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Research

# Investigating the Effects of Protective Face Masks on the Respiratory Parameters of Children in the Postanesthesia Care Unit During the COVID-19 Pandemic

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A B S T R A C T

*Purpose:* The purpose of this study was to investigate the effect of protective face mask usage during the postoperative period on carbon dioxide retention in children during the COVID-19 pandemic.
*Design:* This study was designed as a prospective, randomized trial including 40 ASA I–II patients aged 3 to 10 years who were scheduled for elective surgery.
*Methods:* Patients were randomly allocated to two groups. The first group (group 1) received $O_2$ treatment over the protective face mask. In the second group (group 2), the protective face mask was worn over the $O_2$ delivery system. Heart rate, oxygen saturation ($SPO_2$) level, end-tidal carbon dioxide ($EtCO_2$) level, and respiratory rate were measured using a patient monitor at 0, 5, 10, 15, 30, and 45 minutes and recorded. The primary outcome of the study was the determination of the $EtCO_2$ levels, which were used to assess the safety of the mask in terms of potential carbon dioxide retention.
*Findings:* None of the participants' $SPO_2$ levels fell below 92% while wearing masks. There was no statistically significant difference between the groups in terms of $EtCO_2$, heart rate, $SPO_2$, and respiratory rate ($P > .05$).
*Conclusions:* During the COVID-19 pandemic, protective surgical face masks can be used safely in the postoperative period for pediatric patients aged 3 to 10 years.


During the COVID-19 pandemic, as in all spheres of life, there have been some changes in operating rooms and postanesthesia care units (PACU). Additional measures have been implemented to prevent the spread of the virus among patients and to protect health care workers. Following tracheal extubation after surgery, it is recommended that patients wear protective face masks in addition to oxygen masks or nasal cannulas.[1,2] The World Health Organization and the Centers for Disease Control and Prevention have stated that face masks help to prevent the spread of COVID-19. Furthermore, the Italian Pediatric Society has suggested the use of facial mask protection for children over 3 years of age.[3] However, despite their protective properties, some people believe that wearing masks can cause harmful and even life-threatening conditions in children, such as they restrict respiration, reduce oxygen inhalation, and cause hypercapnia by forcing them to inhale their own exhaled carbon dioxide.[3,4]

General anesthesia and mechanical ventilation impair pulmonary function and result in decreased oxygenation during the postanesthesia period. Patients usually require oxygen supplementation in a PACU for a period of time postoperatively.[5] In a recent study on adult patients, the effect of supplementary oxygen delivery over or under a surgical mask on $FiO_2$ was investigated.[6] In the pediatric patient group, hypoxia and hypercapnia are frequently encountered respiratory problems in the early postoperative period.[7,8] In the literature, there are no reports of studies investigating the effect of protective face mask use on respiratory parameters in pediatric patients. Thus, this study aimed to investigate the effect of protective face mask usage in the postoperative

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period on carbon dioxide retention in children during the COVID-19 pandemic.

## Methods

This study was approved by the Medical Ethics Committee of Ondokuz Mayıs University on October 8, 2020 (Approval no: 2020/572). Parental written informed consent was obtained from all patients who participated in the study.

Individuals aged 3 to 10 years undergoing elective surgery who were classified as American Society of Anesthesiologists I–II were included in the study. Exclusion criteria included patients with emergency conditions, respiratory tract diseases, complications that developed during the perioperative period, inability to tolerate the surgical mask, and an oxygen saturation value ($SpO_2$) of <92%.

The standard anesthesia protocol used in our clinic was applied to all patients. All children were deprived of food for 6 hours and water for 2 hours before the surgery. Preoperative sedation was not performed. Endotracheal intubation was performed after induction of anesthesia with 4 mg/kg of propofol i.v. (intravenous) and 0.6 mg/kg of rocuronium intravenously. Sevoflurane 2% combined with an oxygen–air mixture and 0.2 mcg/kg/min of remifentanil infusion were used to maintain anesthesia. Neuromuscular blockade was antagonized with 0.05 mg/kg neostigmine and 0.02 mg/kg atropine sulfate. Extubation was performed after sufficient spontaneous respiration and return of protective reflexes.

