Original Article

# Evaluation the effect of breathing filters on end-tidal carbon dioxide during inferior abdominal surgery in infants and changes of tidal volume and respiratory rate needs for preventing of increasing end-tidal carbon dioxide

**Parvin Sajedi, Mohsen Abooei, Amir Shafa, Mahboobeh Karbalaei[1], Atefeh Babaei**
Department of Anesthesia and Critical Care, Isfahan University of Medical Sciences, [1]Department of Nurse Anesthesia, AL Zahra Medical Center, Isfahan University of Medical Sciences, Isfahan, Iran

**Background:** The aim of this study was to prevent of increasing end-tidal carbon dioxide ($ETCO_{2)}$ with changing of vital capacity and respiratory rate when using of birthing filter in infants. **Materials and Methods:** In a randomized clinical trial study, ninety-four infant' patients were studied in three groups. Basic values, such as peak inspiratory pressure, tidal volume, minute ventilation, respiratory rate, and partial pressure of ET $CO_2$ ($PETCO_2$) level had been evaluated after intubation, 10 min after intubation and 10 min after filter insertion. In the first group, patients only observed for changing in $ETCO_2$ level. In the second and the third groups, respiratory rates and tidal volume had been increased retrospectively, until that $ETCO_2$ ≤35 mmHg was received. We used ANOVA, Chi-square, and descriptive tests for data analysis. $P < 0.05$ was considered statistically significant. **Results:** Tidal volume 10 min after filter insertion was statistically higher in Group 3 (145.0 ± 26.3 ml) versus 129.3 ± 38.9 ml in Group 1 and 118.7 ± 20.8 ml in Group 2 ($P = 0.02$). Furthermore, respiratory rate at this time was statistically higher in Group 2 (25.82 ± 0.43) versus Groups 1 and 3 (21.05 ± 0.20 ml and 21.02 ± 0.60 ml, respectively) ($P = 0.001$). Minute volume and $PETCO_2$ level were statistically significant between Group 1 and the other two groups after filter insertion ($P = 0.01$ and $P = 0.00,1$ respectively). **Conclusion:** With changing the vital capacity and respiratory rate we can control $PETCO_2$ level ≤35 mmHg during using of birthing filters in infants. We recommend this instrument during anesthesia of infants.

**Key words:** Air filters, capnography, respiratory rate, tidal volume

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## INTRODUCTION

Anatomic dead space is around 25%–30% of the tidal volume. Dead space volume in children because of the smaller tidal volume is more important. Anatomic dead space is age-dependent and is >3 ml/kg in early infancy. In adults, anatomic dead space is 2.2 ml/kg. Furthermore, airway closure and the formation of atelectasis are important contributors of gas exchange impairment during general anesthesia. Use external tools such as breathing airway filter can be affected on increasing gas exchange in this region and any external breathing airways instruments such as anesthesia machine and anesthesia breathing circuit can increase dead space and affect the value of dead space to tidal volume ratio.[1-4]

Filters are designed to prevent microbial contamination of patient' respiratory system.[5] However, add filters may imbalance anatomic dead space and reinforce the

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**Address for correspondence:** Prof. Parvin Sajedi, Department of Anesthesia and Critical Care, Isfahan University of Medical Sciences, Isfahan, Iran. E-mail: sajedi@med.mui.ac.ir
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impact of reduced $CO_2$ removal.[4,6-10] Rising of the partial pressure of end-tidal carbon dioxide ($PETCO_2$) 10 min after filter insertion when compared with $PETCO_2$ before intubation was significant in previous studies.[5,9,10]

It is notable that the difference between $PaCO_2$ in the presence or absence of filter significantly associated with weight and age.[10] Current airway technology had more developing in the World. Rigid filters are manufactured by glass or fiber materials.[7]

Using of rigid filters in children can be reduced a majority of lung gas exchange during ventilation.[8]

Recently, this question is remained that what is the effect of changing Tidal volume and respiratory rate or both during filter insertion. Filters increase arterial blood $CO_2$ tension and $PETCO_2$ and can be increased intracranial pressure and brain herniation, but some studies are demonstrated that increasing respiratory rate and tidal volume can decrease the $PaCO_2$ and $PETCO_2$ level, too.[5,7-10] In the previous study, increasing of end-tidal carbon dioxide ($ETCO_2$) and also increasing of airway pressure remained controversial. Moreover, the effect of changing respiratory rate and tidal volume for correction of increasing $ETCO_2$ during anesthesia were not studied.

