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SCIENTIFIC ARTICLE

Functional residual capacity increase during laparoscopic surgery with abdominal wall lift[☆]



Hiroshi Ueda^a, Takuo Hoshi^{b,*}

^a Ibaraki Prefectural Central, Department of Anesthesiology and Critical Care Medicine, Ibaraki, Japan

^b Ibaraki Clinical and Training Center, Department of Anesthesiology and Critical Care Medicine, Tsukuba University Hospital, Ibaraki, Japan

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KEYWORDS

Abdominal wall lift;
Functional residual capacity;
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Abstract

Background and objectives: The number of laparoscopic surgeries performed is increasing every year and in most cases the pneumoperitoneum method is used. One alternative is the abdominal wall lifting method and this study was undertaken to evaluate changes of functional residual capacity during the abdominal wall lift procedure.

Methods: From January to April 2013, 20 patients underwent laparoscopic cholecystectomy at a single institution. All patients were anesthetized using propofol, remifentanyl and rocuronium. FRC was measured automatically by Engstrom Carestation before the abdominal wall lift and again 15 minutes after the start of the procedure.

Results: After abdominal wall lift, there was a significant increase in functional residual capacity values (before abdominal wall lift 1.48×10^3 mL, after abdominal wall lift 1.64×10^3 mL) ($p < 0.0001$). No complications such as desaturation were observed in any patient during this study.

Conclusions: Laparoscopic surgery with abdominal wall lift may be appropriate for patients who have risk factors such as obesity and respiratory disease.

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PALAVRAS-CHAVE

Elevador da parede abdominal;
Capacidade residual funcional;
Cirurgia laparoscópica

Aumento da capacidade residual funcional durante cirurgia laparoscópica com elevação da parede abdominal

Resumo

Justificativa e objetivos: O número de cirurgias laparoscópicas realizadas está aumentando a cada ano e, na maioria dos casos, o método com pneumoperitônio é o escolhido. Uma opção é o método de elevação da parede abdominal. Este estudo foi feito para avaliar as

[☆] This study was carried out by the Ibaraki Prefectural Central Hospital.

* Corresponding author.

E-mail: thoshi@md.tsukuba.ac.jp (T. Hoshi).

alterações da capacidade residual funcional durante o procedimento de elevação da parede abdominal.

Métodos: De janeiro a abril de 2013, 20 pacientes foram submetidos à colecistectomia laparoscópica em uma única instituição. Todos os pacientes foram anestesiados com propofol, remifentanil e rocurônio. A CRF foi medida automaticamente usando o Engström Carestation antes da elevação da parede abdominal e, novamente, 15 minutos após o início do procedimento.

Resultados: Após elevar a parede abdominal, um aumento significativo foi observado nos valores da capacidade residual funcional (antes da elevação da parede abdominal: $1,48 \times 10^3$ mL; após a elevação da parede abdominal: $1,64 \times 10^3$ mL) ($p < 0,0001$). Não houve complicações, como dessaturação, em nenhum paciente durante este estudo.

Conclusões: A cirurgia laparoscópica com elevador da parede abdominal pode ser apropriada para pacientes com fatores de risco como obesidade e doenças respiratórias.

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Introduction

The use of laparoscopic techniques in surgery is increasing year by year. There are two major techniques for laparoscopic surgery, pneumoperitoneum method and abdominal wall lift method. Establishing a pneumoperitoneum is a major technique for laparoscopic surgery, while lifting procedure is a minor technique. A patient's pulmonary functions are affected by various factors during laparoscopic surgery. Functional residual capacity (FRC) is decreased by the supine position and the induction of anesthesia¹⁻³ during surgery. The decrease in FRC may cause hypoxemia due to increases in blood flow where gas exchange is not taking place. Furthermore, pulmonary compliance is decreased by the pneumoperitoneum method,⁴ but not by the abdominal wall lift.⁵

No previous study has evaluated FRC during laparoscopic surgery with abdominal wall lift. In the current study we test our hypothesis that abdominal wall lift method increases FRC.

Methods

Our study plan was approved from the institutional review board. We retrospectively studied 20 adult patients who underwent elective laparoscopic cholecystectomy with abdominal wall lift from January to April 2013 at Ibaraki Prefectural Central Hospital. We did not exclude anyone from this study. During the procedure, the right costal arch and the navel area were lifted with a subcutaneous wire using the abdominal wall-lift system (Mizuho Ika, Tokyo, Japan). FRC was measured repeatedly by Engstrom Carestation (GE Health Care, UK Ltd., Buckinghamshire, UK). It takes several minutes in the measurement of FRC. We use average of two to three measurements before the abdominal wall lift and 15–30 min after the start of the procedure.

The anesthesia and monitoring

The patients were not given any sedative drugs before surgery. General anesthesia was induced with remifentanil

$0.2 \mu\text{g}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and target controlled infusion of propofol (target concentration of plasma was $3 \mu\text{g}\cdot\text{mL}^{-1}$).

Rocuronium was used for neuromuscular block. Tracheal intubation was performed with tracheal tubes of internal diameters of 7 and 8 mm used for female and male patients, respectively. Anesthesia was maintained with propofol and remifentanil to maintain the bispectral index between 40 and 60 and the systolic pressure at $\pm 30\%$ of pre-anesthetic values. To maintain neuromuscular block, rocuronium was given intermittently and their train-of-four ratio of 0% was confirmed. The lungs were ventilated mechanically with 30–40% oxygen in air, tidal volume $8 \text{ mL}\cdot\text{kg}^{-1}$, at a respiratory rate of 10 min^{-1} .

During anesthesia all patients were monitored by electrocardiogram, non-invasive blood pressure, pulse oximetry, bispectral index, and train-of-four.

