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Effects of Increasing Positive End-Expiratory Pressure (PEEP) Values on Intraabdominal Pressure and Hemodynamics: A Prospective Clinical Study

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ABSTRACT

In the present study, the purpose was to compare the effects of Positive End-Expiratory Pressure (PEEP), which is applied to intensive care patients, on Intraabdominal Pressure (IAP) and hemodynamic parameters.
The patients were selected from among the patients who received mechanical ventilator support and PEEP at various levels in Intensive Care Unit, who were between 18-80 years of age, who did not have abdominal surgery. In the present study, a total of 64 patients were divided into 3 groups. Those who had PEEP value at 4 cmH_2O were included as Group 4, those with PEEP value between 5-8 cmH_2O were included in Group 8, and those with PEEP value between 9-12 cmH_2O were included in Group 12. The intraabdominal pressures, central venous and arterial blood pressures, heart rates, peripheral oxygen saturation values, body temperatures, fluid balances and urine volumes were measured at 0, 6, 12, 18 and 24th hours. The Intra-Bladder Pressure Measurement Method was employed to measure the intra-abdominal pressure.
The lowest IAP values were measured in Group 4, and the highest values were measured in Group 12. The IAP values that were measured in Group 12 were higher than the other groups at a significant level. The intra and inter-group blood pressures, body temperatures, urine outputs, central venous pressures, and fluid balance values were similar in all groups.
In the present study, it was concluded that IAP was low in low PEEP values, and the IAP was high in higher PEEP levels; and this increase caused mild intrabdominal hypertension; however, did not affect hemodynamics.

Key Words: hemodynamics, intraabdominal pressure, mechanical ventilation, Positive End-Expiratory Pressure, Intensive Care Units

Introduction

The most common reason for admission of patients to Intensive Care Units is respiratory insufficiency. In respiratory insufficiency treatment, mostly mechanical ventilation support is applied to patients. Positive End-Expiratory Pressure (PEEP) is an important parameter of mechanical ventilation. PEEP increases the pressure that occurs in the respiratory system during mechanical ventilation, and also contributes to oxygenation of the blood by improving the pulmonary oxygen exchange by opening the collapsed or fluid-filled alveoli (1-4). Although PEEP frequently saves lives, it also brings with it several hemodynamic complications. At times, the potential negative outcomes of high-level PEEP might be more than their benefits (5,6). PEEP also has impacts on the cardiovascular system according to the cardiovascular status, compliance with the respiratory system and its level. PEEP increases the airway and intrathoracic pressure, and reduces the venous return of the heart, which causes a reduction in the pre-load of the heart. This leads to a decrease in the cardiac pulse volume and average arterial pressure (7,8). In addition, it was also reported in several studies that PEEP decreases the mesenteric blood-flow (9). For this reason, it is recommended that the PEEP level is considered when interpreting the Intra-Abdominal Pressure (IAP) values in patients who receive mechanical ventilation (10-12).

Both invasive and non-invasive methods are employed in the follow-up of patients in Intensive Care Units. The IAP follow-up is not carried out routinely because measurement methods are frequently considered to be invasive. For this reason, there must be a clear indication for measurement, which is the case in other invasive procedures. Normal Intra-Abdominal Pressure (IAP) has been