Study randomization was performed on the day of the operation using a computer-generated randomization code. This randomization ID of each patient was delivered to the anesthesiologist in a sealed envelope by an independent assistant. Follow-ups and measurements of all patients in the study were performed by an anesthesia resident in the recovery unit. All patients underwent preoperative real-time reverse transcriptase-polymerase chain reaction tests (RT-PCR) for COVID-19, and negative cases were included in the study.

To minimize variability, we provided all participants with a 3-layer ultrasonic welding disposable face mask with ear loops (Eliss children's mask, Ebrar Group Medical Textile, Ankara, Turkey) and a monitor (Capnostream, Medtronic, Dublin, Ireland). The primary outcome of the study was changes in the levels of end-tidal carbon dioxide ($EtCO_2$) induced by wearing the surgical facemask over or under the OxyMask (Southmedic Inc., Barrie, ON, Canada) during the postoperative period. The secondary outcomes were heart rate (HR), $SPO_2$ level, and respiratory rate (RR).

The OxyMask is a new face mask intended for oxygen delivery. It uses a small "diffuser" to concentrate and direct oxygen toward the nose and mouth, thereby delivering high concentrations of oxygen at a relatively low flow. At the same time, it has been shown to have a high $CO_2$ clearance because of the open mask system.[9,10] Given these advantages, the OxyMask was preferred for supplemental oxygen therapy in our study. $EtCO_2$ was measured from a carbon dioxide sample line attached to the OxyMask.

In group 1, immediately after the patients were extubated, a protective face mask was placed and the patient was transferred to the PACU. In the PACU, 4 L/min $O_2$ treatment was applied with an OxyMask over the face mask (Figure 1). After the patients arrived to the PACU, HR, $SPO_2$ level, $EtCO_2$ level, and RR were measured using a patient monitor and recorded at 0, 5, 10, 15, 30, and 45 minutes.

In group 2, 4 L/min $O_2$ treatment with the OxyMask was administered to patients in the PACU. HR, $SPO_2$, $EtCO_2$, and RR were measured using the patient monitor and were recorded at 0, 5, 10, 15, 30, and 45 minutes. A protective face mask was placed immediately after the patients were extubated, over the OxyMask, to prevent possible virus spread (Figure 2).

**Figure 1.** Oxygen treatment over the face mask. This figure is available in color online at www.jopan.org.

During the follow-up in the recovery unit, $O_2$ treatment was applied at 4 L/min to prevent dilution of the $EtCO_2$ measurements and aerosolization from open areas of the OxyMask. However, it was planned to remove the protective face mask and increase the oxygen flow rate to 8 L/min in patients who developed hypoxia ($SpO_2 < 92\%$). Patients with apnea and desaturation were excluded from the study.

Sample size calculation was performed using Minitab (version 16, Minitab, PA). Based on a similar previous study,[11] at a desired difference of 3 mmHg in $EtCO_2$, a power of 0.8, and a significance level of 0.05, a sample size of 14 participants was required for each group. However, taking into account possible data loss, it was decided to include at least 20 patients in each group. Data were analyzed using SPSS software (version 22 for Windows, SPSS Inc., Chicago, IL). Continuous variables were expressed as means ± standard deviations. Frequency data were expressed as numbers and percentages (%). Frequency data were compared using the chi-square test. Data were tested for normality using the Shapiro–Wilk test. Differences between intervention groups at baseline were assessed using independent *t*-tests for continuous variables. A $P$ value < .05 was considered statistically significant. For HR, $SPO_2$, $EtCO_2$, and RR, two-way repeated-measures analyses of variance were performed, accounting for each group, measurement times (0, 5, 10, 15, 30, 45 minutes), and the interaction term between group and measurement time. For pairwise comparisons in