Then, the aim of this study was evaluation the effect of changing in tidal volume and respiratory rate on preventing the increase of $ETCO_2$ during inferior abdominal surgery with using of breathing airway filters in infants.

## MATERIALS AND METHODS

This was a randomized clinical trial study with a control group which was done during 2014–2015 at AL Zahra Medical Center and Emam Hossin Pediatric Hospital Center in Isfahan. After approval of the ethical committee, 101 infants between 6 months and 2-year (6–15 kg), with American Society of Anesthesiologists physical status Classes I and II who were a candidate for inferior abdominal surgery presented for eligibility of our study and 96 of them agreed to participate in this single-blinded clinical trial study. All pediatric parents signed the consent form. Exclusion criteria included; previous heart diseases, respiratory and metabolic diseases history, needs for open chest surgery or any problem for difficulty in anesthesia.

With assuming at least 1.1 standard deviation (SD) for tidal volume in the control group and 0.8 for a significant difference between the control and the study groups, it was calculated that thirty patients in each group would require to achieve 80% power at 5% type I error.

$$N = \frac{2\,(Z_1 - \frac{\alpha}{2} + Z_1 - \beta)^2 \times S^2}{d^2} = \frac{2\,(1.96 + 0.84)^2 + (1.1)^2}{0.8^2} = 30$$

Eligible patients were divided into three 32-member groups,using random allocation method.

The method of fluid therapy before surgery and fasting time was the same in the three groups. Premedication was induced with midazolam 0.1 mg/kg intravenously (Aburaihan, Pharmaceutical Co., Tehran, Iran). After transferring the child to the operating room, monitoring was done for the basic information (including respiration, heart rate, and blood pressure). General anesthesia induced after preoxygenation and by using, 5 mg/kg of sodium thiopental (Exipental, Exir Pharmaceutical Co., Rasht, Iran), 0.01 mg/kg atropine (Aburaihan, Pharmaceutical Co., Tehran, Iran) 0.5 mg/kg atracurium (Aburaihan, Pharmaceutical Co., Tehran, Iran), and 1 μg/kg fentanyl (Caspian Tamin, Pharmaceutical Co., Rasht, Iran) intravenously. Then intubation procedure performed. Maintenance of anesthesia was obtained with 50% of $O_2$ in $N_2O$ and isoflurane1.5%.

All patients were observed for 10 min after tracheal intubation, and then filter was added to the respiratory system of the patient. We had three groups in our study; in first groups filter was added and patient observed only for $PETCO_2$ level during operation, in the second group after filter installation only respiratory rates was increased until $PETCO_2$ level became ≤35 mmHg and in the third group, after filter installation, only tidal volume had been increased until $PETCO_2$ level became ≤35 mmHg. We monitored every infant continuously, and if the $PETCO_2$ in all three groups increased to 50 mmHg and above, we removed filter and increased ventilation and excluded the subject from the study.

Basic values such as peak inspiratory pressure (PIP), tidal volume, minute ventilation, respiratory rate, and $PETCO_2$ level had been evaluated after intubation, 10 min after intubation and 10 min after filter insertion.

Also surgery time, sedation time: (time that patients had been sedated), recovery time: (time that patients was arrived to the recovery room until the patients had been discharged of recovery room according to ALDERET score 9/10), and extubating time: (time between anesthesia vapor discontinued and extubation of the trachea) had been evaluated.

Data were collected, edited, and analyzed by Statistical Package for the Social Sciences software version 14 software.

Chi-square was used for descriptive analysis such as sex distribution and endotracheal tube size. ANOVA was used for comparison of demographic data such as age, duration of surgery, recovery time, and sedation time. Mean changes of tidal volume, respiratory rate, $PETCO_2$, heart rate, and PIP were also analyzed by ANOVA. We used mean ± SD for quantitative data and qualitative data; we used frequency and percent. The level of significantly was considered as <0.05.

## RESULTS

A total of 101 patients had eligibility for our study. Three patients do not meet inclusion criteria, and two patient's parents refused consent. Thus, 96 patients were randomized and assigned among three groups. Furthermore, two patients excluded from the study because of difficult intubation. Finally, 94 patients completed the study [Figure 1]. The three treatment groups were generally matched at baseline in terms of age, gender, weight, distribution of endotracheal tube size, duration of surgery, and extubation time. The average of age in Group 1 was 15/16 (48.4/51.6) months, Group 2 was 16/15 (51.6/48.4) months, and 15/17 (46.9/53.1) months ($P$ = 0.1) [Table 1]. With using repeated measurement ANOVA test after adjusting age, gender, weight, distribution of endotracheal tube size, duration of surgery and extubating time, tidal volume 10 min after filter insertion had shown significant difference among three groups and in Group 3 (145.0 ± 26.3 ml) was, more than 2 others (129.3 ml in first group and 118 ml in second Group 2 ($P$ = 0.02). In this study, it was shown that respiratory rate had significant difference among three groups after filter insertion ($P$ = 0.001) and in Group 2 (25.82 ± 0.43) was, more than 2 others (21.05 ± 0.20 in the first group and 21.02 ± 0.60 in Group 3).

