

## Effect of prone positioning on cannula function and impaired oxygenation during extracorporeal circulation

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**Abstract** Prone ventilation is an effective method for improving oxygenation in patients with acute respiratory failure. However, in extracorporeal circulation, there is a risk of cannula-related complications when changing the position. In this study, we investigated cannula-related complications when changing position for prone ventilation and the effect of prone ventilation on impaired oxygenation in patients who underwent extracorporeal membrane oxygenation (ECMO). The study subjects were patients who underwent prone ventilation during ECMO in the period from 2004 to 2011. Indication for prone ventilation was the presence of dorsal infiltration shown by lung computed tomography. Factors investigated were cannula insertion site, dislodgement or obstruction of the cannula, malfunction of vascular access and unplanned dislodgement of the catheters when changing position. Mean arterial pressure,  $\text{PaO}_2/\text{FiO}_2$ , PEEP level, blood flow and rotation speed of the pump were also determined before and after position change. Five patients were selected as study subjects. The mean duration of prone positioning was

$15.3 \pm 0.5$  h. Strict management during position changes prevented cannula-related complications in the patients who underwent extracorporeal circulation. There were no significant changes in mean arterial pressure, PEEP level, blood flow and rotation speed of the pump when changing position. Low  $\text{PaO}_2/\text{FiO}_2$  prior to prone ventilation was significantly increased after supine to prone and then prone to supine position. Prone positioning to improve impaired oxygenation is a safe procedure and not a contraindication in patients receiving extracorporeal circulation.

**Keywords** ECMO · Prone ventilation · Acute respiratory failure

### Introduction

Extracorporeal lung support is sometimes performed for patients with severe respiratory failure who do not improve with mechanical support or who do not respond to medical treatment. In such patients, mechanical life support is only a temporary treatment that is used until damaged organs recover. Prone ventilation is one of the effective methods for improving oxygenation in patients with acute respiratory failure. Even in patients in whom organs are supported mechanically by extracorporeal circulation, prone mechanical ventilation is one of the treatment options if pulmonary oxygenation is impaired [1, 2]. However, because problems in pulmonary support circulation can be life-threatening, there is a risk of complications related to the cannula used for extracorporeal circulation when changing the position of the patient. The safety of position change, however, has not been sufficiently examined. In this study, we therefore investigated complications related to the cannula and the effect of prone ventilation on

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impaired oxygenation when changing position for prone ventilation in patients who underwent extracorporeal membrane oxygenation (ECMO) in our hospital.

## Patients and methods

This study was approved by the Institutional Review Board in Sapporo Medical University (Authorized No 24-5019). The subjects of this study were patients who underwent prone ventilation during ECMO in our ICU in the period from January 2004 to December 2011. Indication for prone ventilation was the presence of dorsal infiltration shown by lung computed tomography.

Patients' characteristics including age, gender, underlying disease, acute physiology and chronic health evaluation (APACHE) II score and sequential organ dysfunction (SOFA) score on the day of starting ECMO were investigated.

The inclusion criteria for ECMO treatment are patients with severe but potentially reversible acute respiratory failure. Patients with bilateral infiltration shown by chest X-ray with  $\text{PaO}_2/\text{FiO}_2$  less than 150 mm Hg and PEEP level of more than 10 cm  $\text{H}_2\text{O}$  were considered for ECMO treatment. Patients were excluded if they had been on higher  $\text{FiO}_2$  (more than 0.8) ventilation for more than 7 days, had signs of intracranial bleeding or had contraindication to heparinization. We investigated the cannula insertion site, dislodgement or obstruction of the cannula when changing position, and malfunction of blood access. We also investigated unplanned dislodgement of the tracheal tube, central venous catheter (CVC), chest tube and naso-gastric tube (NG-T) with position change. Moreover, we examined the whole body of each patient after being changed from prone to supine position for the presence of pressure sores on the skin.

The procedure used for prone positioning was the same as that previously reported [3]. In this study, however, an air-floating bed was used when changing the patient to the prone position. At least five hospital staff members including intensive care nurses, medical doctors and clinical engineers participated in each position change. Vital signs were checked immediately after the position change to confirm that the patient was able to tolerate the prone position.

