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Full Length Research Paper

Assessment of respiratory muscle strength, maximal expiratory flow and pain after upper and lower laparotomy

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Abdominal surgeries are frequently associated with postoperative respiratory muscle dysfunction. The aim of this study was to investigate the behavior of maximal inspiratory and expiratory pressure (MIP and MEP), peak expiratory flow (PEF) and pain in the pre-operative and postoperative of open inguinal herniorrhaphy (OIH) and open cholecystectomy (OC). Twenty seven patients with low risk factors for respiratory complications submitted to OIH (n=12) or OC (n=15) were investigated. The MIP, MEP, PEF and pain were measured at times pre-operative and 24 hours postoperative using manovacuometer, peak flow meter and visual analog scale of pain respectively. There was significant reduction of all respiratory measures in the 24 hours after OC (p<0.05) and only of the expiratory variables in the 24 hours after OIH (p<0.05). The level of pain was significantly increased after OIH (p<0.05). We found that both surgery types assessed caused impairment of the respiratory muscle strength and the PEF. Therefore, the respiratory muscle evaluation can be useful to determine the pulmonary dysfunction results from upper and lower abdominal surgery.

Keywords: Respiratory muscles; Respiratory function tests; Pain; Laparotomy.

INTRODUCTION

Laparotomy is frequently associated with postoperative restrictive respiratory function impairments, characterized principally by a reduction in vital capacity, functional residual capacity and tidal volume (Siafakas et al., 1999; Suter et al., 2002). In addition, hypoxemia, increased respiratory work and frequency, reduced maximal expiratory flow, maximum respiratory pressures, changes in breathing pattern and atelectasis are commonly found following surgery (Joris et al., 1997; Miranda et al., 2009).

There is evidence that the pathogenesis of postoperative respiratory dysfunction is multifactorial and that the principal variables related to this condition are the size of the surgical scar, duration of surgery and anesthesia, postoperative pain, local inflammatory process, visceral manipulation and biomechanical alterations in the thoracic cavity (Joris et al., 1997; Siafakas et al., 1999; Mímica et al., 2007; Miranda et al., 2009). In addition, there have been reports that upper abdominal and lower abdominal surgeries give rise to different respiratory repercussions by affecting each one of these variables differently. In the majority of cases, there is a higher incidence of pulmonary complications

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following abdominal surgeries performed through a supraumbilical incision compared to an infraumbilical one (Joris et al., 1997; Mímica et al., 2007). Some evidence suggests that the localization of the area of the surgical incision in relation to the diaphragm and the different levels of visceral manipulation involved in each procedure could be responsible for the differences in the postoperative pulmonary function (Joris et al., 1997; Joris et al., 1998).

Few studies have simultaneously analyzed respiratory muscle performance and its correlation with pain, respiratory muscle strength and maximum expiratory flow, prior to and following upper and lower abdominal surgery (Siafakas et al., 1999; Suter et al., 2002). Therefore, the objective of the present study was to investigate the patterns of MIP, MEP, PEF and pain in the pre-operative and postoperative of patients submitted to open cholecystectomy (OC) or open inguinal herniorrhaphy (OIH).

MATERIALS AND METHODS

This is a prospective, cross-sectional study in which 27 patients submitted to surgery following a clinical diagnosis of unilateral inguinal hernia (n=12) or cholelithiasis (n=15), were evaluated. The patients were enrolled in the study, during a period of one year, according to the service demand. Both the pre-operative and postoperative evaluations and the surgical procedures were all performed by the same surgeon in the Holy House of Charity in the township of Diamantina, Minas Gerais, Brazil.

Exclusion criteria consisted of pregnant women, previous thoraco-abdominal surgery, patients incapable of understanding the procedures required for measuring respiratory variables, patients with thoracic deformities, use of any medication that could affect respiratory muscle function or bronchial diameter, extenuating physical activity less than 12 hours or a full meal three hours prior to the study procedures, cardiac or neuromuscular disease, a past history, clinical or imaging diagnosis of pneumopathies and cases in which the planned surgical technique was modified during surgery (Joris et al., 1998; Neder et al., 1999; Siafakas et al., 2000). The study was approved by the University Research Ethical Board, and all participants signed an informed consent form prior to initiation.