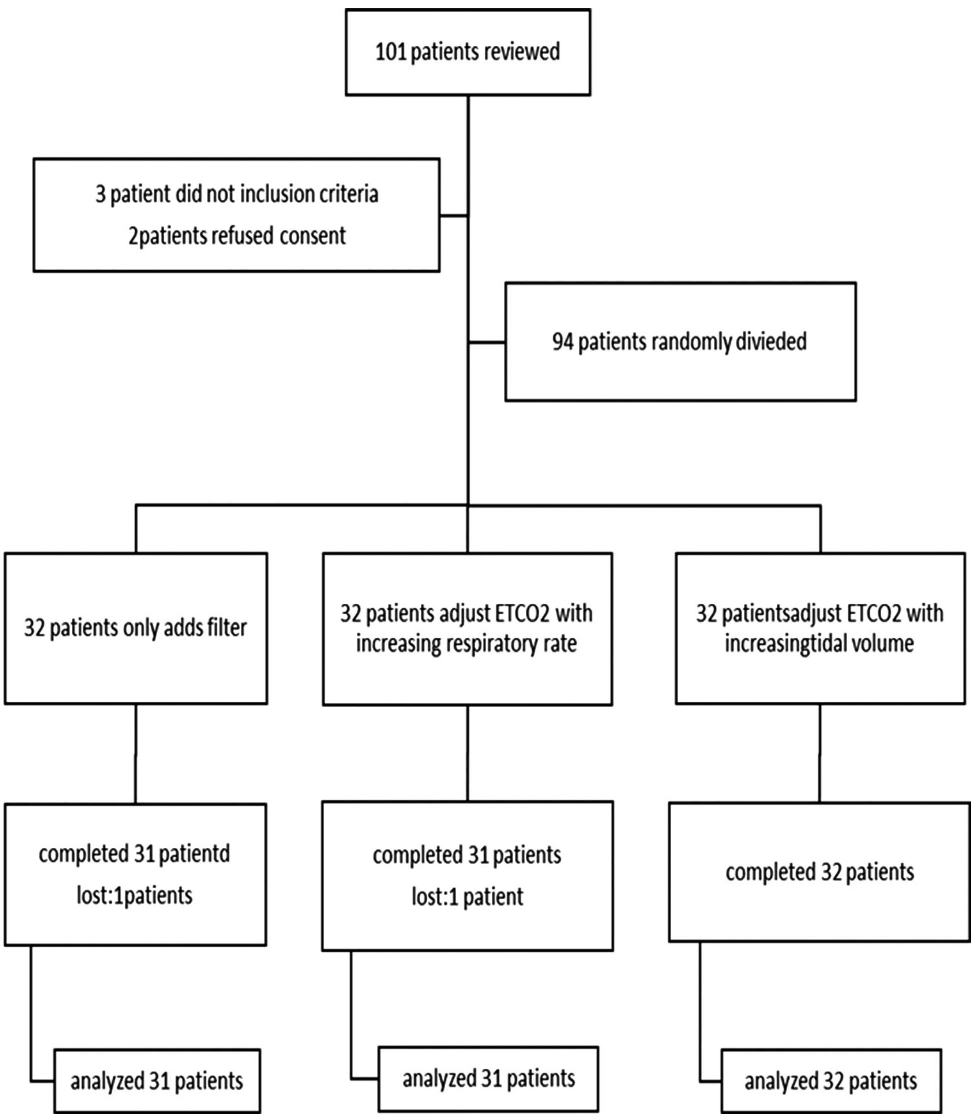


**Figure 1:** Study flowchart

**Table 1: Patients characters in three groups**

| Characters | Group 1 | Group 2 | Group 3 | *P* |
|---|---|---|---|---|
| Gender: Male/female | 15/16 (48.4/51.6) | 16/15 (51.6/48.4) | 15/17 (46.9/53.1) | 0.1 |
| Age (months) | 16.58±8.36 | 16.45±5.40 | 17.59±5.46 | 0.9 |
| Endotracheal tube size (%) | | | | |
| 4 | 12 (38.7) | 7 (22.6) | 5 (15.6) | 0.1 |
| 4.5 | 10 (32.3) | 16 (51.6) | 18 (56.25%) | |
| 5 | 4 (12.9) | 8 (25.8) | 13 (40.6) | |
| 5.5 | 3 (9.7) | 0 | 0 | |
| 6 | 2 (6.5) | 0 | 0 | |
| Total | 31 (100.0) | 31 (100.0) | 32 (100.0) | |
| Operation time (h) | 2.87±1.97 | 3.23±3.23 | 4.06±2.27 | 0.9 |
| Sedation time (min) | 45.16±14.86 | 43.55±12.05 | 45.94±11.67 | 0.7 |
| Recovery time (h) | 0.19±0.07 | 1.48±0.8 | 3.28±2.10 | 0.1 |
| Extubation time (h) | 0.65±0.45 | 1.07±0. 9 | 1.72±1.02 | 0.1 |

Data are presented as the mean, with the SD, except for gender, for which data are presented as the number, with the percentage in parentheses. $P<0.05$ were statistically significant. SD=Standard deviation

**Table 2: Tidal volume (ml) levels, respiratory rate, minute volume, partial pressure of end tidal carbon dioxide, peak inspiratory pressure and heart rate in difference time of study**

| | Group 1 | Group 2 | Group 3 | *P* |
|---|---|---|---|---|
| VT | | | | |
| After intubation | 121.0±35.2 | 121.9±20.2 | 118.7±20.8 | 0.9 |
| 10 min after intubation | 121.2±35.6 | 121.6±20.2 | 118.7±20.8 | 0.7 |
| 10 min after filter insertion | 129.3±38.9 | 118.7±20.8 | 145.0±26.3 | 0.02 |
| Respiratory rate | | | | |
| Before intubation | 20.08±0.56 | 20.55±0.24 | 20.38±0.26 | 0.4 |
| After intubation | 20.04±0.19 | 20.46±0.19 | 20.44±0.29 | 0.5 |
| 10 min after intubation | 20.40±0.31 | 20.46±0.19 | 20.47±0.31 | 0.7 |