**Figure 2.** Oxygen treatment under the face mask. This figure is available in color online at www.jopan.org.

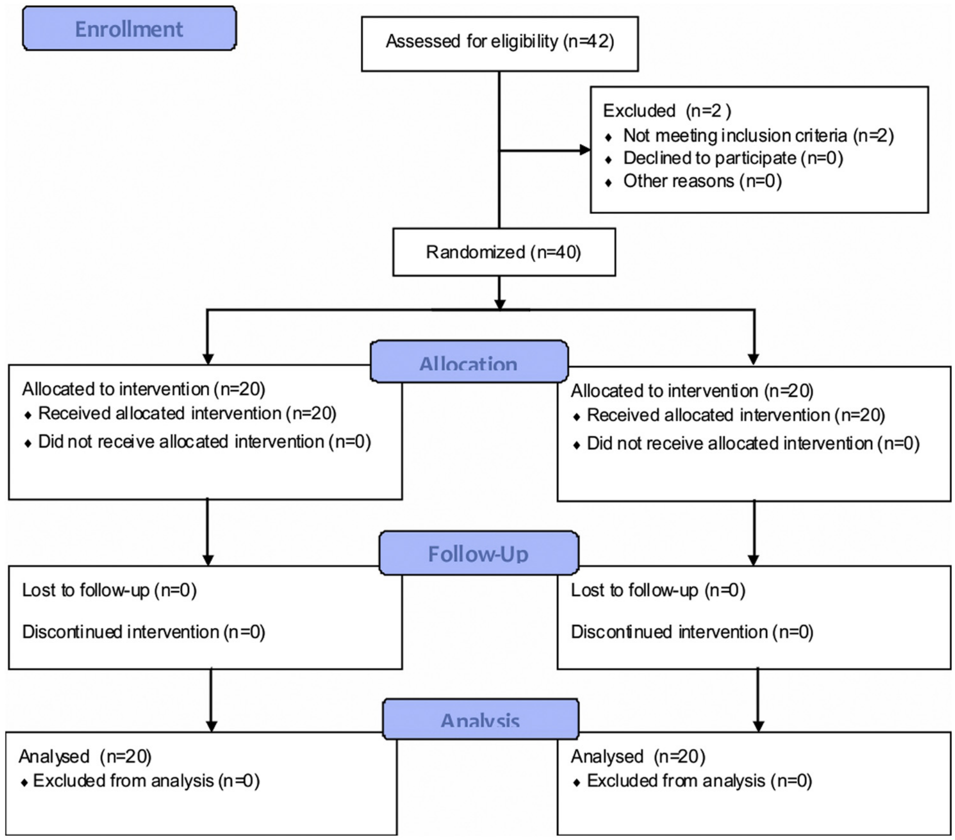


**Figure 3.** Flow diagram of patients' data distribution. This figure is available in color online at www.jopan.org.

further tests, a Bonferroni correction was applied, and the significance level was accepted as $P < .01$.

## Results

Forty patients were included in this study (Figure 3). The average age of the participants was 7.5 ± 2.2 years, 52.5% were male, and mean body mass index was 21.7 ± 6.4 kg/m$^2$. There was no statistically significant differences in age, sex, and body mass index among the study groups ($P > .05$) (Table 1). Demographic characteristics of the groups are shown in Table 1. None of the participants' $SPO_2$ levels fell below 92% while wearing masks.

In group 1, the mean HR was 103.1 ± 13.8 beats/min at 0 min and 97.6 ± 15.8 beats/min at 45 min. In group 2, these values were 106.5 ± 17.2 beats/min and 101.1 ± 15.4 beats/min, respectively. Compared to the time of onset, a tendency for a decrease in HR was observed in both groups. Based on the two-way repeated-measures analyses of variance, this shift in HR was significant with respect to time (Wilks' Lambda: 0.51, F: 6.35, $P < .0001$). The group variable had a significant impact on the decreasing pattern (Wilks' Lambda: 0.60, F: 4.44, $P = .003$) (Table 2) (Fig. 4A). The effects of the group factor at 0 to 5 minutes ($P < .001$) and 15 to 30 minutes were found to be very close to the significance level ($P = .01$) (Table 3). However, there was no significant difference between the groups in terms of the mean HR (F: 2.09, $P = .15$) (Table 2).