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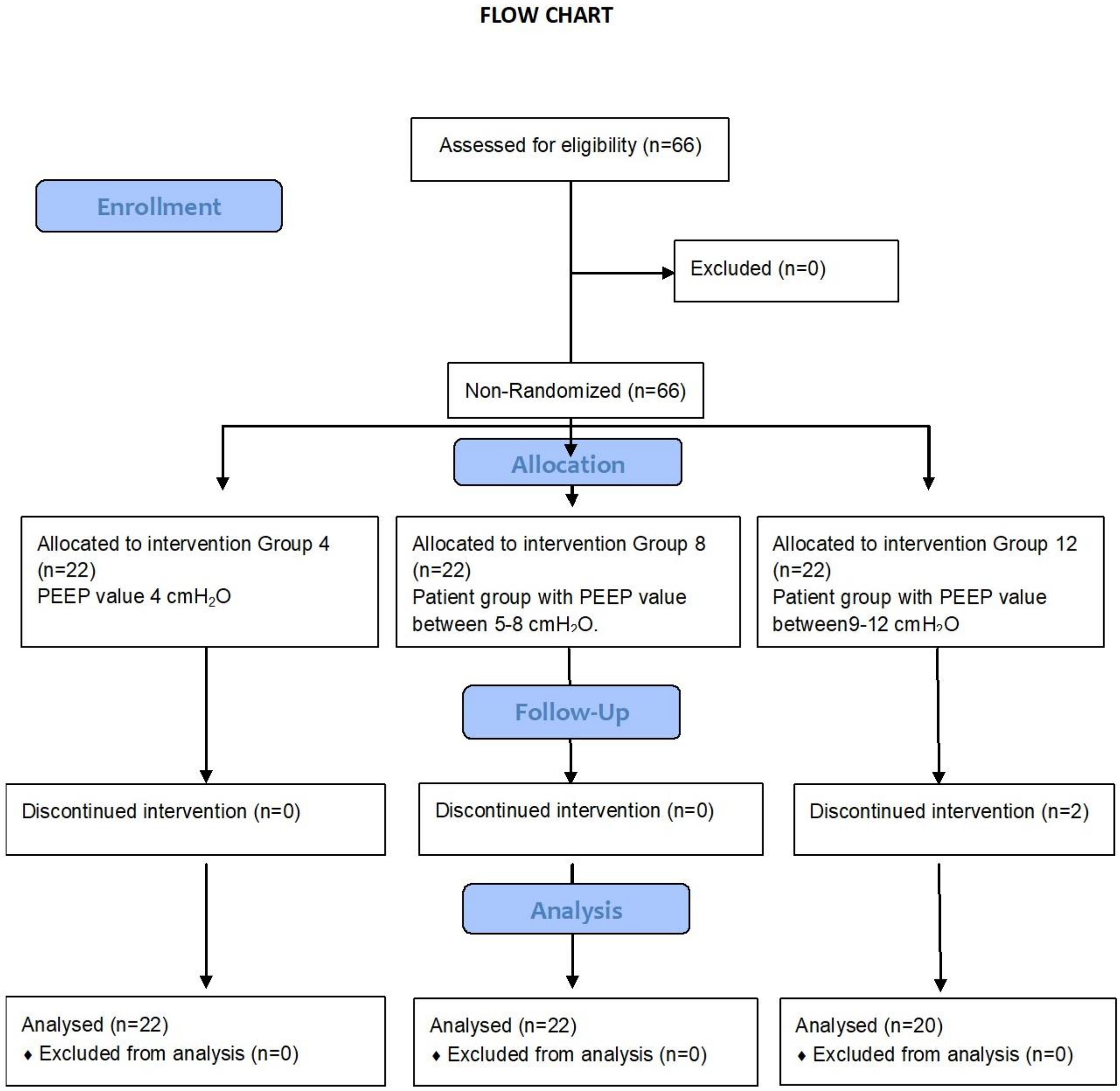

Fig. 1. Flow chart

defined as 10-12 mmHg. The values above this level are defined as Intraabdominal Hypertension (IAH) (13, 14).

Although PEEP has hemodynamic effects, its impacts have not been investigated adequately on IAP.

In the present study, the purpose was to examine the effects of increasing PEEP values on IAP and hemodynamics during mechanical ventilation support.

Material and Method

This study was conducted among patients mechanical ventilation support in intensive care. The relatives of the patients were informed about the study and written and verbal informed consent was obtained before the study. In accordance with the Declaration of Helsinki, before the patients were included in the study, written informed consent was obtained from each relatives of patient (IRB approval date: 11 Apr 2017, decision number: 02). Clinical Trial Number: NCT03714724

Inclusion Criteria for The Study: The patients, who were between 18-80 years of age, who were receiving mechanical ventilator in the Intensive Care Unit, who did not have abdominal surgery, whose PEEP levels were between 4-12 cmH_2O, and who were followed-up for at least 24 hours with the same PEEP levels, were included in the present study. The patients were selected from

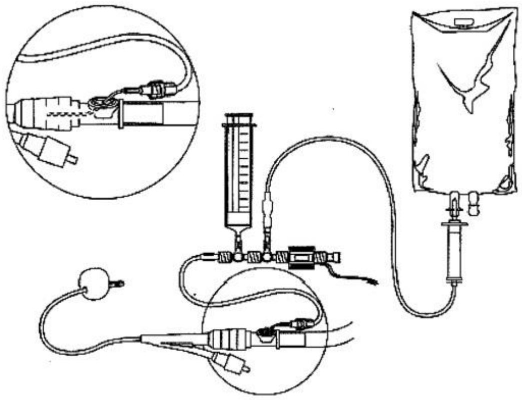

Fig. 2. IAP measurement technology

among those who were followed-up with pneumonia and respiratory insufficiency diagnoses.