Statistical analysis

Based on a previous Japanese study on FRC changes in anesthetized and intubated patients,⁶ power analysis revealed that a minimum sample size of 17 was required in order to detect a difference of 15% in FRC increasing after abdominal wall lift ($\beta = 0.80$, $\alpha = 0.05$). Data are presented as mean (\pm SD). Comparisons are made between the FRC before and after abdominal wall lift by paired *t*-test (Stat View 5.0, SAS Institute, NC, USA) and $p < 0.05$ is considered to be a significant difference.

Results

Patient characteristics are summarized in Table 1. There were 3 obese patients with a Body Mass Index (BMI) of $>30 \text{ kg}\cdot\text{m}^{-2}$. All patients were included in the statistical analysis. After abdominal wall lift, there was a significant increase of functional residual capacity values (before abdominal wall lift 1.48×10^3 mL, after abdominal wall lift 1.64×10^3 mL) ($p < 0.0001$).

Linear regression analysis showed that there was a univariate correlation between BMI and increase of FRC (Fig. 1).

Table 1 Patient characteristics ($n=20$).

	Patient characteristics ($n=20$)
Sex, male/female	14/6
ASA physical status (I/II/III)	5/13/2
Age, y (mean \pm SD)	58.5 \pm 11.8
Height, cm (mean \pm SD)	164.8 \pm 11.2
Weight, kg (mean \pm SD)	68.8 \pm 12.0
BMI (mean \pm SD)	25.3 \pm 3.9

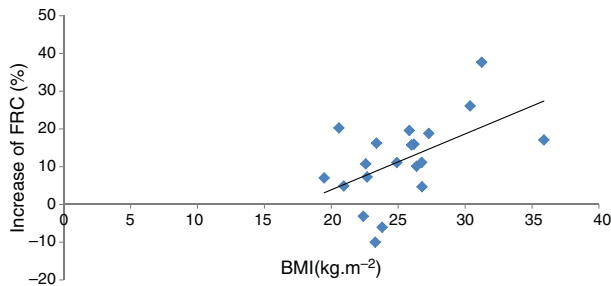


Figure 1 Relationship between BMI and increase of FRC. After abdominal wall lift, there was a significant increase of FRC values. In addition, there was a correlation between BMI and increase of FRC.

The coefficient of determination (R^2) was 0.278 and p -value was 0.017. During this study, no complications such as desaturation were observed in any of the patients.

Discussion

Along with an improvement in the devices and techniques of laparoscopic surgeries the instances of such procedures for patients with respiratory complications are increasing annually. A meta-analysis revealed that the duration of surgery with abdominal wall lift is significantly longer than pneumoperitoneum method.⁷ However, the results of our study suggest that FRC during laparoscopic surgery with abdominal wall lift increases significantly. This may be a great advantage for patients with respiratory complications.

When compared with laparotomy, laparoscopic cholecystectomy is associated with shorter mean postoperative hospital stay, and reduced mean cost.⁸ Laparoscopic cholecystectomy with pneumoperitoneum causes significant decreases in Vital Capacity (VC) and FRC at the postoperative period, although less significant than open laparotomy.⁹ Although we did not compare with postoperative FRC, in our study of the abdominal wall lift method, FRC actually increases with the surgery and a big difference is observed between the decrease and increase of FRC in the respective surgical methods, especially in patients with respiratory problems.

Because this is retrospective study, we do not have exact data of airway pressure or I:E ratio, but we usually ventilate patients with I:E ratio 1:2 without using PEEP and recruitment maneuver.

Abdominal wall lift method involves lifting up the right hypochondrium and umbilical region therefore it may

increase FRC by outward movement of the chest and abdominal wall. The increase of FRC may contribute to the lower levels of PaCO₂ observed postoperatively compared to pneumoperitoneum as reported by Ren et al.,⁷ which is of great benefit for obese patients or those with respiratory disease. However, we have not evaluated postoperative pain at either the lifting site or the wound alongside a postoperative blood gas analysis; therefore it is unknown whether our patients showed lower level of PaCO₂ without extensive pain.

Our study also has suggested that there was a univariate correlation between BMI and increase of FRC during laparoscopic surgery with abdominal wall lift. Eichenberger et al. reported that atelectasis formation would be particularly significant in morbidly obese patients (with a Body Mass Index (BMI) of $>35 \text{ kg}\cdot\text{m}^{-2}$).¹⁰ Furthermore, they showed that atelectasis remained unchanged for at least 24 hours. Although we have only three obese patients and the number of subjects are not enough to discuss the relationship between BMI and FRC, these findings suggest that for obese patients in particular abdominal wall lifting may be more advantageous than pneumoperitoneum. There are several methods of measuring FRC: closed-circuit helium dilution method,¹¹ oxygen (O₂) wash-in method,¹² nitrogen (N₂) washout method (Fowler's method),¹³ body plethysmography, and computed tomography as the gold standard. Engstrom Carestation measures FRC via the nitrogen washout method. This method can measure FRC repeatedly in an anesthetized patient without interrupting mechanical ventilation.

Chiumello et al. demonstrated that the End Expiratory Lung Volume (EELV) measurement by Engstrom Carestation with modified nitrogen washout/washin technique (at all lung volumes) correlates well with CT scanning¹⁴ and is therefore a reliable measurement tool. In the current study we repeatedly measured the FRC for the same patient to verify the data. Therefore, we posit that our data of the numerical increase and decrease of FRC is reliable.

Summary

Laparoscopic surgery via abdominal wall lift may be an appropriate surgical option for patients who have risk factors such as obesity and respiratory disease.

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Conflicts of interest

The authors declare no conflicts of interest.

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