There were no statistically significant differences in $SPO_2$ measurements over time ($P = .054$). Moreover, there was no significant difference between the groups in terms of mean $SPO_2$ values ($P = .31$) (Table 2) (Fig. 4B).

Mean $EtCO_2$ values were between 24.9 ± 3.6 and 20.5 ± 2.8 mmHg for group 1 and 25.7 ± 4.5 and 16.4 ± 2.8 mmHg for group 2 at 0 and 45 minutes, respectively. The changes in mean $EtCO_2$ values at all time points (except 30 to 45 minutes) were statistically significant (Wilks' Lambda: 0.12, F: 46.6, $P < .001$). There was a trend for a decrease (Fig. 4C). The group factor also had an effect on the temporal change in $EtCO_2$ (Wilks' Lambda: 0.54, F: 5.6, $P = .001$) (Table 2). Bonferroni correction showed the effect of the group variable on time to be close to the limit of significance at 15 to 30 minutes and 30 to 45 minutes ($P = .03$, $P = .02$, respectively), while it was not significant at other time intervals ($P > .01$) (Table 3). However, there was no significant difference between the groups in terms of $EtCO_2$ means ($P = .14$) (Table 2).

There was a statistically significant difference ($P < .001$) when the RR measurements were assessed in terms of time variation, but the group variable did not influence this time variation ($P = .11$). There was also no difference between the groups ($P = .72$) (Table 2) (Fig. 4D).

## Discussion

In this study, we found that the use of a protective face mask under or over the OxyMask in the PACU did not affect EtCO2, SpO2, RR, and HR. In addition, all values were within normal limits for the pediatric age group. Although there was no difference in $EtCO_2$ means in the intergroup comparison, the $EtCO_2$ values significantly decreased in the first 30 minute in both groups during the follow-up in the PACU. This decrease may be caused by the increase in muscle strength of the patient during the recovery period and the respiratory parameters reaching the physiological limit. The group effect on the tendency for a decrease in $EtCO_2$ over time was not statistically significant, but as the *P*-values approached significance

**Table 1**
Patient Demographics

| | Group 1 (n = 20) | Group 2 (n = 20) | *P* |
|---|---|---|---|
| Age (years) | 7.7 ± 2.0 | 7.3 ± 2.5 | .63* |
| Sex (M/F) | 11/9 | 10/10 | 1.00† |
| BMI (kg/m$^2$) | 20.3 ± 5.7 | 23.2 ± 7.0 | .19* |
| ASA (I/II) | 16/4 | 15/5 | 1.00† |
| Surgery type (abdomen/extremity/eye/ear) | 13/4/3/0 | 13/1/3/3 | .18† |
| Surgery time (min) | 66.6 ± 27.2 | 83.5 ± 35.5 | .19* |

ASA, American Society of Anesthesiologists; BMI, body mass index.
Continuous variables are presented as mean ± standard deviation (SD), while categorical variables are presented as counts.
* Independent *t*-test.
† Chi-square test.

at 15 to 30 minutes and 30 to 45 minutes, this effect may become evident later.

Oxygen is the drug most widely used perioperatively and during critical care. Oxygen supplementation through face masks is frequently used in perioperative settings.[12] Many cases of severe acute respiratory syndrome occur within hospitals, with infections being transmitted between patients and health care workers. In some cases, it can be transmitted through oxygen delivery and other respiratory support devices.[13] A previous study showed that when wearing a face mask with an oxygen flow rate of 4 L/min, infectious air could reach a distance of approximately 0.4 m after exhalation.[14]

It has been recommended that suspected or confirmed COVID-19 patients should recover after extubation in the operating room, and then be sent directly to the ward.[15] However, it is not possible to use this protocol in all patients. In addition to the RT-PCR test, which was performed for all patients, and an interrogation for symptoms and contact history during preoperative anesthetic evaluation, some methodological changes were introduced in the PACUs. These measures were taken to prevent cross-contamination and minimize transmission to health care workers in cases of false-negative or asymptomatic patients. These changes included strict hand hygiene standards, increasing the distance between patients, and wearing a protective face mask in the PACU.