Exclusion Criteria for The Study: The patients who did not give consent for participating in the study, who were outside the specified age range, who had the initial IAP value above 12 cmH_2O, who received abdominal or bladder surgery, who had high intracranial pressure, who were hypotensive, who had neurogenic bladder, morbid obesity, and Chronic Obstructive Pulmonary Disease, were excluded from the study.

The intensive care doctor determined the best PEEP value to be applied to the patient as the lowest inspiratory oxygen concentration (FiO_2≤%50), the highest arterial oxygen pressure (PaO_2=%80-100), and arterial oxygen saturation (SaO_2≥%88-90).

The treatment was started at a low PEEP level at first (4 cmH_2O). Until the targeted level was reached according to the clinical tolerance of the patient, and until the desired oxygenation level and the increase in $PaCO_2$ level was achieved, 3-5 cmH_2O increases were made in PEEP level. The Synchronized Intermittent Mandatory Ventilation (SIMV) ventilation mode was employed to allow spontaneous breathing in the patients who were included in the study.

Those who had PEEP value at 4 cmH_2O were included as Group 4, those with PEEP value between 5-8 cmH_2O were included in Group 8, and those with PEEP value between 9-12 cmH_2O were included in Group 12. The flow chart is shown in Figure 1.

The IAP, Central Venous Pressure (CVP), Blood Pressure (BP), Heart Rates, peripheral oxygen saturation (SpO2), body temperature, fluid balance and urine volume (mL/kg/h) of the patients were recorded at the 0 (T1), 6^{th} (T2), 12^{th} (T3), 18^{th} (T4) and 24^{th} (T5) hours.

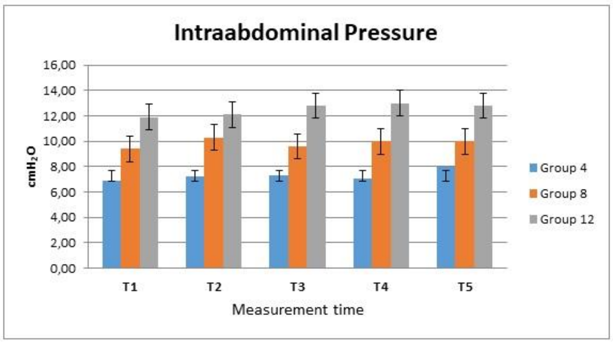

Fig. 3. Mean IAP values measured in groups
δ: Significant value according to Group 4 and Group 8. *: Indicates meaningful value within the group. T1: start, T2: 6th hour, T3: 12h hour, T4: 18h hour, T5: 24h hour

During the measurements, the IAP values that were 12 mmHg were considered as normal, and the values that were above 12 mmHg were considered as IAP. The IAP values that were between 12-15 mmHg were defined as Grade I, those between 16-20 mmHg were defined as Grade II, those that were between 21-25 mmHg were defined as Grade III, and those that were >25 mmHg were defined as Grade IV intraabdominal hypertension (15).

IAP Measurement Method: The Bladder Pressure Measurement Method was preferred for IAP measurements (16). AbViser (AbViser® AutoValve® ABV320, IAP Monitoring Device, Wolfe Tory Medical, Utah, USA) intraabdominal pressure measurement kit was used for this purpose (Figure 2).

The AbViser® AutoValve® ABV320 Kit was attached to the ureteral catheter in sterile conditions. A 0.9% saline solution was attached to the set for the purpose of removing the air, and the set was sterile-washed. The transducer of the kit was connected to the monitor, and the setting of the monitor was made. The Symphysis Pubis was taken as the reset point of the Pressure Transducer when the patient was in supine position, and the Transducer was reset in this way. In the measurements, 20 mL Isotonic was given to the bladder for a few seconds in a sterile way with an injector in the closed system. By so-doing, it was ensured that the auto-valve was closed in the AbViser® System, and the bladder pressure was recorded in the monitor.