Sociodemographic data and any pulmonary risk factors were recorded prior to surgery at an interview and classification of anesthetic risk in accordance with the criteria defined by the American Society of Anesthesiologists (ASA) (Wolters et al., 1996). Obesity and overweight were evaluated by calculating body mass index [BMI = weight (kg) / height (m^2)]. Patients were considered to be overweight when their BMI was ≥ 25 and < 30 kg/m^2 and obese when their BMI was ≥ 30 kg/m^2 (Joris et al., 1998; Weiner et al., 1998). Following surgery, data were collected from the patients charts with respect to the occurrence of complications during surgery, the duration of surgery and anesthesia. MIP, MEP, PEF and pain were measured on the morning prior to surgery and again 24 hours after surgery by the same previously trained evaluator in all cases. The order in which the respiratory measurements were taken was randomized in each case and an interval of 10 minutes was established between the measurements of each variable analyzed (Joris et al., 1998).

Surgical procedures

All the surgical procedures were performed by the same general surgeon. Cholecystectomy was carried out as previously described by Coelho et al., 1993. Anesthesia was induced by the intravenous administration of 2.0 ml/kg of propofol and 3 mg/kg of fentanyl, adjusted according to the body weight of each patient. The intraoperative neuromuscular block was achieved using 0.5 mg/kg of atracurium, while orotracheal intubation was facilitated by using 1 mg/kg of succinylcholine. Anesthesia was maintained with 50% nitrous oxide in oxygen and isoflurane (Joris et al., 1998). Inguinal hernia repair was performed as previously described by Vianna et al., 2004. The anesthetic technique used was the same in all patients submitted to herniorrhaphy: rachianesthesia consisting of a 4-ml injection of 0.5% bupivacaine solution combined with 15 mg of the sedative midazolam applied intravenously (Roche, Rio de Janeiro, Brazil).

Postoperative pain was controlled with dipyrone (15 mg/kg) and 1 ml of pethidine chlorohydrate (50 mg/ml) were administered parenterally every six hours beginning at discharge from the post-anesthesia care unit and maintained until 48 hours after the surgical procedure.

Evaluation of respiratory muscle strength

MIP and MEP were measured using a handheld manovacuometer, with operational intervals of ±300 cm$H_2$0 (Globalmed, São Paulo, SP, Brazil). A previous study compared measurements of respiratory muscle strength generated by a portable handheld manovacuometer with values obtained using a pressure transducer, a device that is considered the gold standard, and found no statistically significant differences (Hamnegard et al., 1994), confirming the precision and reproducibility of the handheld manovacuometer.

Measurements were taken in accordance with the guidelines defined by Black and Hyatt (1969). Maximum respiratory effort was sustained for at least two seconds and the manoeuvres were repeated up to a maximum of five times, including three acceptable manoeuvres.[(4)] Manoeuvres were considered acceptable when there was no leakage of air and the measurements were considered reproducible when the variation was ≤ 10% of the greatest value. The highest measurement among the reproducible manoeuvres was used in the analysis (Neder et al., 1999; Miranda et al., 2009). MIP was measured following maximum expiration and MEP following maximum inspiration. A minimum interval of one minute was established between each measurement to allow the individual to recover (Black and Hyatt, 1969; Miranda et al., 2009).

Evaluation of peak expiratory flow rate

PEF was measured using an Assess peak flow meter (HealthScan, Cedar Grove, NJ, USA) with an operational range of 60-880 L/min. The patient's head was put in a neutral position to reduce the effect of hyperextension and of flexion in the tracheal complacence and in the measurements taken. With the device in the horizontal position, maximum inspiration was performed followed by maximum forced, short, explosive expiration. At least three measurements were carried out and the manoeuvre was repeated until the difference between them was no greater than 20 L/min. The highest of the three readings was used in the analysis (Miranda et al., 2009).

A good correlation (79-92%) has been found between the PEF measurements obtained using portable meters, including the one

Table 1. Mean values and Standard deviation (SD) of the demographic and anthropometric features and surgery process of patients submitted to open inguinal hernia (n=12) and to open cholecystectomy (n=15).

Variable	Inguinal Hérnia		Cholecystectomy		P value
	Mean	SD	Mean	SD	
Age (years)[1]	45.83	14.67	47.73	16.45	0.76
Height (m)[1]	1.61	0.11	1.59	0.082	0.29
Body Mass (kg)[1]	66.16	9.51	65.95	7.35	0.90
BMI (kg/m^2)[2]	25.54	3.72	26.20	4.04	0.68
Anesthesia (min)[1]	73.75	16.53	57.33	16.02	<0.05*
Surgery (min)[1]	50.00	16.38	37.67	17.1	0.07

BMI: Body Mass Index. [1]Student's t-test; [2]Mann-Whitney Test; *p<0.05.

used in the present study, and the values generated at spirometry for the same variable (Miranda et al., 2009). Gardner et al. (1992) reported good reliability and reproducibility of data generated by eight portable PEF meters including the Assess peak flow meter.

