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Impact of laparoscopic surgery on thoracoabdominal mechanics and inspiratory muscular activity

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ABSTRACT

Objective: To evaluate the effect of laparoscopic surgery on pulmonary volume distributions and inspiratory muscles activity. Respiratory consequences associated with postoperative pain were also evaluated.
Methods: This study enrolled 20 patients without lung disease performed spirometry and chest wall kinematic analyses (i.e., chest wall, upper and lower ribcage and abdominal volumes), and measured the activity of inspiratory muscular before and 2 days after laparoscopic surgery. Pain was also assessed.
Results: After laparoscopy, the patients demonstrated decreased volumes in all three thoracoabdominal compartments: abdomen (ABD), upper and lower rib cage (URC and LRC, respectively) compared with the pre-operative measurements: ABD = 0.38 ± 0.20 L vs. 0.55 ± 0.25 L; URC = 0.45 ± 0.18 L vs. 0.55 ± 0.21 L; and LRC = 0.31 ± 0.18 L vs. 0.41 ± 0.23 L; $p < 0.05$. A reduction in the inspiratory muscular activity after surgery was also observed (sternocleidomastoid: $10.6 \pm 5.1 \times 10^{-3}$ mV vs. $12.8 \pm 6.3 \times 10^{-3}$ mV; intercostals: $16.8 \pm 12.4 \times 10^{-3}$ mV vs. $25.1 \pm 21.3 \times 10^{-3}$ mV; $p < 0.05$). In addition, lower volumes during deep breathing were observed in patients who reported significant pain than those who did not (0.51 ± 0.17 L vs. 0.79 ± 0.29 L; $p < 0.05$, respectively).
Conclusion: Laparoscopic surgery reduces chest wall ventilation and inspiratory muscular activity during deep breathing. The effects appear to depend on the patient's reported pain level.

1. Introduction

Current procedures for laparoscopic surgery are less invasive with lower hospital costs than those for open surgery (Roumm et al., 2005); however, laparoscopic surgery is not free from postoperative complications. Respiratory changes during the postoperative period following laparoscopic surgery appear to be associated with increased abdominal pressure caused by intraoperative pneumoperitoneum (Koivusalo et al., 2008), diaphragmatic paresis caused by inhibition of the phrenic nerve (Erice et al., 1993; Ayoub et al., 2001), and postoperative pain (Kawamura et al., 2008). Several studies have shown that laparoscopic surgery reduces pulmonary volumes and capacities during the postoperative period, especially forced vital capacity (Damiani et al., 2008; Karagulle et al., 2008; Kimball et al., 2008). However, these studies evaluated lung function using spirometry, which requires an intense effort from the patient and does not assess thoracoabdominal motions or breathing patterns. The effects of the laparoscopic surgery on chest wall mechanics and breathing patterns have not been properly investigated.

Optoelectronic plethysmography (OEP) is a new technology that was developed to assess thoracoabdominal mechanics and breathing patterns using three-compartment analyses (Aliverti et al., 2009). OEP is noninvasive and permits the evaluation of chest wall mechanics simultaneously with other measurements, such as respiratory muscular activity. This technology has been applied in various clinical situations (Aliverti et al., 2006, 2009); however, no study in the surgical field has been published. OEP analyses may help to elucidate the impact of laparoscopic surgery on thoracoabdominal mechanics and indicate the need for additional postoperative respiratory care.

1.1. Objective

The aim of the present study was to evaluate the effect of laparoscopic surgery on the distribution of pulmonary volumes and inspiratory muscles activity. Respiratory consequences associated with postoperative pain were also evaluated.

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2. Methods

2.1. Design

This prospective cohort study was approved by the Hospital Research Ethical Committee (protocol number 0681/11), and all subjects provided written informed consent.

2.2. Participants

The study population included 20 consecutive patients, ≥18 years of age, admitted for laparoscopic surgery (cholecystectomy, colectomy or fundoplication surgery) in a university tertiary hospital, with an estimated surgical time longer than 120 min. The exclusion criteria included deformity of the chest wall or spine, the presence of pulmonary or cardiac disease, inability to perform spirometry, or previous abdominal surgery.

2.3. Study protocol

After signing the informed consent, patients performed spirometry, which was followed by an analysis of their thoracoabdominal kinematics and inspiratory muscular activity, both assessed concurrently. All patients were evaluated twice: one day before their scheduled surgery (1st assessment) and on the second postoperative day (2nd assessment). Their pain was also assessed on the second postoperative day.