Prone positioning in each patient was performed during the night shift period for nurses (16:00–9:00). To evaluate pulmonary oxygenation capability in the patients, blood gas analysis was performed using blood obtained after cessation of oxygen insufflation to the artificial lung at the time of position changes. Changes in mean arterial pressure, pulmonary oxygenation, blood flow ( $Q_B$ ), rotation speed of the centrifugal pump and positive end-expiratory pressure (PEEP) level were determined before, shortly after

prone positioning, before changing from prone to supine position, and after repositioning from prone to supine. When performing prone positioning a few times, mean arterial pressure,  $\text{PaO}_2/\text{FiO}_2$ ,  $Q_B$ , rotation speed of the centrifugal pump, and PEEP level prior to the prone positioning were compared with those performed at the last session. The criterion for weaning from extracorporeal circulation was a  $\text{PaO}_2$  of 80 mm Hg or more with inspired fraction of oxygen in the ventilator set at 0.6.

## Statistical analysis

Data are expressed as mean  $\pm$  standard deviation (SD). Serial changes in mean arterial pressure,  $\text{PaO}_2/\text{FiO}_2$ ,  $Q_B$ , rotation speed of the centrifugal pump and PEEP level were analyzed by one-way repeated analysis of variance (ANOVA). Bonferroni's post-hoc test was performed when a significant difference was detected in the one-way ANOVA. A  $p$  value less than 0.05 was considered statistically significant.

## Results

We performed ECMO on 14 patients in our hospital during the study period. Of those patients, five patients who underwent ECMO were selected as subjects of this study. The background characteristics of the patients are shown in Table 1.

The ECMO system used in this study consisted of a central unit controller for extracorporeal circulation using a MEDTRONIC 550 BIO-CONSOLE (Medtronic Inc., Minneapolis, MN, USA), centrifugal pumps using Gyro-Pump (Medtronic Inc., Minneapolis, MN, USA) in adult patients and ROTAFLOW (MAQUET, Hirrlingen, Germany) in a child patient, and membrane oxygenators using MERA HPO-20WH-C (SENKO MEDICAL INSTRUMENT MANUFACTURING Co. Ltd., Tokyo, Japan) in adult patients and BIOCUBE2000 (NIPRO, Osaka, Japan) in a child patient.

In all adult cases, a 19 Fr outlet cannula was placed from the right femoral vein to the inferior vena cava, and a 15 Fr inlet cannula was placed in the right jugular vein. In a child (case 2), a 15 Fr outlet cannula and a 14 Fr inlet cannula were used for ECMO treatment. Heparin was used as an anticoagulant drug during ECMO at the infusion rate of 200–500 U/h to maintain activated clotting time of circuit blood at more than 200 s. Oxygen flow to insufflate the artificial lung was regulated to maintain  $\text{PaCO}_2$  in the range of 35–50 mm Hg.

The mean duration of prone positioning was  $15.3 \pm 0.5$  h. The average number of position changes (supine to prone and reposition from prone to supine) was  $1.8 \pm 0.8$ .

**Table 1** Demographic data of patients

Case	Age	Disease	APACHE II score	SOFA score	Duration of prone (h)	Frequency of prone position	Weaning after prone positioning	Outcome	Cause of death
1	65	Interstitial pneumonia (cytomegalovirus)	13	6	15.5/15.0/16.0	3	No	Death	Respiratory failure
2	6	Drowning, Pulmonary edema	6	10	15.0	1	Yes	Survival	–
3	32	ARDS after pneumonia (mycoplasma)	16	8	16.0	1	Yes	Death	Intracranial hemorrhage
4	54	ARDS after acute myocardial infarction	18	7	14.5 / 15.0	2	Yes	Death	Arrhythmia
5	69	ARDS after abdominal surgery	34	14	15.0 /15.5	2	Yes	Survival	–

ARDS acute respiratory distress syndrome, APACHE II acute physiological assessment and chronic health II, SOFA sequential organ failure assessment

**Table 2** Changes in PaO<sub>2</sub>/FiO<sub>2</sub>, PEEP level, mean arterial pressure, blood flow and rotation speed

	Prior to prone position	Prone position	Shortly after reposition to supine
PaO <sub>2</sub> /FiO <sub>2</sub>	143.0 ± 38.1	262.7 ± 99.1 <sup>#</sup>	235.5 ± 87.1 <sup>#</sup>
PEEP(cm H <sub>2</sub> O)	10.2 ± 2.9	10.2 ± 4.3	10.2 ± 4.3
MAP (mm Hg)	80.1 ± 14.7	83.6 ± 19.2	80.6 ± 14.4
Q <sub>B</sub> (l/min)	2.8 ± 0.7	2.6 ± 0.8	2.6 ± 0.8
Rotation speed of the pump (rpm)	2,698 ± 693	2,714 ± 646	2,652 ± 746