The bedside of the patient was mostly taken as 0 degrees when measurements were carried out. In the patients that were considered that the 0^o would have a negative effect, the measurements were made at 10^o. However, the patients were kept at the same angle in all the measurements. The

Table 1. Demographic characteristics of groups

	Group 4 (n:22)	Group 8 (n:22)	Group 12 (n:20)	Mean (n:64)
Gender (F/M)	0/22	1/21	7/13	8/56
PEEP (cmH2O)	4.00±0	6.36±1.17	10.09±0.97	6.71±2.67
Age (years)	62.68±9.70	61.36±10.29	61.55±7.05	61.86±9.01
Weight (kg)	76.77±5.35	78.95±9.31	75.91±11.30	77.21±8.65
BMI kg/m2	23.68±1.39	23.27±1.31	23.41±1.40	23.45±1.36

Values are given as mean ± SD

Pressure Transducer was reset at the Symphysis Pubis level each time prior to each measurement.

The measurements were made after at least 1 minute to balance the IAP following the saline that was given into the bladder. Following each measurement, the bladder was emptied, and the discharged volume was measured. In this way, the bladder was emptied to avoid that the fluid volume given for IAP measurement would not affect the following measurement.

Statistical analysis: According to previous studies, the standard deviation (σ) was considered as 2 for the Intraabdominal pressure. Effect size (d) was assumed to be 0.9, and a Z value of 1.96 was used for the 0.05 type I error rate. The sample size was found to be 19 (about 20) by using the equation for sample size calculation ($n = Z^2.\sigma^2/d^2$), and 22 patients were included in each group.

Descriptive statistics for the continuous variables were expressed as mean, standard deviation, minimum and maximum values. One-way analysis of variances (ANOVA) was performed to compare the mean values of continuous variables. Following the ANOVA, Duncan multiple comparison test was also performed to determine different groups. Statistically significant level was considered as 0.05, and SPSS ver: 20.0 (SPSS, SPSS Inc., Chicago, IL, USA) Statistical Package program was used to all statistical computations.

Findings: The study was planned over a total of 66 patients, as 22 patients in each group. However, in 2 patients in Group 12, the initial IAP values were above 12 mmHg, therefore, these patients were excluded from the study. The demographic data of the groups are given in Table 1.

The average PEEP value was 4.00 in Group 4; 6.36±1.17 in Group 8; and 10.09±0.97 in Group 12. All IAP values that were measured in Group 12 (average PEEP=10.09±0.97) were higher than those of Group 4 (average PEEP=4.00) and Group 8 (average PEEP=6.36±1.17) (Figure 3).

No intra and inter-group differences were detected at significant levels in the comparisons that were carried out for OKD and peripheral O_2 saturation ($p>0.05$). Hypoxia was not observed in any of the groups ($p>0.05$).

The intra and inter-group CVP and fluid balance values were found to be similar ($p>0.05$). In intra-group comparisons, the CVP values that were measured at the 4th hour in Group 4 were lower than those measured at 18th and 24th hours ($p<0.05$). There were no differences between the CVP values that were recorded in the measurement hours in Group 8 and Group 12 ($p>0.05$) (Table 2).

When the groups were examined in terms of body temperatures, it was determined that the average body temperature values of all groups were within normal limits. While the lowest body temperature average was 36.1°C, the highest body temperature average was 36.8°C. No body temperature was detected that could be considered as fever or hypothermia ($p>0.05$).

There were no differences in the inter-group comparisons between the urinary output and fluid balance ($p>0.05$) (Table 2).

Discussion

PEEP is commonly used to increase oxygenation, improve alveolar ventilation, decrease atelectasis and VQ mismatch, in ICU. It was determined in this study that the IAP was low in low PEEP values. We determined that the IAP increased with the increase in PEEP values, and caused mild IAH. However, this increase was not at a level that could affect the hemodynamics in the patients.

Hess et al. conducted a study (17), and reported that the PEEP values up to 15 cmH_2O constituted the usable level, and the PEEP values above 30 cmH_2O constituted dangerous levels. In the present study of ours, we compared the PEEP levels between 0-12 cmH_2O.

