

# Mechanical ventilation management in patients diagnosed with Covid-19 who underwent pediatric open-heart surgery

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## Abstract

**Aim:** The new pneumonia pathogen "Covid-19" has been causing the pandemic since December 2019. There has been an increase in the number of cases reported in the pediatric population, particularly in adult patients. In the pediatric population, where asymptomatic transmission is standard, some mandatory protocol changes in preoperative and postoperative mechanical ventilation management must be made concerning pediatric cardiac surgery.

**Material and methods:** Our study retrospectively reviewed 215 patients operated on in our pediatric cardiac surgery clinic from March 11, 2020, to April 15, 2021. Eleven patients who were asymptomatic preoperatively and had rt-PCR (-) but had rt-PCR (+) in the postoperative period and 15 patients who required emergency surgery and had rt-PCR (+) in the preoperative period were included in the study.

**Results:** The intensive care period of the patients ranged from 2 to 51 days, with an average of  $10.61 \pm 13.58$  days. The duration of stay connected to the ventilator is 1 to 44 days. It was found that the total time spent on a ventilator was  $8.11 \pm 13.27$  days. The average service follow-up time was  $9.23 \pm 5.54$  days, with a range of 0 to 21 days. Three of the patients required ECMO, and all of those who required ECMO died.

**Conclusion:** Mechanical ventilation management in pediatric patients should be adjusted according to the patient's unique underlying pathophysiology and conducted under the physician's close clinical supervision. While a lung-protective approach is critical in this patient group, where barotrauma occurs frequently, each clinic should handle the process according to its resources and experience.

**Key words:** mechanical ventilation, COVID-19, barotrauma, pediatric cardiac surgery

## Introduction

In December 2019, a new coronavirus strain was added to pneumonia pathogen viruses [1]. Pediatric pneumonia cases have been identified in the later period due to new knowledge about the virus and mutations. However, the outbreak is thought to be mild and asymptomatic in the pediatric population in the early period [2].

Clinicians had to follow some mandatory protocol changes before and after pediatric cardiac surgery operations in the pediatric population where the

asymptomatic transition is common during the pandemic [3]. While knowledge on management and treatment methods is still limited, it is not appropriate to tackle the epidemic using a single method. Each country should develop a strategy to tackle the outbreak based on its own experiences, health dynamics, capacity, vaccination rates, and medication availability in the follow-up and treatment of COVID-19 patients [4].

Intensive care beds and mechanical ventilators have become strategically important due to the course of the epidemic. Patients' respiratory support, postural changes, mobilization, and weaning from invasive

mechanical ventilator (MV) support are areas in which respiratory physiotherapists play an important role [5,6]. It is also known that it improves oxygenation in the prone position in adults [7]. In adult Covid-19 patients who need a ventilator due to pulmonary complications, mortality rates range from 24% to 28% [8,9]. Patients with MV can develop pulmonary complications such as barotrauma due to Covid-19 pneumonia [10]. Special ventilation management is required in this patient group, such as a high positive end-expiratory pressure (PEEP) strategy and a low tidal volume [11].

While this whole process continues, babies with congenital heart disease with Covid-19 positivity are born, and these patients need to be operated on urgently. Covid-19 positivity can be detected after preoperative asymptomatic elective cases with Polymerase Chain Reaction (PCR) control along with normalization processes [12]. After open-heart surgery, we plan to present postoperative mechanical ventilation strategies and experiences in patients with Covid-19 PCR positive.

## Material and methods

In our study, 215 patients operated in our pediatric cardiac surgery clinic from March 11, 2020, to April 15, 2021, were retrospectively reviewed. 11 patients (42.3%) who were asymptomatic and PCR (-) preoperatively but had PCR (+) postoperatively, and 15 (57.6%) patients with PCR (+) in the preoperative period who required emergency surgery and underwent surgery were included in the study.

Our study is a retrospective, observational, single-center case series study. The patients' age, gender, weight, diagnosis, previous operations, treatment, mechanical ventilation, and PCR results were recorded. All patients with Covid-19 positivity were followed up in the isolation units of our clinic's intensive care unit.

Regardless of the Covid-19 PCR positive or negative difference, all patients were intubated with a video-assisted laryngoscope in the preoperative phase. During the operation, a virus filter was used. It was only used during surgery if aspiration was necessary. Furthermore, closed aspiration systems were used.

