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Prone Position in Treatment of Hypoxemia in Patients Who Underwent Type A Aortic Dissection Surgery

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ABSTRACT

Background: Postoperative hypoxemia is a high-risk complication after acute type A aortic dissection (TAAD) surgery. Prone position (PP) is an effective treatment for acute respiratory failure, which may improve the gas exchange of the injured lung and the patient's survival. PP is reported to improve the respiratory condition after cardiac surgery. However, limited data exist on the effect of PP in patients who underwent acute TAAD surgery.

Methods: We retrospectively analyzed the clinical outcomes of seven patients with severe hypoxemia who underwent PP after acute TAAD surgery. The results of arterial blood gas, chest X-ray, and survival were collected.

Results: Seven patients (3 female, mean age 48.3±11.7 years) were recruited in this study. All patients received total arch replacement and frozen elephant trunk implantation procedure. The PaO_2 at day 1 after PP was higher than before PP (126.3±49.3 vs. 77.8±15.5 mmHg). The oxygenation index rose sharply from 83.0 (80.0, 87.0) to 188.3±56.5 at day 3 after PP. There was no significant difference in heart rate between before and after PP procedure. Chest X-ray showed the diffuse shadow was significantly improved after PP. All patients responded well to PP, and all patients were discharged except for one patient, who died perioperatively due to multiple organ failure.

Conclusions: PP is a safe and feasible option for severe hypoxemia patients after TAAD surgery.

INTRODUCTION

Acute type A aortic dissection (TAAD) is often complicated with severe systemic pathophysiological changes and associated with a high mortality rate because of severe multi-system and multiorgan perioperative complications [Furusawa 2006]. Of note, postoperative hypoxemia is a high-risk complication with an incidence of 51% [Yang 2016]. Postoperative hypoxemia not only increases the mortality, but also extends the length of ventilator support and ICU stay. In addition to the patient's own factors, such as obesity and smoking history, the inflammatory response to TAAD, cardiopulmonary bypass, and deep hypothermic circulatory arrest further aggravates leukopenia and neutrophil activation, leading to the occurrence of hypoxemia. Nasal catheter oxygen inhalation, high-flow oxygen inhalation, and tracheal intubation assisted breathing were properly used for treating hypoxemia after TAAD surgery.

Prone positioning (PP) is a simple and effective treatment to improve gas exchange in severely hypoxemia patients [Guérin 2013; Gattinoni 2013]. The effect is achieved by inducing a more uniform distribution of ventilation and perfusion [Gattinoni 2013; Gregoretti 2002; Wang 2013]. During the COVID-19 pandemic, a multi-center retrospective study demonstrated that prone ventilation of non-intubated COVID-19 patients significantly reduced the risk of tracheal intubation and death [Coppo 2020]. Saha and colleagues reported that PP could be considered for the treatment of acute respiratory failure after cardiac surgery to improve short-term respiratory conditions and possibly facilitate extracorporeal membrane oxygenation (ECMO) weaning [Saha 2020]. However, limited data exists on the effect of PP in patients who underwent acute TAAD surgery.

The aim of this study was to analyze the clinical outcomes of patients with severe hypoxemia who underwent PP after acute TAAD surgery.

METHODS

Patient data: This study was conducted, according to the Ethics Committee of Changhai Hospital affiliated to Second Military Medical University (Number: CHCS012016). A total of seven patients, including four males, aged 48.3±11.7 (range, 27–60) years, with severe hypoxemia who underwent PP after acute TAAD surgery between October 2018 and October 2020 in cardiovascular ICU were enrolled in this study. The patients' profile is shown in Table 1. (Table 1) Inclusion criteria: 1) severe hypoxemia; and 2) end-expiratory positive pressure (PEEP) ≥ 15cmH2O, oxygenation index

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(PaO_2/FiO_2) ≤150mmHg. Exclusion criteria: 1) hemodynamic instability; 2) bronchial obstruction by secretions and pleural effusion; and 3) postoperative bleeding >100 ml/h. After the initial 4-6h session of prone ventilation, patient positioning (from supine to prone and vice versa) was changed every 4 h. The PP was maintained until stable oxygenation index over 200 mmHg was reached with no major oxygenation drop during the supine position. In addition, PP was used in the daytime in our study for sufficient support of cardiovascular ICU faculty to achieve maximum patient safety.