Respiratory problems frequently occur in the early postoperative period and may cause serious morbidity and mortality. PACU nurses providing postoperative care play an important role in preventing common complications by monitoring patients' respiration, circulation, consciousness, muscle strength, and oxygen saturation.[16]

Protective masks used during the recovery period may adversely affect blood-gas exchange by increasing airway resistance and respiratory load.[17] In studies conducted in healthy adults, mask use for 1 hour was shown to cause mild-to-moderate increases in carbon dioxide levels.[18-20] It was observed that the use of an FFP-2 respirator with a surgical mask cover significantly increased the $EtCO_2$ and $FiCO_2$ values in healthy health care workers while in a resting position.[21] However, Chan et al reported that the use of 3-layer nonmedical masks in healthy adults does not affect the $SpO_2$ value.[4] Similarly, Samannan et al showed that the use of surgical masks did not significantly affect gas exchange even in people with severe lung disease.[22] In this study, we showed that the use of masks in the early postoperative period did not have a negative effect on respiratory parameters and hemodynamics.

**Table 2**
Repeated-Measures Analysis of Variance Results and Means of Physiological Parameters

| | HR (Beats/min) | $SPO_2$ (%) | $EtCO_2$ (mmHg) | RR (Breaths/min) |
|---|---|---|---|---|
| 0 min | | | | |
| Group 1 | 103.1 ± 13.8 | 99.5 ± 0.8 | 24.9 ± 3.6 | 14.3 ± 5.5 |
| Group 2 | 106.5 ± 17.2 | 99.9 ± 0.3 | 25.7 ± 4.5 | 12.1 ± 4.5 |
| 5 min | | | | |
| Group 1 | 99.2 ± 15.0 | 99.7 ± 0.7 | 23.8 ± 4.6 | 15.4 ± 4.6 |
| Group 2 | 108.7 ± 18.5 | 100.0 ± 0.0 | 23.7 ± 4.2 | 14.6 ± 3.3 |
| 10 min | | | | |
| Group 1 | 96.4 ± 12.8 | 100.0 ± 0.0 | 22.3 ± 3.9 | 15.5 ± 4.2 |
| Group 2 | 106.6 ± 16.8 | 100.0 ± 0.0 | 21.1 ± 4.1 | 16.6 ± 3.1 |
| 15 min | | | | |
| Group 1 | 97.0 ± 13.4 | 99.9 ± 0.2 | 21.8 ± 4.0 | 16.8 ± 5.6 |
| Group 2 | 104.6 ± 16.8 | 100.0 ± 0.0 | 19.4 ± 3.8 | 17.3 ± 3.4 |
| 30 min | | | | |
| Group 1 | 96.0 ± 16.0 | 99.9 ± 0.2 | 20.5 ± 3.4 | 16.4 ± 4.0 |
| Group 2 | 103.6 ± 16.6 | 100.0 ± 0.0 | 17.5 ± 3.1 | 17.4 ± 2.9 |
| 45 min | | | | |
| Group 1 | 97.6 ± 15.8 | 100.0 ± 0.0 | 20.5 ± 2.8 | 17.9 ± 3.9 |
| Group 2 | 101.1 ± 15.4 | 100.0 ± 0.0 | 16.4 ± 2.8 | 16.4 ± 2.8 |
| Time p | **0.0001*** | 0.054 | **0.00001*** | **0.0001*** |
| Group p | 0.15 | 0.02 | 0.14 | 0.72 |
| Group × time p | **0.003†** | 0.14 | **0.001†** | 0.11 |

HR, heart rate; $SpO_2$, oxygen saturation; $EtCO_2$, end-tidal carbon dioxide; RR, respiratory rate.
The comparison of changes in measurements according to the time, group, and group × time was performed with repeated-measures analysis of variance. *P* values shown in boldface represent statistical significance.
* Time effect.
† Group × time effect.

