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Investigating the partial pressure of carbon dioxide (CO_2) in the respiratory gases in laparoscopic gallbladder surgery and comparing it with arterial partial pressure of carbon dioxide

Babak Hosseinzadeh Zoroufchi,[a] Setareh Soltany,[b] Abolfazl Abdolahpour[a]

[a]Department of Anesthesiology, Kowsar Hospital, Semnan University of Medical Sciences, Semnan, Iran
[b]Cancer Research Center, Kowsar Hospital, Semnan University of Medical Sciences, Semnan, Iran
Corresponding author: Abolfazl abdollahpour (Email: Abolfazlabdollahpoor@semums.ac.ir)
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Objective The aim of this paper is determining the end-expiratory dioxide pressure in gallbladder laparoscopic surgery and compares it with the arterial carbon dioxide pressure.
Methods This cross-sectional study was performed on 30 patients undergoing laparoscopic cholecystectomy. At the beginning of operation, arterial blood gas (ABG) sample was taken from the patient's radial artery before CO_2 was injected into the abdomen. At the same time, CO_2 was measured by a capnography device. At the end of surgery, ABG sample was prepared for the second time before CO_2 was removed from the abdomen and CO_2 was recorded simultaneously by capnography device. After collecting data from ABG samples, arterial $PaCO_2$ was compared with those obtained from capnography device results and SPSS 16 software was used for data analysis.
Results The mean pre-operative $PaCO_2$ for laparoscopic ($PaCO_{2\text{-}1}$) was 34.343 and the mean pre-operative $ETCO_2$ for laparoscopic ($ETCO_{2\text{-}1}$) was 31.37. These values after laparoscopic surgery were 34.813 for $PaCO_2$, 34.813 ($PaCO_{2\text{-}2}$) and 33.13 ($ETCO_{2\text{-}2}$). There was also a correlation between $PaCO_{2\text{-}1}$ and $ETCO_{2\text{-}1}$ results between $PaCO_{2\text{-}2}$ and $ETCO_{2\text{-}2}$, which was stronger between $PaCO_{2\text{-}2}$ and $ETCO_{2\text{-}2}$.
Conclusion There was a strong correlation between $ETCO_2$ results from capnography and $PaCO_2$ from ABG and to monitor carbon dioxide retention, capnography can be used as an alternative to ABG for laparoscopic gallbladder surgery patients.
Key words capnography, end-expiratory pressure, arterial carbon dioxide pressure, cholecystectomy, laparoscopy

Introduction

Gallstones are one of the most common diseases of the gastrointestinal tract. Most of these stones remain asymptomatic throughout the patient's life. For unknown reasons, some patients progress to a symptomatic stage that develops biliary colic following cystic duct obstruction by gallstones. This may lead to complications including cholecystitis, chronic cholecystitis, cholangitis, pancreatitis, fistula between the gallbladder and part of the intestine, and eventually ileus caused by gallstones and gallbladder carcinoma.[1, 2] Therefore, if bile stones develop or are symptomatic or in conditions that are more likely to cause these complications, cholecystectomy is required. This can be done in an open procedure or in a so-called laparoscopic procedure.[3] The use of this method has been growing increasingly so that it has been replaced by the open method of choice[4] due to it its many benefits and fewer side effects such as reduced post-operative pain, faster return to work, reduced hormonal neurotoxicity, patients' satisfaction with the appearance of the scar and the less invasive nature of laparoscopic surgery than open surgery. The use of this method has been growing increasingly so that it has been replaced as an alternative choice method.

In this way, it is necessary to dilate the space inside the abdomen to create the proper space for working with the necessary devices and tools. Therefore, various gases such as nitrogen, helium and CO_2 are used for dilution, each with its advantages and disadvantages. The most common gas used in laparoscopy is CO_2 because it is non-combustible, absorbs rapidly in dissolved blood and is excreted through the respiratory tract.[5, 6] Arterial carbon dioxide ($PaCO_2$) pressure is one of the most important determinants of blood pH, so its changes can cause many disorders for patients. Since the probability of this change was high during anesthesia and it's not possible to monitor $PaCO_2$ directly, during anesthesia, ET-CO_2 expiratory CO_2 pressure monitoring is used to estimate $PaCO_2$. It is nowadays one of the standard monitoring methods during anesthesia and is often used as a non-invasive procedure for patients during anesthesia as well as in recovery and intensive care units.[7]

According to the ASTM International (formerly known as American Society for Testing and Materials), the measurement of CO_2 pressure is now mandatory monitoring and capnography is a standard anesthesia monitoring.[8, 9] Continuous measurement of exhaled CO_2 is one of the methods that are used in the operating room for evaluation during anesthesia and in patients intubated in the tracheal intubation. But this approach can even be a non-invasive, rapid, and reliable method for predicting $PaCO_2$ in non-intubated patients.[10] This measurement enables the estimation of $PaCO_2$ pressure without the need for arterial blood sampling. If there is a consistent relationship between the CO_2 pressure and the arterial end, this method is reliable and there will be no need for repeated arterial blood sampling.[11, 12] So, the aim of this paper is to determining the end-expiratory dioxide pressure in gallbladder laparoscopic surgery and compares it with the $PaCO_2$ pressure.