| 10 min after filter insertion | 21.05±0.20 | 25.82±0.43 | 21.02±0.60 | 0.001 |
| Minute volume | | | | |
| After intubation | 2.24±0.08 | 2.33±0.09 | 2.03±0.09 | 0.2 |
| 10 min after intubation | 2.24±0.08 | 2.84±0.12 | 2.48±0.12 | 0.09 |
| 10 min after filter insertion | 2.24±0.08 | 2.98±0.14 | 2.97±0.09 | 0.01 |
| $PETCO_2$ | | | | |
| Before intubation | 40.02±3.60 | 40.31±4.25 | 40.45±2.51 | 0.3 |
| After intubation | 39.80±3.27 | 40.16±4.03 | 40.03±2.36 | 0.4 |
| 10 min after intubation | 39.56±3.86 | 40.78±4.45 | 39.52±2.69 | 0.04 |
| 10 min after filter insertion | 43.5±3.48 | 37.66±1.88 | 37.74±2.90 | 0.001 |
| PIP | | | | |
| After intubation | 13.83±2.38 | 12.34±2.39 | 14.77±2.19 | 0.09 |
| 10 min after intubation | 12.66±2.21 | 12.53±2.57 | 13.06±2.03 | 0.4 |
| 10 min after intubation | 13.03±2.22 | 12.45±2.33 | 15.65±2.22 | 0.1 |
| 10 min after filter insertion | 13.66±2.21 | 12.53±2.57 | 13.06±2.03 | 0.07 |
| Heart rate | | | | |
| Before intubation | 145.66±11.52 | 145.19±12.26 | 147.45±12.75 | 0.6 |
| After intubation | 147.44±11.63 | 145.84±12.51 | 148.84±12.65 | 0.7 |
| 10 min after intubation | 147.18±11.55 | 146.69±12.09 | 150.97±12.91 | 0.1 |
| 10 min after filter insertion | 145.00±12.10 | 144.78±12.14 | 146.23±15.20 | 0.9 |

Data are presented as the mean, with the SD, $P<0.05$ were statistically significant. SD=Standard deviation; PIP=Peak inspiratory pressure; $PETCO_2$=Partial pressure of end tidal carbon dioxide; VT=Tidal volume

In this study, we found that minute volume had shown a significant difference between Group 1 and the other two groups after filter insertion ($P = 0.01$) [Table 2]. In this study, it was shown that $PETCO_2$ level had a significant difference between the Group 1 and the two other groups 10 min after filter insertion ($P = 0.001$), too.