Evaluation of pain

A visual analog scale (VAS) was used to evaluate pain. The patients were asked to indicate on a scale of 0 (no pain) to 10 (maximum pain) the level of pain perceived prior to initiating the procedure of measuring respiratory strength and flow at each one of the two moments evaluated (prior to and 24 hours following surgery). The VAS is an instrument that is simple to administer, valid and widely used to evaluate postsurgical pain (DeLoach et al., 1998).

Statistical Analysis

Data analysis was performed using the SPSS (*Statistical Package for the Social Sciences*), version 11.0. Means and standard deviations (SD) were calculated to describe the demographic, anthropometric and clinical characteristics of the patients in the study sample. All quantitative data were subjected to the Shapiro-Wilk normality test for defining the use of either parametric or non-parametric tests in the bivariate analysis. The Paired-sample t-test (variables with normal distribution) or Wilcoxon test (variables with non-normal distribution) was used for the comparison intra-group. Correlations between the variables of pain, MIP, MEP and PEF were analyzed using Spearman's test. A significance level of 5% was defined throughout the statistical analysis.

RESULTS

Twenty-seven patients participated in the present study, 12 of who were submitted to OIH and 15 to OC. Of the patients submitted to OIH, 11 were male and 8 were non-smokers. In addition, 8 were eutrophic, 3 were overweight and 1 was obese. According to the criteria defined by the American Society of Anesthesiologists, the anesthetic risk of 8 patients was classified as ASA I while 4 were classified as ASA II. With respect to the group of patients submitted to OC, 14 were female and 13 were non-smokers. In addition, 9 of the individuals were eutrophic, 3 were overweight and 3 were obese. In the OC group, 6 patients were being classified as ASA I, 8 as ASA II and 1 as ASA III. All the patients investigated had normal preoperative exams and during hospitalization there were no records of intrasurgical or postsurgical complications.

Comparison between the mean values for age, anthropometric parameters, duration of surgical procedure and anesthesia showed a significant difference between the OC and OIH groups only with respect to the duration of anesthesia (table 1).

When pre-operative and postoperative mean values of the respiratory variables were compared in the OC group, a significant reduction was found in MEP (48.1%) and PEF (37.8%) following this surgical procedure. A significant reduction in these variables was also found in the OIH group, in which postoperative MEP (42.3%) and PEF (17.7%) values were lower than those recorded preoperatively. A significant reduction (51.6%) occurred in MIP only in the OC group. Unlike the results described for the variables of force and expiratory flow, pain scores were higher in the postoperative period compared to the preoperative period for both surgical procedures; however, statistical significance was only found in the OIH group, in which this variable increased 123.9%. The behaviors of these variables are shown for the OIH and OC groups in figures 1 and 2, respectively.

No significant correlation was found between pain and the variables of respiratory muscle strength or expiratory flow in either group at either of the moments evaluated (Table 2).