PP work standards:

Assessment: 1) hemodynamics: vital signs are relatively stable and PP can be tolerable; 2) sedation: the Richmond agitation-sedation scale (RASS) score is -4 to -5; 3) artificial airway: check the depth of the trachea cannula and clear the

Table 1. Patient profile

Patient	Gender	Age	Hypertension	Smoking	Surgical procedure	CPB time/min	DHCA time/min	Cross-clamp time/min	Outcome
1	Female	27	No	No	Aortic root repair + total arch replacement + frozen elephant trunk implantation	192	35	144	Death
2	Male	60	Yes	No	Aortic root repair + total arch replacement + frozen elephant trunk implantation	209	30	132	Survive
3	Male	51	Yes	Yes	Aortic root repair + total arch replacement + frozen elephant trunk implantation	112	21	77	Survive
4	Male	59	No	No	Aortic root repair + total arch replacement + frozen elephant trunk implantation + CABG	170	36	114	Survive
5	Male	39	Yes	Yes	Aortic root repair + total arch replacement + frozen elephant trunk implantation	114	21	60	Survive
6	Female	52	No	No	Aortic root repair + total arch replacement + frozen elephant trunk implantation	117	18	75	Survive
7	Female	50	Yes	No	Bentall + total arch replacement + frozen elephant trunk implantation	121	22	68	Survive

CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass; DHCA, deep hypothermic circulatory arrest

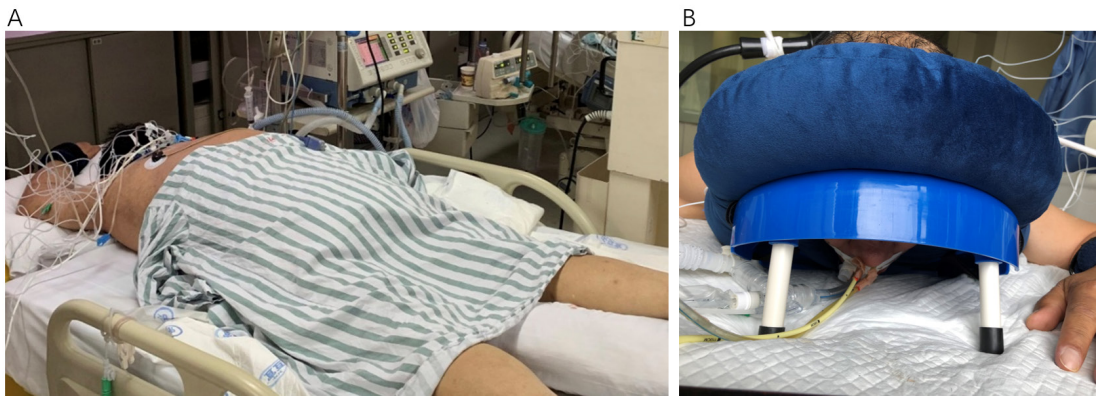

Figure 1. Prone position. A) Typical subject in the prone position. B) Pronepillow was used to prevent facial compression and facilitate fixation of the tracheal cannula and nasojejunal tube.

secretions; 4) gastrointestinal tract: suspend the enteral nutrition at least 2h before PP, withdraw the contents of the stomach before PP to avoid reflux and aspiration caused by excessive residual gastric volume, early insertion of the nasojejunal tube, if necessary; 5) check all catheters of obstructions.