Verzili et al. (9) examined the impacts of PEEP and BMI on IAP, and obtained similar results with

Table 2. Hemodynamic data of groups.

	Group 4 (n:22)	Group 8 (n:22)	Group 12 (n:20)	*p.
IAP	7.3±0.15b	9.8±0.28b	11.58±0.32a*	0.001*
Heart rate	107.2±5.35	105.78±1.90	91.42±4.17	0.1
Mean BP	84.7±2.65	86.58±1.96	87.54±3.01	0.2
SpO2	96.52±0.4	96.74±0.72	96.78±0.63	0.23
CVP	6.78±0.27	6.12±0.45	7.72±0.42	0.12
Body temperature	36.16±0.04	36.62±0.05	36.72±0.15	0.16
Urine output	1.21±0.85	1.29±0.06	1.17±0.07	0.19
Fluid Balance	356.66±91.94	394.94±74.45	446.62±103.23	0.1

Values are given as mean ± SD. *: Different lover cases in the same row represent statistically significant differences between groups

our study. In their study, they observed that as the PEEP levels increased, the IAP also increased. In another study that examined the effects of PEEP on IAP, Ferrer et al. (18) observed that there was an increase in IAP with PEEP, which is similar to the results we obtained in this study.

However, Sussman et al. (19) reported that 15 cm H_2O or less PEEP values did not have any effects on IAP. In the present study of ours, we determined that elevated PEEP values increased IAP. It was concluded that in correlation with the increase in PEEP values, IAP also increased, and the IAP value measured in the group with 12 cmH_2O PEEP was evaluated as Grade 1 IAH. In this study, it was not understood if the increase continued in a correlated manner or not because PEEP values that were higher than 12 cm H_2O were not used. Evaluating IAP levels in high PEEP levels might be the subject matter of future studies.

There are different results reported in the literature about the hemodynamic effects of PEEP. In this study, we determined that as the PEEP levels increased, so did the IAP levels; and the highest IAP values were measured in Group 12. The increasing PEEP values did not cause any hemodynamic changes, and hemodynamic data were similar in all groups. Similarly, Verzili et al. (9) reported that elevated PEEP levels did not cause any changes in hemodynamics. However, there are also some authors who claim just the opposite. Lentscehener et al. (20) conducted a study and inflated the abdomen with CO_2 until 15 mmHg. They reported that when the IAP increased, there was a direct press on the abdominal aorta, the venous return decreased, and there were hemodynamic changes. In another study, the effects of applying 10 cmH_2O PEEP in lumbar disc herniation operations on prone position were examined, and it was shown that there was a significant decrease in blood pressure in all patients who received PEEP (21).

In connection with hemodynamics, Shojaee et al. (22) claimed that PEEP was effective on CVP directly in mechanical ventilation. Kiefer et al. (23), on the other hand, defined the hemodynamic differences that were caused by PEEP to be inconsistent. In the present study, no differences were detected between the CVP values.

In this study, there were no significant differences among the groups in terms of urine output. However, there are several studies in the literature that report that high PEEP values affected urine output. In a prospective study, it was reported that IAH developed in 107 of 263 patients who were in intensive care unit. Renal dysfunction was detected in 32.7% of those who had IAH; and in 14.1% of those who did not have IAH (24). In this study, the reason why urine output was not affected might be due to the fact that IAH was Grade 1 and hemodynamic parameters were not affected. Although Bertsen et al. (25) stated that PEEP caused increases in heart rates, Cicek et al. (26) stated that PEEP did not affect heart rates, blood pressures, and SpO_2 values. There were no differences in our study among the heart rates, blood pressures, and SpO_2 values in the groups, which is similar to the results of the study of Çiçek et al.

The inability of adjusting the defecation frequency in intraabdominal pressure measurements in Intensive Care Units, and the variability of defecation times of patients limited this study in terms of IAP.

As a result, it was concluded that IAP was low in low PEEP values applied in the same mechanical ventilation mode, the IAP was high in higher PEEP values, this increase caused mild IAH; however, this did not affect the hemodynamics. However, we believe that further studies must be conducted to examine the impacts of higher PEEP values on IAP.

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