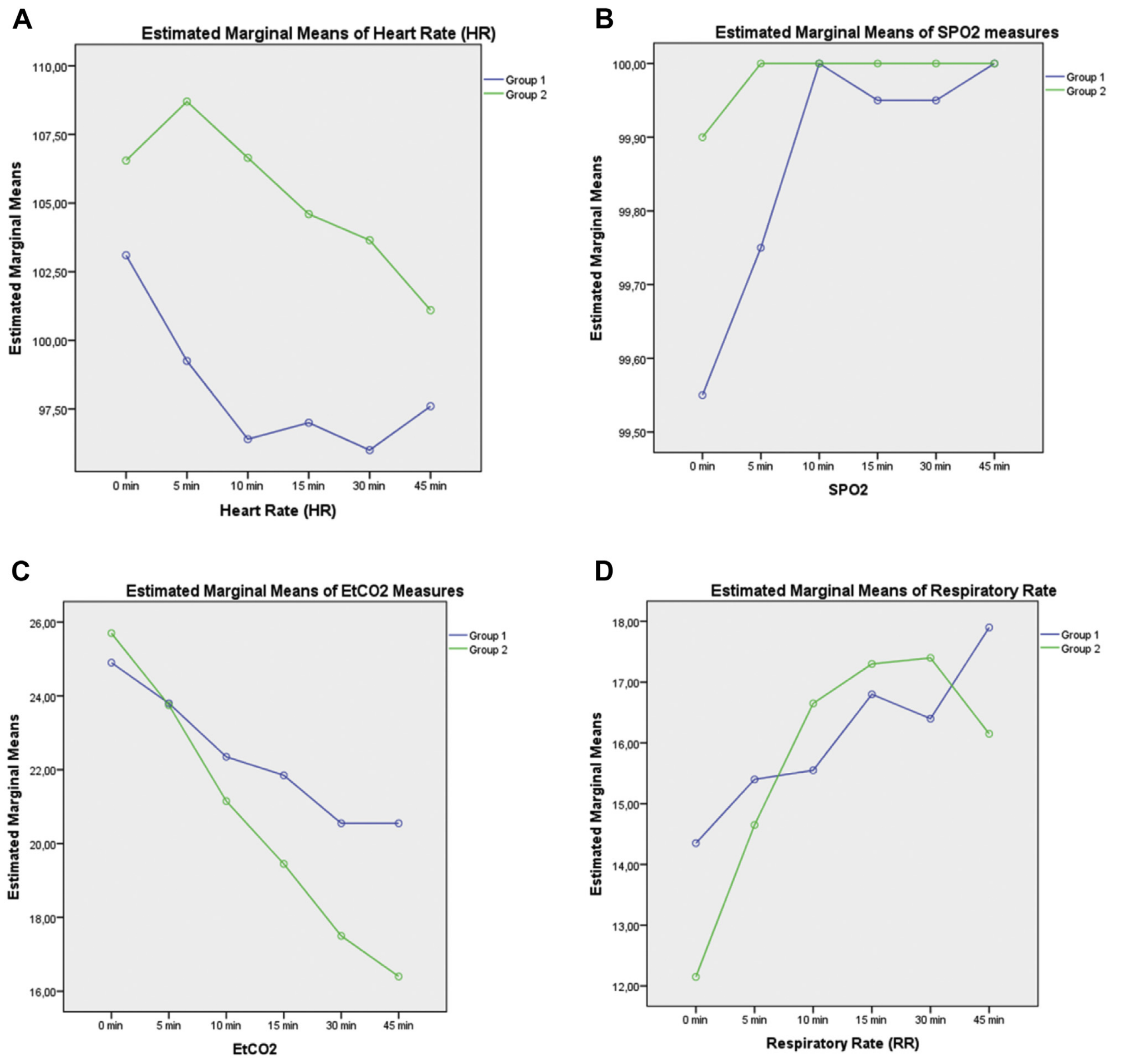


**Figure 4.** Change in (A) heart rate (HR), (B) oxygen saturation ($SpO_2$), (C) end-tidal carbon dioxide (EtCO2), and (D) respiratory rate (RR) in both groups over time. This figure is available in color online at www.jopan.org.