Preparation: 1) item preparation: 3 pillows, pronepillow, foam dressing; 2) patient preparation: ensure the evaginable direction; remove the electrode slice to back; close the non-emergency catheter, such as stomach tube, ureter; place foam cushions at the vulnerable sites to prevent the pressure ulcer.

Farm-out: 1) the first person located at the head of the bed is responsible for the respirator's canal and the patient's head; 2) the second person located at the left of the bed is responsible for the monitor's lead wire; 3) the third person located at the left of the tailstock is in charge of the ureter and other catheters from the lower part of the body; 4) the fourth person located at the right of the bed is in charge of the venous needle and other catheters from the right upper part of the body; 5) the fifth person located at the right of the tailstock is in charge of the catheter from the right lower part of the body; 6) after confirming the safety of the patient, listen for the first person's password and turn the patient to a 90° lateral position at the same time, and then 5 people simultaneously turn the patient (from left to right or right to left) 180° to the PP (Figure 1A); 7) use the pronepillow to ensure the patient's comfortable position (Figure 1B). (Figure 1)

Operating procedures in the end: 1) clean up the secretions of the respiratory tract and oral; 2) remove the electrode slice to the chest; 3) organize the pipelines and fix them properly; 4) clean the face, change the fixing tape of tracheal intubation for oral care.

Statistical analysis: All data retrospectively were analyzed. Continuous variables are presented as mean ± SD or median (range). Categorical variables are stated as absolute numbers. ANOVA was used to compare the oxygenation index, SpO_2, PaO_2, and heart rate at different time points during prone positioning. The statistical analysis was performed by SPSS-V21.0 Software. In all analysis, $P < 0.05$ was considered statistically significant.

RESULTS

Baseline characteristics: Patients' profiles are listed in Table 1. In this study, the mean age was 48.3±11.7 years old, three patients were female, and two patients had a history of smoking. All patients received the total arch replacement and frozen elephant trunk implantation procedure. One patient concomitantly received coronary artery bypass grafting. The mean cardiopulmonary bypass time and cross-clamp time were 121.0 (114.0, 192.0) min and 95.7±33.7 min, respectively. The mean deep hypothermic circulatory arrest time was 26.1±7.4 min.

The effect of PP in patients who underwent TAAD surgery: As shown in Figure 1, the patient who required prone ventilation was placed at PP. To prevent complications induced by PP, a pronepillow (shown in Figure 1B) was placed

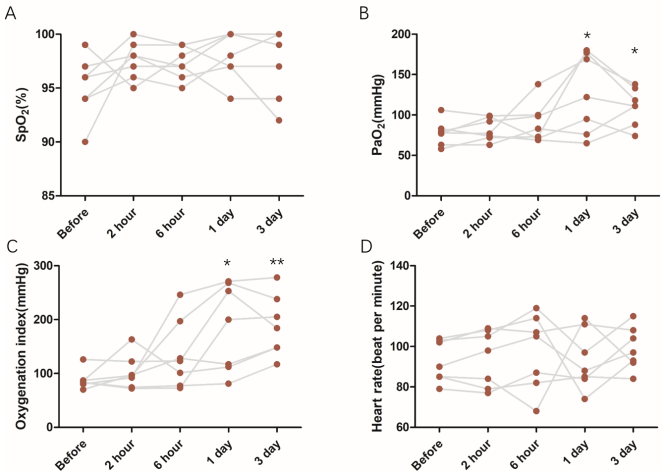

Figure 2. Prone position significantly improves oxygenation in patients underwent TAAD surgery. A) SpO2 change before and after prone position. B) PaO2 change before and after prone position. C) Oxygenation indexes change before and after the prone position. D) Heart rate change before and after prone position. TAAD, type A aortic dissection. *Represents $P < 0.05$, **represents $P < 0.01$.