Methods and Materials

This cross-sectional study was performed on 30 patients undergoing laparoscopic cholecystectomy. They were randomly assigned to Kowsar Hospital of Semnan, Iran in 2018–2019. All stages of the study were approved by the Research

and Ethics Committee of Kowsar Hospital in Semnan. All patients underwent the implementation of the plan before entering the study and a consent form was obtained from all patients. The inclusion and exclusion criteria were evaluated in this study.

- Inclusion criteria: Cholecystitis patients candidate for laparoscopic surgery.
- Exclusion criteria: Patients with lung obstruction diseases such as asthma, emphysema, COPD, and pulmonary embolism.

Demographic data including age, sex, height, weight, and smoking were recorded. After visiting patients at the clinic, pre-op and recording heart rate, respiratory rate, and blood pressure were measured. Patients underwent laparoscopic cholecystectomy under general anesthesia with intravenous induction and maintenance of general anesthesia with inhaled and evaporated anesthetics. At the beginning of surgery before the CO_2 gas is pumped into the abdomen, sampling site was sterilized with 70% alcohol in order to obtain the arterial blood gas (ABG) sample after the Allen test to ensure proper flow of the sample in the hand. It was then prepared using a heparinized G20 syringe from the ABG patient's radial artery. At the same time, CO_2 was measured by a capnography and to facilitate laparoscopic surgery, the intraperitoneal space was filled with CO_2 up to a pressure of up to 20 cm. Exposure to CO_2 was monitored by capnography at all stages of surgery. At the end of surgery, ABG sample was prepared for the second time before CO_2 removal from the abdomen and at the same time, CO_2 was measured and recorded by the CapnoTrue® ASP CO_2/Spo2 Monitor Capnography. ABG samples were immediately sent to the laboratory and analyzed by a blood gas analyzer (AVL995 Blood Gas Analyzer) and $PaCO_2$ levels were measured and recorded. After collecting data from ABG samples, arterial $PaCO_2$ levels were compared with those obtained from capnography results. At the end of the operation, the patient was awakened by neostigmine at the rate of 40 mg/kg after discontinuation of the anesthetic and reversal of the relaxant and transferred to recovery.

Data Analysis

Descriptive findings were reported in subgroups using mean and standard deviation. Multivariate regression models were used to investigate the relationship between arterial CO_2 pressure and CO_2 pressure with and without underlying variables and the final analysis was performed on the reduced model. To analyze the difference between the two aforementioned values, One-sample *t*-test was used and compared with 0. The significance level for all tests was 0.05. SPSS 16 software was used for data analysis.

Ethical Considerations

Obtain informed consent to adhere to ethical principles and ensure confidentiality of research information.

Result

Twenty-four patients participated in this study which 80% were female and 20% were male. The mean age of the subjects was 41.77 ± 13, 13.89 years. The youngest was 26 years and the oldest was 80 years old. The mean height, weight, and BMI of the patients were 163.5, 70.5 and 26.35, respectively. Also, 28 (93.3%) were non-smokers and 2 (6.7%) were smokers. In this study, systolic blood pressure (SBP) and diastolic blood pressure (DBP) and mean arterial blood pressure (MAP) were reported as 18, 76, and 90, respectively. The mean pre-operative $PaCO_2$ for laparoscopic surgery was 34.343 $PaCO_{2\text{-}1}$ and the mean pre-operative $ETCO_2$ for laparoscopic surgery was 31.37. These values for post-operative laparoscopy were 34.813 for $PaCO_2$, $PaCO_{2\text{-}2}$ and 33.13 for $ETCO_2$, $ETCO_{2\text{-}2}$. The mean and standard deviation of the difference between $PaCO_{2\text{-}1}$ and $ETCO_{2\text{-}1}$ were 2.9 and 4.11, respectively. These values were 1.6 and 3.72, respectively, for the difference between $PaCO_{2\text{-}2}$ and $ETCO_{2\text{-}2}$, with a *P*-value of less than 0.05 for both cases.

According to Table 1, there was a correlation between $PaCO_{2\text{-}1}$ and $ETCO_{2\text{-}1}$ results as well as between $PaCO_{2\text{-}2}$ and $ETCO_{2\text{-}2}$. This correlation was stronger between the values of $PaCO_{2\text{-}2}$ and $ETCO_{2\text{-}2}$.