**Table 3**
Comparison of the Temporal Differences of Physiological Parameters Using Repeated-Measures Analysis of Variance

| | HR | | $SPO_2$ | | $EtCO_2$ | | RR | |
|---|---|---|---|---|---|---|---|---|
| | F ($P^*$) | F ($P^{\dagger}$) | F ($P^*$) | F ($P^{\dagger}$) | F ($P^*$) | F ($P^{\dagger}$) | F ($P^*$) | F ($P^{\dagger}$) |
| 0–5 min | 1.4 (0.23) | 17.9 (**0.0001**[‡]) | 4.8 (0.03) | 0.54 (0.46) | 21.1 (**0.0001**[‡]) | 1.64 (0.207) | 21.7 (**0.001**[‡]) | 3.6 (0.06) |
| 5–10 min | 7.9 (**0.007**[‡]) | 0.21 (0.64) | 2.01 (0.16) | 2.02 (0.16) | 58.9 (**0.0001**[‡]) | 1.28 (0.264) | 3.6 (0.06) | 2.6 (0.11) |
| 10–15 min | 1.5 (0.22) | 5.1 (0.02) | 1.0 (0.32) | 1.0 (0.32) | 25.1 (**0.0001**[‡]) | 1.47 (0.25) | 4.7 (0.03) | 0.4 (0.49) |
| 15–30 min | 1.02 (0.31) | 6.5 (0.01) | - | - | 32.0 (**0.0001**[‡]) | 4.75 (0.03) | 0.1 (0.71) | 0.3 (0.55) |
| 30–45 min | 0.34 (0.56) | 0.0 (0.97) | 1.0 (0.32) | 1.0 (0.32) | 5.4 (0.02) | 5.48 (0.02) | 0.1 (0.73) | 13.6 (**0.001**[‡]) |

HR, heart rate; $SpO_2$, oxygen saturation; $EtCO_2$, end-tidal carbon dioxide; RR, respiratory rate.
The time intervals of the measurements were evaluated using repeated-measures analysis of variance. Bonferroni correction was applied for advanced statistics. *P* values shown in boldface represent statistical significance.
[*] Time effect.
[†] Time × group effect.
[‡] $P < .01$.

Children tend to retain carbon dioxide more than adults due to a higher dead space/tidal volume ratio and increased airway resistance because of secretions in the postoperative period.[23] Therefore, the use of masks in children will make these clinical changes more distinct. Goh et al showed that the use of the N95 mask was safe in healthy children and did not significantly increase $EtCO_2$ values.[11] However, there have been no studies in the literature regarding the use of masks during the postoperative period in children. Since no previous study has assessed the use of protective masks in the PACU for pediatric participants, there are no comparable data for reference. A study by Binks et al showed that wearing a surgical facemask under or over the Hudson mask did not significantly affect FiO2 values in adults.[6] Similarly, in this study, we showed that wearing a face mask over or under a supplemental oxygen mask did not cause significant changes in respiratory and hemodynamic parameters during the postoperative period in pediatric patients.

## Limitations

One of the limitations of this study is that we had to use protective masks for all groups because the possibility of COVID-19 could not be completely excluded by RT-PCR. Since this study was performed during the pandemic period, we did not choose the option of not wearing protective masks for patient and employee safety concerns. Second, we observed changes in healthy children without respiratory problems, but in future, studies should be performed in younger age groups and in children with respiratory problems.

## Conclusion

We have shown that the use of protective surgical face masks in pediatric patients does not cause negative changes in respiratory and hemodynamic parameters during the early postoperative period. During the COVID-19 pandemic, protective surgical face masks can be used safely in the postoperative period for pediatric patients aged 3 to 10 years.

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