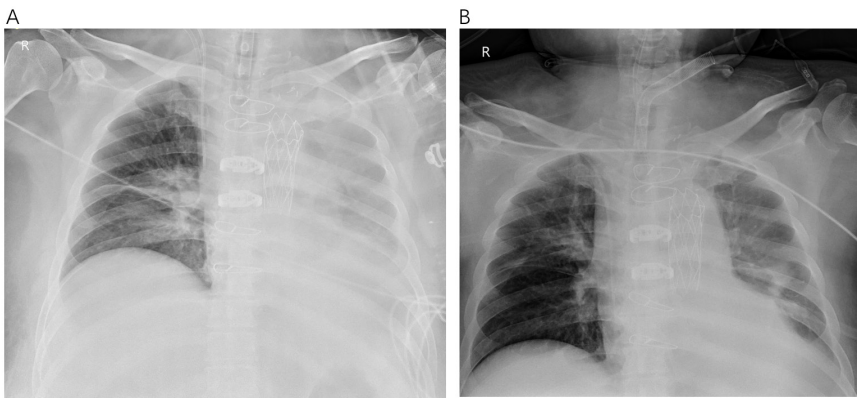

Figure 3. Prone position significantly improves chest X-ray imaging performance. Chest X-ray imaging showed that the diffuse shadow in left lung was significantly improved after prone position. A) Before prone position; B) after prone position.

Table 2. The result of arterial blood gas

	Before	1 day after PP	3 days after PP
SpO_2/%	95.1±2.9	98.0±2.2	97.3±1.2
PaO_2/mmHg	77.8±15.5	126.3±49.3*	110.4±22.9*
Oxygenation index/mmHg	83.0 (80.0, 87.0)	186.0±81.5*	188.3±56.5**
Heart rate/bpm	92.6±10.3	93.3±14.8	99.0±10.6

PP, prone position; bpm, beats per minute. *represents $P < 0.05$, **represents $P < 0.01$

under the patient's face in advance. Soft pillows were used to protect the skin at the contact zone, where was the patient was vulnerable to pressure after the PP procedure. Meanwhile, the electrodes were moved from the chest to the back. No complication related to PP was observed in this study. The results of arterial blood gas are presented in Table 2 and Figure 2. Both PaO_2 and oxygenation index after PP was significantly higher than before PP. The PaO_2 increased from 77.8±15.5 mmHg to 126.3±49.3 mmHg at day 1 after PP, and the oxygenation index rose sharply from 83.0 (80.0, 87.0) to 188.3±56.5 at the third day after PP. In addition, the SpO_2 rose from 95.1±2.9% to a more optimistic range. There was no significant difference in heart rate before and after the PP procedure. Taken together, there was a significant immediate improvement in PaO_2 and oxygenation index after 1 day of PP, whereas those improvements eased slightly after 3 days. Figure 3 shows the improvement of lung infiltrates after PP procedure. (Figure 3) All patients responded well to PP, and all patients were discharged except for one patient, who died perioperatively on account of multiple organ failure.

DISCUSSION

In this study, we demonstrated the beneficial effects of PP in postoperative hypoxemia with acute TAAD patients. In addition, no complications related to PP were found. TAAD is one of the most urgent diseases because of its high mortality and morbidity. Although cardiac surgery has been a universal choice for TAAD, patients are still disturbed by life-threatening perioperative complications, such as hemorrhage, renal dysfunction, cerebral dysfunction, and hypoxemia. Hypoxemia has a high incidence of 51% [Yang 2016]. Postoperative hypoxemia was defined as oxygenation index (PaO_2/FiO_2) ≤150mmHg in the first 24 hours after surgery with the assistance of mechanical ventilation [Gregoretti 2002]. As a lethal postoperative complication for TAAD, hypoxemia may lead to prolonged mechanical ventilation and ICU stay [Wang 2013]. A number of studies reported that postoperative hypoxemia after TAAD surgery was related to obesity, long-term smoking history, prolonged cardiopulmonary bypass time, and intraoperative blood transfusion.