And also, PIP had no significant difference among three groups at any time of study ($P > 0.05$). We show that heart rate had not shown significant difference among 3 groups at any time of the study ($P > 0.05$) [Table 2].

## DISCUSSION

Since infants have a greater need for warming and humidification of inspired gasses, and they also have increased susceptibility to lower respiratory tract contamination by Viruses and bacteria,[11-13] the use of breathing system filters may be particularly beneficial in infants, compared to children and adults.

During ventilation, a significant part of the airways that does not participate in gas exchange is called as dead space.[1] Dead space is divided into four subgroups: Anatomical dead space, alveolar dead space, and physiologic dead space and airways devices. The increase in dead space could potentially increase the amount of $CO_2$, so it can effect on $PaCO_2$ and $PETCO_2$.[6] Filter can increase dead space and according to some studies, filters can lead to higher values for $PETCO_2$, so in clinical situation, it is important to measure $PETCO_2$.[2,7]

During general anesthesia in pediatrics, due to increase resistance in breathing by using equipment, dead space volume had been increased. Also, measurement of $PETCO_2$ showed incorrect measurement and it can be effect on deciding for adjustment of the minute volume or fresh gas flow for patients, respectively.[1,3,4,11,12,14-17]

In the article by Hartman *et al*.[17] it was demonstrated that one of common instrument that used in pediatric anesthesia is breathing filters. These filters can lead to disturbance of $PETCO_2$. They found that in patients in both ventilated and spontaneously breathing groups, $PETCO_2$ was higher at the side of the filter ($P < 0.002$ for each). This finding is in coordinated with the finding of our study, in the first group but, we corrected the $ETCO_2$ for the others two groups with increasing respiratory rate and tidal volume.

The routine use of breathing system filters is recommends by Association of Anesthetists of Great Britain and Ireland. Reducing the intraoperative systemic cooling is done with heat-moisture exchangers in breathing system filters are often, and it may due to error happen in $PETCO_2$ measurement.[17]

In this study, we found that $PETCO_2$ at 10 min after intubation in Groups 1 and 2 and three was 39.56 ± 3.86, 40.78 ± 4.45, and 39.52 ± 2.69, respectively. $PETCO_2$ 10 min after filter insertion in Groups 1 and 2 and three was 43.5 ± 3.48, 37.66 ± 1.88, and 37.74 ± 2.90, respectively.

This manuscript showed that increasing tidal volume in Group 3 after filter insertion could reverse the effect of increasing of dead space 10 min after filter insertion respectively in comparison with Group 1 (43.5 ± 3.48 vs. 37.74 ± 2.90). Also, increasing of respiratory rate after filter insertion did the same effect in Group 2 in comparison with Group 1 (43.5 ± 3.48 vs. 37.66 ± 1.88). These findings of our article is accordance with Chau *et al*. and Enekvist *et al*. studies.[8,10]

Then according to the finding of our study using filter in pediatric anesthesia can increase $PETCO_2$ but this effect could reverse with increasing respiratory rate or tidal volume. PIP did not increase in our study. This finding of our study is contrary to the finding of Yoshidome *et al*. and Morgan-Hughes *et al*. studies.[18,19] The study done by Whitelock and de Beer showed that increased resistance provided by filters should not produce a clinically significant increase in the work of breathing during general anesthesia, because of controlled ventilation, for pediatric surgical procedures. However, an increase in the work of breathing may become more significant when spontaneous ventilation is established at the end of a surgical case. Our study findings confirm the findings of Whitelock and de Beer.[13] Another study done by Bell *et al*. showed that using filter can increase airway resistance and work of breathing. This study recommended for alternative means of humidification and filtration during periods of spontaneous ventilation in small infants.[20] $SaO_2$ and hart rate of patients did not significant differences among three groups at different times of the study.

## CONCLUSION

According to findings of our study, we recommend the use of breathing filter in pediatric anesthesia for prevention of contamination of respiratory system with adjustment of respiratory rate and tidal volume for correction of the effect of $CO_2$ retention of the filters. Also, it is recommended that the future study with larger sample size, according to the number and size of instruments of breathing circuit is needed, and it seems, some studies are be necessary to evaluate the efficiency of filters effect on other breathing parameters.

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### Conflicts of interest

The authors have no conflicts of interest.

## AUTHORS' CONTRIBUTION

PS, MA, AS contributed in the conception of the work, conducting the study, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work MK and AB contributed in the conception of the work, drafting and revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work.

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