Original Article

Efficacy and safety of early prone position in postoperative cardiac surgery adults with acute respiratory distress syndrome: a single-center retrospective cohort study

Longxiang Su[1#], Jing Zhang[2#], Hua Zhao[1], Zunzhu Li[1], Hongbo Luo[1], Jianzhou Liu[3], Qi Miao[3], Haibo Deng[3], Na Cui[1], Huaiwu He[1], Wenzhao Chai[1], Yun Long[1]

[1]Department of Critical Care Medicine, State Key Laboratory of Complex Severe and Rare Diseases, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China; [2]Department of Intensive Care Unit, Chongqing General Hospital, Chongqing University, Chongqing, China; [3]Department of Cardiac Surgery Care, Peking Union Medical College Hospital, Chinese Academy of Medical Science and Peking Union Medical College, Beijing, China

Contributions: (I) Conception and design: Y Long, W Chai, L Su, J Zhang; (II) Administrative support: Y Long, L Su; (III) Provision of study materials or patients: J Liu, Q Miao, H Deng; (IV) Collection and assembly of data: J Zhang, L Su, Z Li, H Luo; (V) Data analysis and interpretation: J Zhang, L Su, H Zhao, N Cui, H He, W Chai; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

[#]These authors contributed equally to this work.

Correspondence to: Wenzhao Chai, MD; Yun Long, MD. Department of Critical Care Medicine, State Key Laboratory of Complex Severe and Rare Diseases, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, No. 1 Shuaifuyuan Wangfujing, Dongcheng District, Beijing 100730, China. Email: chaiwenzhao@126.com; ly_icu@aliyun.com.

Background: Acute respiratory distress syndrome (ARDS) is a leading cause of postoperative respiratory failure after cardiac surgery, and the mortality rate is extremely high. Although prone positioning (PP) may be safe and effective for ARDS, it is still not widely adopted in cardiac surgery patients. We aimed to assess the efficacy and safety of early PP in ARDS after cardiac surgery.

Methods: This is a single-center retrospective cohort study. We included adult intensive care unit (ICU) patients who developed ARDS with arterial pressure of oxygen to fraction of oxygen ratio (P/F) ≤200 mmHg within 72 hours after cardiac surgery between 1 January 2019 and 1 August 2023. The outcomes were P/F after 1 session of PP, duration of mechanical ventilation (MV) and ICU stay, and adverse events.

Results: In total, 79 patients who underwent PP and 87 patients who underwent supine position (SP) were included. The mean time to perform PP after ICU admission was 38.0 hours. The P/F improved significantly after 1 session of PP treatment [160.0 (127.8–184.3) *vs.* 275.0 (220.0–325.0) mmHg, P<0.001], the duration of MV and ICU stay in the PP group were significantly shorter than those in the SP group [84.0 (64.0–122.0) *vs.* 120.0 (97.0–182.0) h, P<0.001; 6.0 (5.0–8.0) *vs.* 8.0 (6.0–12.0) days, P<0.001, respectively]. No adverse events were observed during the PP even in patients with intra-aortic balloon pump (IABP).

Conclusions: Early PP treatment is effective and safe for patients with moderate to severe ARDS after cardiac surgery and it is even safe in a subgroup placed with IABP.

Keywords: Acute respiratory distress syndrome (ARDS); cardiac surgery; prone position; intra-aortic balloon pump (IABP); adverse events

Submitted Feb 27, 2024. Accepted for publication Jun 14, 2024. Published online Aug 22, 2024.
doi: 10.21037/jtd-24-323
View this article at: https://dx.doi.org/10.21037/jtd-24-323

Introduction

Cardiac surgery is a known risk factor for acute respiratory distress syndrome (ARDS). More than 300,000 patients undergo cardiac surgery each year in the United States, and as many as 20% of them develop ARDS (1-3). ARDS is a leading cause of postoperative respiratory failure after cardiac surgery, and the mortality rate can be as high as 80% in the subset of patients undergoing of cardiac surgery (4,5); survivors may have increased length of intensive care unit (ICU) and in-hospital stay, as well as substantial long-term psychological and physical morbidity (6). Currently, drugs comprise only part of the ARDS treatment strategies; prevention strategies do exist such as preoperative protective ventilation [lower tidal volumes (VTs): 4–8 mL/kg predicted body weight (PBW)], and lower inspiratory pressures (plateau pressure ≤30 cmH_2O). In addition, prone positioning (PP) is considered almost beneficial for ARDS, according to a recent report (7). Therefore, it is necessary to find a specific treatment strategy to improve the clinical outcomes of patients with ARDS after cardiac surgery.