To of the risk of infection with repeated procedures in patients with proven Covid-19 positivity, the team was reduced to the minimum, and the most experienced people intubated patients. Until intubation, neuromuscular blockers were used to suppress cough in patients without a history of the difficult airway. The dead spaces of the viral filters were calculated, and our tidal volume was modified accordingly. Respiration rates were adjusted based on the children's ages and blood carbon dioxide levels.

The cuff part of the intubation tube was inflated and followed to avoid aerosol contamination in intubated patients. Cuff pressure (20-30 mmHg) was monitored daily. A nasogastric tube was placed after tracheal intubation was completed and ventilation was provided safely.

In addition to surgical antibiotic prophylaxis, vitamin C, and vitamin D aspirin to support the immune system, all patients were started on LMWH for pulmonary embolism prophylaxis in the postoperative period. Nebules were routinely applied to the patients during mechanical ventilation with the aid of an antiviral filter via a nebulizer.

In all of the patients, the same type of ventilator was used (Maquet SERVO-i intensive care ventilator). Except for patients with particular pathologies (patients with single ventricle physiology) and heart failure, where intrathoracic pressure affects venous and pulmonary return, PEEP (Positive End-

Expiratory Pressure) was used to decrease alveolar collapse, thus avoid atelectasis in all patients.

Patients were ventilated with pressure control. It aimed to protect the lungs from barotrauma by maintaining the tidal volume at a minimum level according to the patient's need, with a goal of 4-8 mL/Kg. In patients in need, the tidal volume was increased according to the patient's needs.

The patients were MV under sufficient neuromuscular blockade (rocuronium 10-12 mcg/kg/min), sedation (midazolam 0.05-0.6 mg/kg/h), and analgesia (fentanyl 1) infusions before extubation was considered to prevent pulmonary damage caused by transpulmonary pressure fluctuations caused by the patient's own effort. After extubation, sedation (dexmedetomidine 0.2-2.0 mcg/kg/hour) infusion was used.

Attention was paid to immune modulation, and steroid therapy was initiated in patients with severe disease to protect the lungs from cytokine release from biotrauma.

Fio<sub>2</sub> values were held as low as possible in all patients to protect against the adverse effects of oxygen radicals produced due to high oxygen.

Only when clinically necessary was aspiration performed, with the parameters of saturation and blood gases being monitored.

Patients were regularly placed in the intermittent prone position as long as they were on mechanical ventilation.

The patients were extubated in the intensive care unit after adequate spontaneous breathing and airway reflexes were detected. Response to simple instructions, oropharyngeal temperature greater than 36.5°C, hemodynamic stability, and the absence of uncontrollable arrhythmias were considered when deciding whether or not to extubate. In addition, in arterial blood gas analysis, the condition was sought that the pH should be more than 7.30, the Fio<sub>2</sub> should be less than 50%, the PaO<sub>2</sub> should be higher than 60 mmHg, and the PaCO<sub>2</sub> should be higher should be lower than 45 mmHg. Early mobilization, postural drainage, and breathing exercises were conducted in the presence of our expert respiratory physiotherapists during the MV separation of the patients during the postoperative period.

All personnel working on the Covid-19 patient follow-up were provided with protective masks and visor equipment. Isolation of the follow-up personnel from other patients and personnel were given to prevent contamination of other patients.

High flow nasal oxygen support was performed with a mask to prevent aerosol exposure in potential patients, and HFNO support was avoided in cases of patient incompatibility.

Sildenafil (0.5-2 mg/kg/dose every 4-6 hours, maximum 20 mg/dose every 8 hours) and nitric oxide were started in patients who did not respond to treatment. Venovenous and venoarterial ECMO were used in patients who did not respond.

Permission was obtained from the Ministry of Health for the study. It was made retrospectively in compliance with the Declaration of Helsinki by observing ethical rules.

For statistical analysis, the NCSS (Number Cruncher Statistical Systems) 2007 software (Kaysville, Utah, USA) was used. Descriptive statistical methods (Average, Standard Deviation, Median, Frequency, Ratio, Minimum, Maximum) were used to evaluate the study data.