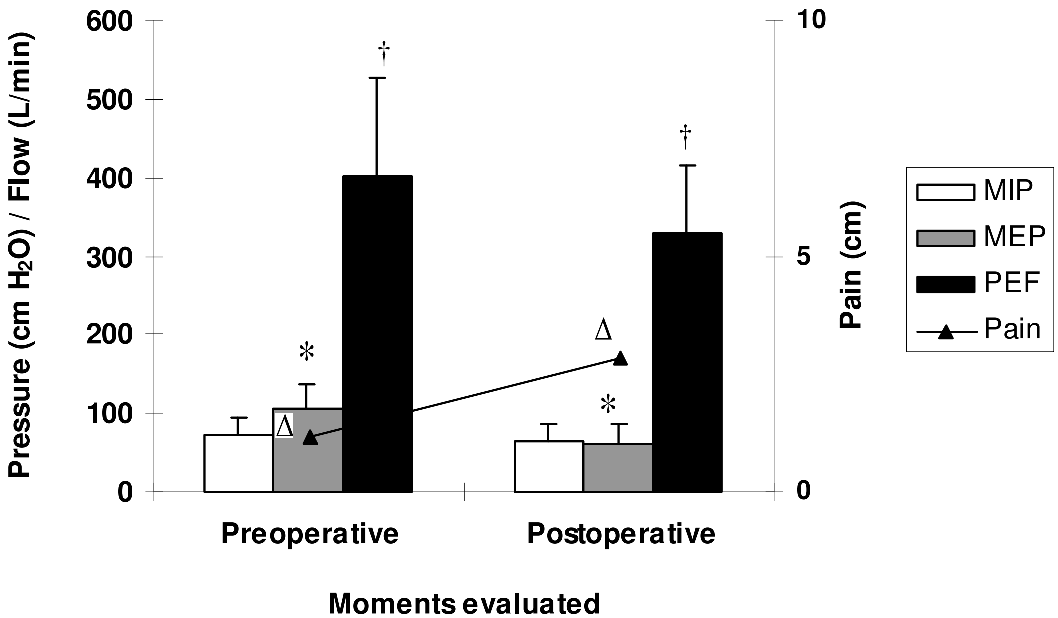

Figure 1. Mean values and Standard deviation (SD) of pain, maximal inspiratory and expiratory pressure and peak expiratory flow evaluated in pre-operative time and 24 hours after open inguinal hernia. MIP: maximal inspiratory pressure; MEP: maximal expiratory pressure; PEF: peak expiratory flow. Δ†* statistical difference between the measures; $p<0.05$.

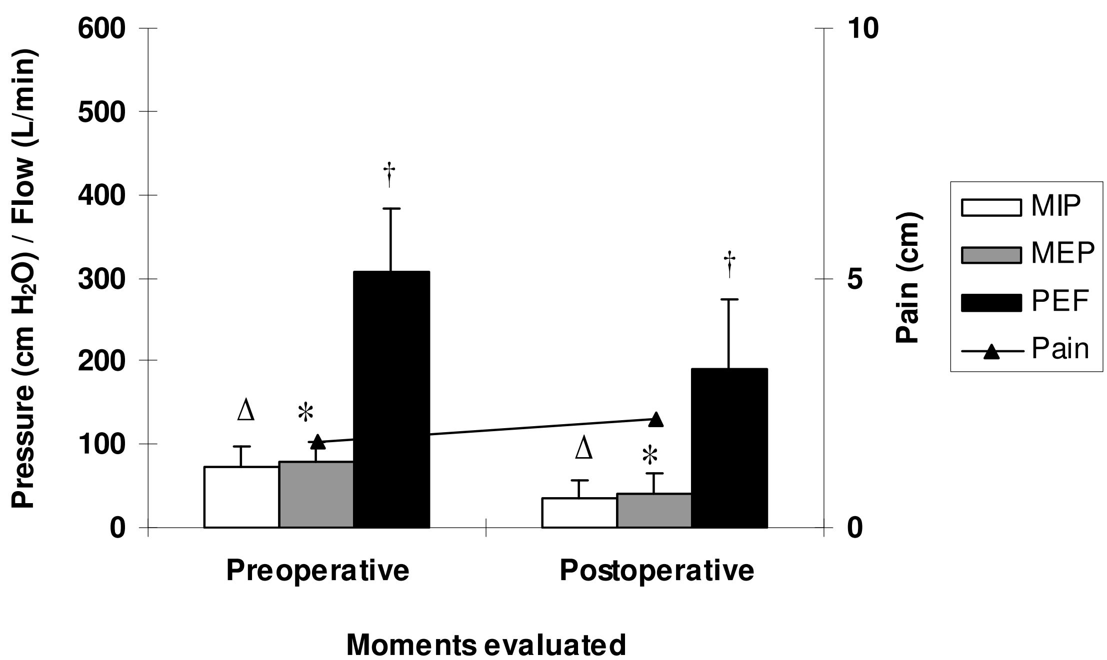

Figure 2. Mean values and Standard deviation (SD) of pain, maximal inspiratory and expiratory pressure and peak expiratory flow evaluated in pre-operative time and 24 hours after open cholecystectomy. MIP: maximal inspiratory pressure; MEP: maximal expiratory pressure; PEF: peak expiratory flow. Δ†* statistical difference between the measures; $p<0.05$.

Table 2. Analysis of Spearman's correlation between the variables: pain, maximal inspiratory and expiratory pressure and peak expiratory flow for the groups submitted to open inguinal hernia (n=12) and open cholecystectomy (n=15).