The treatment of ARDS typically aims at increasing blood oxygen levels, providing respiratory support, and treating the underlying cause of the disease (7). Clinical studies and meta-analyses have demonstrated that early application of prolonged PP can improve the oxygenation (8-10) and decrease mortality in patients with moderate to severe ARDS, but a large multi-center randomized control study excluded the patients who had undergone cardiac surgery within the last 15 days (11). Moreover, there are currently only 5 retrospective studies including 249 patients that have reported on the efficacy of PP in adult patients after cardiac surgery (12,13). As a result, information regarding the efficacy of PP in patients with ARDS after cardiac surgery is limited.

The complications of PP after cardiac surgery have also been inconsistent in published studies. Maillet *et al.* (12) included 16 ARDS patients, but 5 of them developed pressure sores and 2 others had superficial sternal wound infections; Brüssel *et al.* (14) reported that 50% of participants developed pressure bruises on the forehead and anterior chest wall and 1 patient developed superficial ulcerations; Saha *et al.* (15) and von Wardenburg *et al.* (16) found that there were no adverse events during PP.

Owing to the paucity of available data on the efficacy and complications of PP, it has not been widely adopted among postoperative cardiac patients (17). Thus, we aimed to evaluate the efficacy and safety of early PP for patients with ARDS after cardiac surgery. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-323/rc).

Highlight box

Key findings

- Early prone positioning (PP) significantly improved arterial pressure of oxygen to fraction of oxygen ratio (P/F) in patients with acute respiratory distress syndrome (ARDS) after cardiac surgery.
- Early PP can shorten the duration of mechanical ventilation and intensive care unit stay, and no adverse events were observed during PP.
- Early PP treatment is effective and safe for patients with moderate to severe ARDS after cardiac surgery and it is even safe in a subgroup placed with an intra-aortic balloon pump (IABP).

What is known and what is new?

- PP can improve P/F in patients with ARDS after cardiac surgery.
- This is the first study to report the safety and efficacy of early PP in cardiac surgery.
- This is the first study to report PP being applied in patients with IABP.

What is the implication, and what should change now?

- PP may be considered for the treatment of ARDS after cardiac surgery in the early postoperative period both in ordinary patients or even those with an IABP.

Methods

This is a single-center retrospective cohort study that included cardiac surgery patients admitted to the ICU of Peking Union Medical College Hospital (PUMCH) between 1 January 2019 and 1 August 2023. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Informed consent was not applicable due to the retrospective nature of the study and waived by the Institutional Research and Ethics Committee of Peking Union Medical College Hospital. This is a retrospective observation study, which exempted ethics after we consulted to the Ethics Committee of Peking Union Medical College Hospital.

Patients who met all of the 4 following criteria were included: (I) post-cardiac surgery admitted to ICU; (II) age ≥18 years; (III) presence of ARDS as defined by the Berlin definition (18): lung ultrasonography or computed tomography (CT) showed consolidation of both lower lungs; (IV) arterial pressure of oxygen to fraction of oxygen ration ratio (P/F) ≤200 mmHg within 72 h after cardiac

surgery (19). The exclusion criteria were as follows: (I) active bleeding; (II) pregnancy; (III) initiating PP >72 h after surgery.

In order to maximize patient safety, avoid adverse events, and prevent catheter and cannula displacement, PP was performed during the daytime by the attending medical team (experienced intensivists, nurses, and surgeons). To avoid pressure ulcers and secure the catheter, foam pads were placed in all vulnerable areas and turned over every 2 h. In order to avoid compression and poor healing of the chest wound, we fixed the ribcage with an elastic chest strap and placed a water pad under the compressed chest (Figure S1).