## Results

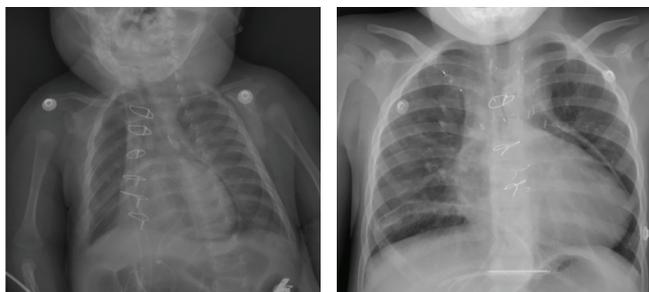
In our postoperative intensive care unit, 26 patients were followed up. 15 of them were female (57.6%), 11 were male (42.3%). 4 out of 26 patients died (mortality 15.38%). 5 patients received prolonged ventilation (>14 days), pneumopericardium in 2 patients, pneumothorax in 3 patients, and prolonged antibiotic

therapy for pneumonia in 5 patients. Out of the 26 patients, CPB was used in 19 of them. Subcutaneous emphysema was seen in 1 patient. Pulmonary embolism was not observed in any patient. Due to a gastric tolerance disorder, four patients were initiated on parenteral nutrition. 3 patients needed ECMO, and all of the patients requiring ECMO died.

Patent Ductus Arteriosus closure (n=2), Ebstein Cone repair (n=1), Atrial septal defect closure (ASD) (n=1), Ventricular septal defect (VSD) closure (n=2), ASD and VSD closure (n=1), Tetralogy of Fallot total correction (n=3), total anomalous pulmonary venous return repair (n=1), pulmonary banding (n=1), modified Blalock-Taussig shunt (n=1), VSD and PDA Closure (n=1), Aortic ridge resection (n = 1), arterial switch operation (jatenne procedure) (n=2), Aortic arcus reconstruction (n=3), End to end aortic coarctation repair (n=2), Drain insertion due to pericardial effusion (n=1), The Norwood stage1 (n=2) in hypoplastic left heart syndrome, Fontan procedure (n=1) were performed.

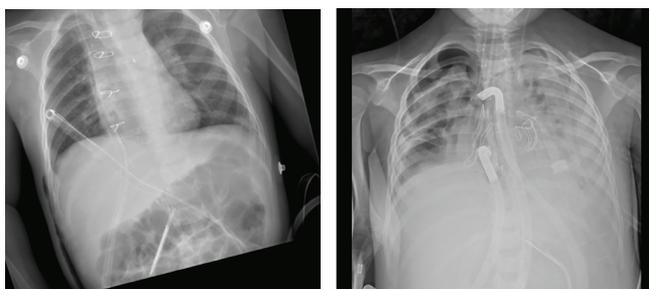
A 4-year-old female patient who underwent the Fontan procedure, two patients who underwent the Norwood stage 1 procedure, and a 12-day female patient who underwent the arterial switch procedure are patients with Ex.

**Figure 1** - Image of 2 different patients with pneumopericardium



In two patients who underwent Arcus reconstruction and VSD closure, postoperative pneumopericardium developed and disappeared in their follow-up.

**Figure 2** - ECMO patient with subcutaneous emphysema and Right pneumothorax



Subcutaneous emphysema regressed in patients with subcutaneous emphysema who were followed up on and needed no additional treatment. The patient, who had Fontan surgery, needed ECMO in the postoperative period, as his lung parenchyma rapidly deteriorated and his pneumothorax persisted amid thoracic drains. The patient died on the 28th day after surgery.

The 26 patients included in the study ranged in age from 13 days to 187 months, and the average was found as 30.21±51.45 months. The patients' weights ranged from 2.2 to 42 kilograms, and the mean was detected as 10.68±11.15 kilograms. The patients' cardiopulmonary bypass duration ranged from 0 to 1182

**Figure 3** - Ventilator view of a patient needing prolonged ventilation under full sedation (a) and a patient considering extubation (b)



**Table 1** Demographic, Postoperative parameters

	N	Minimum	Maximum	Mean	Std. Deviation
AGE		0.13	187.00	30.21	51.45
WEIGHT		2.20	42.00	10.68	11.15
CPB (min)		0.00	182.00	84.88	61.07
CC (min)		0.00	154.00	66.96	52.93
ICU		2.00	51.00	10.61	13.58
VENTILATION (day)		1.00	44.00	8.11	13.27
SERVICE (day)		0.00	21.00	9.23	5.54
Valid N (listwise)	26				

minutes, and the average was found as 84.88±61.07 minutes. The cross-clamp period is between 0 and 154 minutes, and the mean was determined as 66.96±52.93 minutes.