The regression equation based on the final model is as follows:

$$PaCO2\text{–}2 = -34.676 + 0.885\ ETCO2 - 2 + 6.030\ Sex\ 7.088\ Smoker + 0.267PR$$

Table 1. **Correlation between $PaCO_2$-2 and $ETCO_2$-2 results before laparoscopic surgery**

Pearson correlation coefficient	0.423
***P*-value**	0.020
Quantity	30

Table 3. **Correlation between $PaCO_2$-2 and $ETCO_2$-2 results after laparoscopic surgery**

Pearson correlation coefficient	0.720
***P*-value**	0.000
Quantity	30

Table 2. **Distribution graph and its fitted line based on the regression equation for predicting $PaCO_{2\text{-}1}$ using $ETCO_{2\text{-}1}$**

Squared R	F	Degree of Freedom 1	Degree of Freedom 2	P	Constant number	The regression coefficient
0.179	6.095	1	28	0.020	19.451	0.475

Table 4. **Distribution graph and its fitted line based on the regression equation for predicting $PaCO_{2\text{-}2}$ using $ETCO_{2\text{-}2}$**

Squared R	F	Degree of Freedom 1	Degree of Freedom 2	P	Constant number	The regression coefficient
0.519	30.180	1	28	0.000	6.430	0.857

Table 5. **Multiple linear regression model of initial and final decrease to predict arterial dioxide pressure after intervention based on explanatory variables**

Model	Primary model			Final reduced model		
	The regression coefficient	The standard error	P	The regression coefficient	The standard error	P
Constant number	–74.474	48.263	0.134	34.676	11.704	0.007
$EtCO_{2-2}$	0.971	0.157	0	0.885	0.127	0
Gender	5.021	2.405	0.05	6.03	1.666	0.01
Age	0.024	0.059	0.691	-	-	-
BMI	0.042	0.182	0.819	-	-	-
Smoker	5.677	3.778	0.149	7.088	2.875	0.021
Number of breaths	–0.194	0.234	0.417	-	-	-
Heart beat	0.258	0.137	0.073	0.267	0.09	0.007
Mean arterial pressure	–0.003	0.074	0.973	-	-	-
Arterial oxygen saturation percentage	0.446	0.492	0.375			

Discussion

CO_2 gas is one of the most common gases used in laparoscopic surgery and its monitoring during surgery is very important. The importance of monitoring CO_2 pressure is that changes in blood can cause changes in the blood pH of the patient and cause problems for the patient.[13] ABG measurement is used as the gold-standard for monitoring oxygenation and also checks the CO_2 retention rate.[14, 15] The aim of this paper is determining the end-expiratory dioxide pressure in gallbladder laparoscopic surgery and compares it with the arterial carbon dioxide pressure.

In this study, there was a strong correlation between $PaCO_2$ and $ETCO_2$ results before and after surgery in gallbladder laparoscopic patients. In the studies that have been done, such as the study by Husaini and Cho[16] in which 35 patients underwent intraoperative craniotomy in different surgical stages, the evidence suggests that the results of capnography agree with ABG at all stages of craniotomy, both before general anesthesia and after skull opening and at the beginning of dural closure. And, there was a strong correlation between $ETCO_2$ and $PaCO_2$ results at all stages of craniotomy (correlation coefficients were 0.571, 0.559, and 0.629). The results of their study were consistent with our study.

In another study by Yazdani and Tohidi, 75 COPD patients were included. They found that there was a strong correlation between $ETCO_2$ values from capnography and $PaCO_2$ in arterial blood gases at both the initial admission and 30 min after oxygen and bronchodilator treatment (correlation coefficient r = 0.782 and $P = 0.005$). Further evaluation by Bland–Altman analysis indicated the agreement of the results of the two methods of capnography and ABG for measuring the relative pressure of CO_2 in both stages of the study. The results of their study were in line with ours.[17]

Hasani et al.[11] conducted a study comparing end-expiratory and arterial CO_2 in patients undergoing coronary artery bypass grafting. They found that there was no statistical difference between the CO_2 and arterial end points at the time before and after cardiopulmonary bypass. As a result, capnography is a non-invasive, healthy monitoring to estimate arterial blood CO_2 levels. End-expiratory and arterial CO_2 have a direct relationship with patients with no underlying disease in coronary artery bypass graft surgery. They noted that measurement of $ETCO_2$ in healthy patients may eliminate the need for arterial blood to determine $PaCO_2$.

Warner et al.[18] found that $ETCO_2$ results in patients with severe trauma requiring tracheal intubation were poorly correlated with $PaCO_2$ outcomes. Therefore, capnography should not be used to monitor this group of patients, which seems to be due to the patient's poor hemodynamic status and its effect on arterial blood gases, which were inconsistent with our study.

Conclusion

This study indicated that although there was a significant average 3 and 1.6 unit of difference between the mean arterial CO_2 pressure and CO_2 pressure at the beginning and end of the operation but there was a strong correlation between $ETCO_2$ results from capnography and $PaCO_2$ from ABG. And to monitor CO_2 retention in gallbladder laparoscopic surgery, patients can use capnography as an alternative to ABG. Finally, it is recommended that further studies be conducted with a larger sample size.

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