rapidly growing alternative technique to conventional open surgery for many types of surgical procedures because of its minimal invasiveness, reduced risk of haemorrhage, lower postoperative pain, and a consequent earlier discharge.[1–3] An adequate surgical exposure requires the application of a CO_2 pneumoperitoneum (PP) and often a concomitant steep head-down position (up to 45°; Trendelenburg position; TP).

Pneumoperitoneum and the consequent increased intra-abdominal pressure can have many systemic physiological consequences, including decreased venous return, hypercapnia, and respiratory acidosis as a result of absorption of CO_2 across the peritoneal surface.[4 5] Haemodynamic and respiratory effects are generally mild and well tolerated.[6]

The effects of PP and the TP on intracranial pressure (ICP) are poorly documented, but there is growing evidence that demonstrates a positive correlation between intra-abdominal pressure and ICP.[7 8] In an animal model, ICP increased significantly during increased intra-abdominal pressure (15 mm Hg) combined with the TP.[9]

The effect of PP and the TP on ICP cannot be determined easily during surgery[10] as invasive ICP monitoring is contraindicated in this group of patients because of the possible complications.[11] Therefore, in particular for patients at risk of developing intracranial hypertension during laparoscopic surgery, a non-invasive method to monitor ICP would be desirable.[12]

The aim of this study was to assess the extent of hypothetical ICP changes resulting from PP and the TP by applying ultrasonographic measurement of the optic nerve sheath diameter (ONSD) and transcranial Doppler (TCD)-derived methods in patients with no head injury undergoing laparoscopic surgery; furthermore, we discuss and compare the use of each method in this setting.

Methods

The study was approved by the institutional ethics committee on April 10, 2015 (registration number 029REG2015), and written informed consent was obtained from all participants. Forty-three ASA class I or II adult patients undergoing abdominal laparoscopic surgery requiring PP and the TP were initially enrolled between May 2015 and October 2015 at Galliera Hospital, Genoa, Italy.

Patients younger than 18 yr, with pre-existing ophthalmic diseases, a history of ophthalmic surgery, or affected by any type of neurological disease were excluded. In three patients, an appropriate temporal window for TCD measurement could not be found, and these patients were excluded from the cohort.

On arrival in the surgical suite, standard monitoring was applied, including pulse oximetry, ECG, and non-invasive arterial blood pressure. Patients were not premedicated. After preoxygenation, general anaesthesia was induced with propofol (1.5 mg kg^{-1} i.v.) and fentanyl (1 μg kg^{-1} i.v.). To facilitate tracheal intubation, cisatracurium besilate (0.15 mg kg^{-1} i.v.) was administered. Mechanical ventilation was performed with a tidal volume of 8 ml kg^{-1}, and the respiratory rate was adjusted to maintain an end-tidal carbon dioxide partial pressure (PE'_{CO_2}) of 4.6–5.5 kPa during surgery. Anaesthesia was maintained with remifentanil 0.05–0.2 μg kg^{-1} min^{-1} and 1–1.5 minimal alveolar concentration of sevofluorane in 50% oxygen/air. The head-down TP was achieved by tilting the table to an angle range of 20–25° (visually assessed), adjusted for surgical exposure and laparoscopic accessibility. Carbon dioxide PP was established using an intra-abdominal pressure between 10 and 15 mm Hg.

Ultrasonographic measurements of ONSD and of the middle cerebral artery flow velocity (FV) by transcranial colour Doppler were conducted by a single trained investigator (C.R.) as previously described (DC-T6; Mindray Medica, Schenzen, China)[10] with a linear 7.5 MHz ultrasound probe (7L4a; Mindray Medica Dc-n3) and 2.5 MHz ultrasound probe (2P2; Mindray Medica Dc-n3), respectively (Fig. 1). In addition, the duration of surgery, duration of anaesthesia, intraoperative blood loss, and the volume of administered fluids were assessed. Mean arterial pressure (ABPm), PE'_{CO_2}, middle cerebral artery flow velocities [systolic (FVs), mean (FVm), and diastolic (FVd)], and ONSD were recorded at the following time points: B, baseline, after induction of anaesthesia; PP, after pneumoperitoneum, 10 min after pneumoperitoneum insufflation; TP+PP, 10 min after Trendelenburg positioning with pneumoperitoneum insufflation; and A, at the end of surgery, after pneumoperitoneum and in the neutral position, still under general anaesthesia.

Pulsatility index (PI)-derived non-invasive ICP (ICP_{PI}) was calculated according to a linear regression model between ICP and PI, obtained from data described by Budohoski and colleagues.[13] The PI was calculated according to Gosling's method[14] (PI= (FVs−FVd)/FVm).

$$ICP_{PI} = 8.35 + 7.60 \times PI \text{ (in millimetres of mercury)}$$

The FVd-based non-invasive ICP (ICP_{FVd}) was derived from work of Czosnyka and colleagues,[15] in which the authors describe a method for non-invasive estimation of cerebral perfusion pressure (CPP) in traumatic brain injured patients, as follows:

$$CPP = ABPm \times (FVd/FVm) + 14 \text{ (in millimetres of mercury)}$$

In this instance, non-invasive ICP (nICP) was estimated as the difference between inflow (ABPm) and non-invasive cerebral perfusion pressure, as follows:

$$ICP_{FVd} = ABPm - CPP \text{ (in millimetres of mercury)}$$