2.4. Measurements

2.4.1. Lung function test

Spirometry (Spirobank®, Italy) was performed using the technical procedures recommended by the European Respiratory Society/American Thoracic Society (Miller et al., 2005) with the predicted normal values proposed by Pereira (2002).

2.4.2. Thoracoabdominal kinematics

These measurements were assessed using optoelectronic plethysmography (OEP System, BTS, Italy) as previously described (Aliverti et al., 2006). This equipment is based on eight special video cameras (solid-state charge-coupled devices) operating at 100 frames per second and synchronized with an infrared flashing light-emitting diode (LED). Four cameras were positioned in front of the subject and four behind. Briefly, 89 retro-reflective markers were placed on the anterior and posterior side of the trunk, according to the protocol previously described by Aliverti et al. (2009) (Fig. 1A). The equipment was calibrated in three dimensions based on the manufacturer's recommendation. Afterward, assessments were performed with the subjects seated on a wheelchair without a back support to permit the evaluation of the thoracoabdominal kinematics from a wide range of angles around the chest wall. We tested the reproducibility of the method by evaluating the association between of chest volumes during quiet breaths in 2 distinct days and we observed a strong correlation ($r = 0.83$; $p < 0.001$).

- *Respiratory resources*: During the thoracoabdominal mechanics assessment, subjects were instructed to perform eight quiet breaths followed by eight deep breaths (as deep as possible, in the same manner as during the inspiratory phase of spirometry) (Paisani et al., 2012). The average of 6 homogeneous quiet respiratory cycles and the average of 6 homogeneous deep respiratory cycles were considered for the data analysis performed by a bioengineer who was blinded to the patient's condition. The chest wall volumes and inspiratory muscular activity were assessed concurrently. The correlation among the pre- and post-operative chest wall volumes during quite breathing was tested to check the quality of the measurements.

The following variables were measured.

2.4.2.1. Total chest wall (CW) and compartmental volumes. The OEP software (SMART) reconstructed the three-dimensional position of each marker during the recording and computed the chest wall volumes with high accuracy. The algorithms computed the changes in volume of the whole chest wall and of the following compartments: upper ribcage (URC), lower ribcage (LRC) and abdomen (ABD). The values are expressed in absolute values and percentages (Fig. 1B).

- *Quiet breathing* was defined as the amount of air displaced during normal inspirations and expirations when no extra effort was applied.
- *Deep breathing* was defined as the amount of air displaced during the deepest voluntary inspiration.

2.4.2.2. Thoracoabdominal asynchrony. This calculated value indicated the relationship between the position of the upper ribcage and the abdominal phase angle according to Agostoni and Mognoni (1966). Briefly, this value was calculated by determining the time lag between the peaks of the signals from the upper ribcage and the abdomen and dividing the obtained value by the cycle time as 360 degrees.

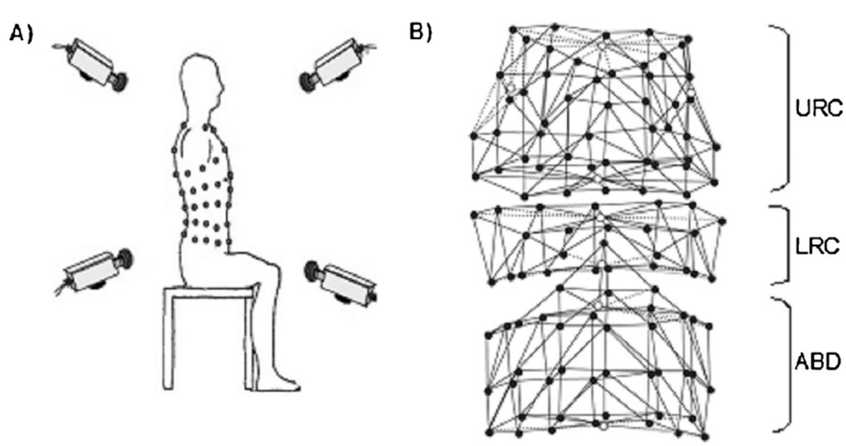

Fig. 1. (A) Retro-reflective markers positioning on the front and back of the subject and cameras positioned in front of and behind the subject. (B) The actual triangulation for the different compartments of the chest wall (URC = upper ribcage, LRC = lower ribcage and ABD = abdominal). For better measurements, the position of the markers in each compartment was represented slightly shifted in the vertical direction.