The acute systemic inflammatory response was the primary cause of postoperative hypoxemia [Kurabayashi 2010]. Compared with the patients who did not have hypoxemia, the level of C-reactive protein (CRP) in hypoxemia patients were significantly increased [Girdauskas 2010; Komukai 2005]. Girdauskas's results suggested that injured oxygenation was dramatically connected with higher levels of postoperative CRP. The releasing of pro-inflammatory factors lead to the aggregation and activation of neutrophil that damaged the alveolar epithelial cells and increase the permeability, which results in the fluid accumulation and collapse of alveolus pulmonis.

Ventilation was the most effective way of treating hypoxemia. PP has been used for more than 40 years to treat patients with severe acute respiratory distress syndrome (ARDS) [Kallet 2015; Piehl 1976; Douglas 1977]. PP was known to have numerous effects on gas exchange, both under normal conditions and in patients with ARDS [Liu 2017; Johnson 2017]. In the COVID-19 pandemic, a mass of studies demonstrated that PP was feasible and effective in patients with COVID-19 pneumonia [Coppo 2020]. Compared with the traditional supine position, first, the pressure gradient of the chest can be flipped vertically during the prone posture, resulting in dorsal recruitment maneuvers and a more uniform distribution of stress and strain. Second, prone posture can effectively decrease the superimposed pressure of the heart and enterocoelia, and lastly, approximately 20% of lung tissue is above the level of the heart compared with 50% below the heart in the supine posture [Gattinoni 2013]. Saha et al. [Saha 2020] reported that PP can be helpful for the treatment of acute respiratory failure after cardiac surgery. This study further clarified that PP could improve the patient's oxygenation index, respiratory index, and lung compliance, thereby improving the patient's lung ventilation function. The mechanisms were as follows: PP increases functional residual volume; changes the movement mode and position of the diaphragm; facilitates the drainage of secretions; improves the ventilation and blood perfusion in the lung-dependent area; reduces the compression of the mediastinum and the heart on the lung and changes the compliance of the chest wall.

In our center, standard supportive therapy with low tidal volume ventilation was initiated once the oxygenation index was (PaO_2/FiO_2) ≤200mmHg in hypoxemia patients after TAAD surgery. Besides this, the oxygen concentration of the ventilator increased to 50%-60% with the PEEP of 5-8 cmH2O. If the patient did not respond to standard supportive therapy and the oxygenation index dropped to ≤100mmHg, mechanical ventilation combined with PP was considered.

ECMO therapy was another optimal choice for patients with severely impaired oxygenation. However, it is not suitable for TAAD due to its high bleeding risk. In this study, we found that compared with the supine position, PP enhanced oxygenation and had no effect on patients' hemodynamic conditions.

The expertise of the team (nurse and doctor) was important in the process of shifting body position from supine to prone. In addition, sedatives and muscle relaxants were required before PP [Chanques 2020]. Complications related to PP may occur during and after the postural change [Bruni 2021], including accidental extubating and/or obstruction of the endotracheal tube; accidental loss of vascular access (including ECMO cannulas), drainage bags, and catheters; pressure injuries; facial, palpebral and/or conjunctival edema; corneal injuries; muscular-skeletal spasm; brachial plexus injury; regurgitation and/or intolerance of enteral nutrition, and alterations in hemodynamic and/or respiratory state. Among them, the highest incidence rate was pressure ulcers [Guérin 2020]. Therefore, we strictly request nurses to check the pressure area every 2 hours and make a record according to a checklist to prevent ulcer complications. Meanwhile, we supply the comfortable pillow and foam dressing for key decompression positions, including eyes, forehead, face, arms, knee, toes, and perineum. No complications were observed during the PP procedure in our study.

CONCLUSION

The PP shows satisfactory outcomes in patients with severe hypoxemia after TAAD surgery. Therefore, we consider the PP is safe and feasible in hypoxemia patients after TAAD surgery while needs further exploration.

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