The intensive care period of the patients ranged from 2 to 51 days, with an average of 10.61±13.58 days. The duration of stay connected to the ventilator is 1 to 44 days. It was determined that the total time spent on a ventilator was 8.11±13.27 days. The service follow-up duration ranged from 0 to 21 days, and the average was found to be 9.23±5.54.

**Table 2** Postoperative Ventilator Parameters of the Patients

	N	Minimum	Maximum	Mean	Std. Deviation
Fio2		21.00	100.00	50.5000	20.31403
frequency		20.00	42.00	31.7308	4.96030
Ppeak		13.00	38.00	19.6154	6.30604
PEEP		.00	11.00	5.0385	2.59970
Tidal (total)		12.00	336.00	88.4358	94.99249
Tidal (kg/ml)		4.20	14.80	7.3323	2.22477
weight		2.20	42.00	10.6846	11.15404
Valid N (listwise)	26				

The patients' postoperative FiO2 values ranged from 21% to 100%, with an average of 50.50±20.31%. The patients' postoperative minute respiratory rate (respiratory frequency) ranged between 20 and 42; its average was determined as 31.73±4.96. The peak pressures of the patients in the postoperative ventilator were found between 13 and 38 Ppeak; its average was calculated as 19.61±6.30. Patients' positive exhalation pressures (PEEP) ranged from 0 to 11, with a mean of 5.03±2.59. The tidal volumes of the patients ranged from 12 mL to 336 mL and were calculated as 88.43±94.99 on average. Tidal volumes per kilo of patients ranged from 4.2 kg/mL to 14.8 kg/mL and were measured as 7.33±2.22.

## Discussion

Intensive care beds and mechanical ventilators have become more critical due to the COVID-19 pandemic's increasing need. We want to share our knowledge and experience managing mechanical ventilation after open-heart surgery in COVID-19 positive pediatric patients, a complex, challenging, and experience-demanding population for mechanical ventilation.

Endotracheal intubation is known to have the most significant risk since the person performing the procedure would perform the process with their face very close to the patient's airways. It is necessary to use personal protective equipment, an intubation tube of suitable size, and to be done by experienced people [8]. Preoperative intubations are performed in our clinical practice under deep anesthesia using a cuffed intubation tube, with adequate personal protective equipment, and by the team's most experienced members.

Intubation under deep anesthesia is considered to minimize infection because it suppresses reflexes, including coughing and sneezing, which carry a high risk of viral transmission [9]. Patients were intubated with adequate neuromuscular blockade, sedation, and analgesia in our clinical practice and monitored with MV.

In the treatment of COVID-19 patients, postoperative changes, mobilization, and respiratory physiotherapy conducted by specialist physiotherapists, as highlighted in the study by Lazzeri et al., play an essential role in the correction of hypoxia and patient separation from the mechanical ventilator [10]. In the postoperative period, we also provide respiratory physiotherapy, mobilization, and postural drainage by our specialist physiotherapist to all of our patients, whether they are COVID-19 positive or not.

In their study of patients who needed mechanical ventilation due to Covid-19 pneumonia, Udi et al. reported 40% barotrauma despite lung-protective MV strategies [11]. We found pneumopericardium in two patients, pneumothorax in three patients, and subcutaneous emphysema in one patient in our postoperative case series. We believe that lung damage (alveolar rupture) secondary to pulmonary fibrosis and adhesions caused by the Covid-19 virus triggers barotrauma. Based on our own experience with these patients who are more prone to pulmonary problems, we used our lung-protective mechanical ventilation strategy. Despite this, we encountered more barotrauma in this group compared to the normal population.

Mechanical ventilation strategies should be designed following the specific underlying pathophysiology, and the strategy should be reviewed regularly. Lung expansion should be adjusted appropriately, the patient should be protected from atelectasis, and high tidal volume should be avoided [12]. By blinding them to the patients' blood gas parameters, we adjusted the tidal volume of the patients at 4-8 mL/kg 4 times a day (1 in 6 hours) in our clinical practice. We tried to keep the patients' tidal volume to a minimum based on their needs.

In their study of the Covid-19 positive pediatric population, Sankar et al. presented their treatment and follow-up strategies to the literature [13]. We have also developed our follow-up and treatment plan for patients who test positive for Covid-19. In addition, we used a cuffed tube in all patients and tried to prevent the spread of the virus to healthcare personnel by strict isolation measures.