Variable	Inguinal Hernia		Cholecystectomy	
	Correlation (r)	P value	Correlation (r)	P value
Pre-Pain X Pre-MIP	0.26	0.417	0.32	0.24
Pre-Pain X Pre-MEP	0.20	0.534	-0.16	0.57
Pre-Pain X Pre-PEF	-0.06	0.847	-0.38	0.15
Post-Pain X Post-MIP	0.19	0.555	-0.21	0.44
Post-Pain X Post-MEP	-0.14	0.667	-0.26	0.35
Post-Pain X Post-PEF	-0.24	0.453	-0.26	0.35

MIP: maximal inspiratory

DISCUSSION

In this study, patients with low risk factors for pulmonary complications presented reduction of the respiratory measures and increase of pain following upper and lower abdominal surgery. The decrease in respiratory muscle strength and expiratory flow was found 24 hours after both surgical procedures. This reduction was significant for all the respiratory variables analyzed in the OC group, whereas in the OIH group, a significant difference was found for MEP and PEF when the measurements were compared in the pre-operative and postoperative moments. It has been well established that OC and OIH provoke respiratory damage of neural and muscular origin (Coelho et al., 1993; Mímica et al., 2007; Miranda et al., 2009); therefore, a reduction in MIP, MEP and PEF values following these procedures is not unusual, since these variables are dependent on inspiratory and expiratory muscle function, respectively. Studies on abdominal muscle and diaphragm activation carried out using electromyography and sonography have confirmed this finding by demonstrating that, following laparotomy and laparoscopy, a reduction occurs in the activation of these muscles with a consequent alteration in respiratory biomechanics (Sharma et al., 1999; Ayoub et al., 2001; Berdah et al., 2002). In both surgical procedures, the mechanical lesion of the abdominal wall muscle leads to a reduction in the strength of the abdominal rectus muscle, and internal and external oblique muscles (Joris et al., 1997; Vianna et al., 2004). The action of these muscles during forced expiration is recognized and, since MEP and PEF are measurements that are dependent on expiratory strength, it is to be expected that damage to abdominal muscle strength would lead to a decrease in these variables (Suter et al., 2002). With respect to MIP, it was clearly shown that OIH did not reduce this variable significantly in the postoperative period. It has already been reported that in cases of OC the reduction in MIP is principally related to inhibition of the phrenic nerve due to sensitization of the afferent splanchnic nerve with consequent diaphragmatic insufficiency (Sharma et al., 1999; Ayoub et al., 2001; Berdah et al., 2002; Miranda et al., 2009). Therefore, since the principal mechanism involved in the reduction of MIP is the compromised contractile capacity of the diaphragm (Sharma et al., 1999; Ayoub et al., 2001; Berdah et al., 2002), no significant alteration was expected in this variable in the OIH group.

The behavior of pain in the postoperative period differed in both groups from that observed with respect to the respiratory variables studied. Higher levels of pain were identified in the 24 hours following the surgical procedures, nevertheless, this increase was only significant in the OIH group. A correlation has been described between pain levels and the degree of respiratory dysfunction following abdominal surgery (Mímica et al., 2007). However, this relationship remains controversial. In the present study, no correlation was found between pain and the respiratory variables evaluated in either of the study groups. This finding is in agreement with previous studies that showed that the use of analgesics administered enterally and parenterally failed to improve respiratory function in patients submitted to this type of surgical procedure. Therefore, pain has been excluded or considered less important in the genesis of respiratory muscle dysfunction following abdominal surgery (Joris et al., 1998; Miranda et al., 2009). Consequently, these findings indicate that pain should not be considered as a single factor to explain the reduction in these variables following inguinal herniorrhaphy and open cholecystectomy.

The first limitation of our study is regarding the small size of the sample in both surgeries groups. The patients were evaluated during a year according to the service demand. During the period of the data collection only 12 patients were submitted to the OIH and 15 to the OC. Second, the OC group were composed predominantly by women, whereas, the OIH group were by men. Once the variable sex influences the respiratory measure were not possible to compare the results found between the two surgery groups.

In conclusion, there was a significant reduction in the respiratory measures at 24 hours after OC and OIH surgeries. The more pronounced decrease was found in the upper abdominal surgery corroborating to other previous studies. The lack of correlation between pain, respiratory muscle strength and peak expiratory flow, in both groups evaluated, indicate that pain could not be the mainly factor to explain the respiratory alterations found. Moreover, our data suggest that respiratory muscle evaluation can be useful to determine the pulmonary dysfunction results from upper and lower abdominal surgery and should be done in patients with increase risk factors for respiratory complications.

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