PEEP positive end-expiratory pressure, Q<sub>B</sub> blood flow, MAP mean arterial pressure, rpm revolutions per minute

<sup>#</sup>  $p < 0.05$  vs prior to prone position

PaO<sub>2</sub>/FiO<sub>2</sub> values before changing to the prone position, after changing from the supine position to prone position, and after changing from the prone position to supine position are shown in Table 2. The impaired level of PaO<sub>2</sub>/FiO<sub>2</sub> prior to position change improved significantly after prone positioning. The increased level of PaO<sub>2</sub>/FiO<sub>2</sub> induced by prone positioning persisted after changing to the supine position in all patients except for patient no. 1 (Table 1). There were no significant changes in positive end-expiratory pressure (PEEP) levels in any of the patients after changing from the supine position to prone position and then back to the supine position (Table 2).

There was no change in cannula position shown by X-ray in any of the patients when changing position, and there was no malfunction of blood access due to bending or dislodgement of the cannula when changing position. There were also no significant changes in mean arterial pressure, Q<sub>B</sub> and rotation speed of the pump after changing from the supine position to prone position and then back to the supine position (Table 2).

## Discussion

ECMO for severe respiratory failure is only a temporary life support that is used until the effects of other treatments are effective. Obstruction or accidental removal of cannulas can cause fatal complications [4]. In our patients, complications related to cannulas did not occur with change in position. Our results indicated that prone ventilation can be performed safely even in patients who are receiving mechanical life support by extracorporeal circulation, as previously reported [3].

Complications with the highest risks that occur when changing a patient to the prone position are accidental removal or dislodgement of a central venous catheter, tracheal tube, chest tube, or cannula for extracorporeal circulation. Cannula-related complications did not occur in our patients because position change was performed carefully and safely by many hospital personnel including clinical engineers, ICU nurses and other ICU staff. There have been similar reports on safety for both pediatric [5] and adult [3] patients receiving ECMO. There is a tendency for bleeding during extracorporeal circulation due to the use of strong anticoagulants. Bleeding may occur from the puncture site when the position of the patient is changed to the prone or supine position. In our patients, bleeding that required management did not occur from the puncture site for a catheter or cannula.

The most frequent complication in patients in the prone position is pressure sores. Since our patients lay in the prone position on an air-floating bed, pressure from body weight was evenly distributed, and the development of pressure sores was prevented despite the long time spent in the prone position. Since no excessive pressure is exerted on a puncture site for a CVC or an outlet or inlet cannula and it is difficult for a tracheal tube to be bent when an air-floating bed is used, special cushions are not needed for

patients in the prone position. An air-floating bed is therefore considered to be useful for changing patients to a prone position during extracorporeal circulation.

Although there is controversy regarding improvement in the prognosis of mechanical ventilation in the prone position for acute lung injury/acute respiratory distress syndrome (ALI/ARDS), impaired oxygenation is improved by prone ventilation [6, 7]. Prone ventilation is particularly effective for patients with consolidation due to dependent lung atelectasis of the lung [8]. In our patients, prone ventilation was conducted after confirming the presence of dependent lung atelectasis by CT. When a patient is placed in the prone position, the mismatch between lung ventilation and lung perfusion is improved and impaired oxygenation is improved after several hours in the prone position. However, deterioration of oxygenation that has been improved by prone positioning is often seen after the patient has been changed to the supine position. Drainage of peripheral airway secretions is thought to contribute to the improvement in impaired oxygenation in the prone position [9]. The period of prone positioning is thought to be important for this drainage to be effective as previously described [10]. Since our patients remained in the prone position for a relatively long period, improvement in oxygenation persisted in most of the patients after changing to the supine position.

## Conclusion

Strict management during position changes, such as supine to prone or prone to supine, did not result in cannula-related complications in patients who underwent extracorporeal circulation. Therefore, prone positioning to improve impaired oxygenation is a safe procedure and not a contraindication in patients receiving extracorporeal circulation.

**Conflict of interest** All the authors have declared no competing interest.

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