Although viral filters decrease transmission from patients to healthcare professionals, they add 10-40 mL of dead space to the system [14]. We calculated these dead spaces in our clinical practice and modified our tidal volume accordingly. The

respiration rates were adjusted based on the children's ages and blood gas carbon dioxide levels.

In a study conducted in Brazil, Prata-barbarasa et al. stated that the prognosis was strong in children under one year; patients with high inflammatory biomarkers had a bad prognosis [15]. Aminophylline (infusion therapy 0.4 mg/kg/hour dose) and budesonide (inhaled corticosteroid 500 g/dose) were given to protect patients requiring prolonged intubation and ECMO from inflammatory biotrauma and bronchodilation. Despite this, five patients needed prolonged ventilation.

There are opinions that high-flow oxygen therapy may increase droplet transmission in viral infections. If high-flow oxygen therapy is to be used, a mask should be placed on the patient after the nasal cannulae have been placed. In addition to the N95, FFP2, and similar masks, healthcare workers who regularly care for patients requiring oxygen therapy or non-invasive mechanical ventilation (NIMV) should use personal protective equipment (gloves, gowns, safety glasses, or face shields). If NIMV is to be applied to the patient, it should be applied in a negative pressure room, if possible [16,17]. We avoided High-flow oxygen therapy as much as possible in our clinical practice and only used it in one patient.

Burton-Papp et al. reported in an adult study that the prone position can improve oxygenation in Covid-19 patients [18]. In our pediatric patient group, we still use the prone position frequently, and we think it positively impacts the patients' pulmonary condition.

In patients with excessive volume loading MV or left ventricular failure, cardiac "output" may increase due to decreased venous return, reducing left ventricular afterload, and increasing circumferential positive intrapleural pressure. Patients who are provided positive end-expiratory pressure may experience hemodynamic side effects (PEEP). During positive pressure ventilation, a decrease in cardiac "output" and a slight decline in systemic blood pressure is observed. Reduced perfusion can exacerbate the ventilation/perfusion mismatch and decrease oxygen delivery to tissues. As a result, organ damage increases, and complications may occur [19]. We adjusted the PEEP values for our patients when applying PEEP to prevent atelectasis in MV, taking into account their pathophysiology. We believe that the PEEP values of these patients in the postoperative period are much more important for patient prognosis than predicted.

Dhont et al. stated in their research that lung expansion and mechanics were well maintained in the early days of the disease. There was no rise in airway resistance or dead space, so the patient would not experience respiratory discomfort. There could be a false sense of well-being. However, they did note that sudden and rapid respiratory decompensation can occur in this patient group, with tachypnea and hyperpnea being the most significant clinical warning signs of respiratory failure in COVID-19 patients [20]. We aimed to diagnose potential clinical deterioration in postoperative intensive care by conducting near blood gas monitoring and routine chest X-ray and biochemistry tests at 6-hour intervals four times a day.

While pediatric intensive care medicine has advanced rapidly over the last decade, much data on mechanical ventilation guidelines in children have been omitted from adult studies. The need for well-designed pediatric randomized controlled experimental and clinical trials to optimize pediatric ventilator interaction is demonstrated [21]. Even before the pandemic, the COVID-19 positivity of pediatric patients following open-heart surgery, for whom mechanical ventilation control takes significant clinical experience and effort, compelled us to

establish a strategy that protects both the patient and healthcare professionals. We developed our clinical protocol based on published adult and pediatric Covid-19 -19 studies and our prior clinical experience.

According to Marraro et al., effective therapies to prevent progressive lung damage are essential for the prognosis of patients who test positive for Covid-19. They can help reduce complications in intensive care [21,22]. Additionally, we started all patients on LMWH in the postoperative phase for vitamin C and D supplementation and pulmonary embolism prophylaxis.

## Conclusion

In postoperative Covid-19 rt-PCR positive pediatric patients, the information found in any mechanical ventilation protocol cannot substitute for a physician's professional judgment, cannot be used alone for diagnosis or treatment, and can only direct the physician in light of general information.

Pediatric mechanical ventilation should be adjusted according to the patient's unique underlying pathophysiology and should be done under the physician's close clinical supervision. While lung protection is essential in this patient group because barotrauma occurs frequently, each clinic should manage this process according to its resources and experience.

**Limitation:** Our study is a single-center retrospective study, and studies with large populations are needed to establish precise protocols.

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