Data collection

The patient data extracted included the basic characteristics of age, sex, body mass index (BMI), Acute Physiology and Chronic Health Evaluation II (APACHE II) score, and New York Heart Association (NYHA) class. VT according to ARDS-net ideal weight calculator, positive end-expiratory pressure (PEEP), fraction of inspiration of O_2 (FiO_2), mean airway pressure (Pmean), central venous pressure (CVP), arterio-venous carbon dioxide partial pressure difference (CO_2-GAP), central venous oxygen saturation ($ScVO_2$), and lactic acid (Lac) were extracted at the time of ICU admission. The lowest P/F within 72 h after cardiac surgery was extracted. We also extracted the data of comorbidities, surgery details, time of initiating PP, duration of the first PP, total number of PP, total duration of PP, and duration of intra-aortic balloon pump (IABP). Data acquisition was based on the institutional database and then identified. Primary outcomes included P/F ratio after 1 session of PP, duration of mechanical ventilation (MV) and ICU length of stay, and duration of norepinephrine and epinephrine use. Secondary outcomes were the duration of IABP use and adverse events associated with PP including poor wound healing, pressure ulcer, arrhythmia, unintended extubation, and mediastinal infection.

Statistical analysis

Data were tested for normal distribution using Shapiro-Wilk test. Categorical variables were evaluated using the chi-squared test. Continuous variables satisfying the normal distribution and homogeneity of variance were tested by using independent sample *t*-test, otherwise Mann-Whitney *U* test was used. Results were expressed as mean ± standard deviation, or medians with interquartile ranges and percentages. The null hypothesis was rejected, and significant difference was assumed with P values ≤0.05. Data were analyzed using the software IBM SPSS Statistics Data Editor version 27 (IBM Corp., Armonk, NY, USA).

Results

Baseline parameters

The flow diagram is presented in *Figure 1*. A total of 1,610 patients were admitted to the ICU after cardiac surgery during the study period. Some 186 patients developed moderate to severe ARDS, of whom 20 patients with PP initiated >72 h were excluded, 79 patients underwent PP, and 87 patients underwent supine positioning (SP). Among them, 4 in the PP and 6 in the SP group had an IABP placed intraoperatively. Their basic clinical characteristics are reported in *Table 1*. The median age was 60 (54–66) years in the PP group and 63 (54–69) years in the SP group, with 69.6% and 71.3% of the patients being male, respectively. The APACHE II score was 14 (12–18) in the PP group and 16 (13–20) in the SP group. The lowest P/F ratios within 72 h after cardiac surgery were 160.0 (127.8–184.3) and 155.3 (142.5–176.3) mmHg in the PP group and SP group, respectively. Preoperative NYHA class, ventilator parameter settings including VT, PEEP, FiO_2, and Pmean upon ICU admission had no statistically significant differences between the 2 groups (P>0.05). There were 24 (30.4%) and 29 (33.3%) patients who underwent coronary artery bypass graft (CABG), 17 (21.5%) and 27 (31.0%) cases underwent valve surgery, and 4 (5.1%) and 6 (6.9%) cases underwent IABP and CABG or valve surgery in the PP and SP groups, respectively. The time to initiation of PP after ICU admission was 38.0±16.0 h (Table S1).

Outcomes

The P/F improved significantly after 1 session of PP treatment [160.0 (127.8–184.3) *vs.* 275.0 (220.0–325.0) mmHg, P<0.001] (Table S1), and the duration of postoperative MV and ICU stay in the PP group were significantly shorter than those in the SP group, and the differences were statistically significant [84.0 (64.0–122.0) *vs.* 120.0 (97.0–182.0) h, P<0.001; 6.0 (5.0–8.0) *vs.* 8.0 (6.0–12.0) days, P<0.001, respectively]. There were 4 patients with IABP in the PP group and 6 patients with IABP in the SP group; subgroup analysis delivered the same results as above that the duration of MV and ICU stay were shorter in the PP group than

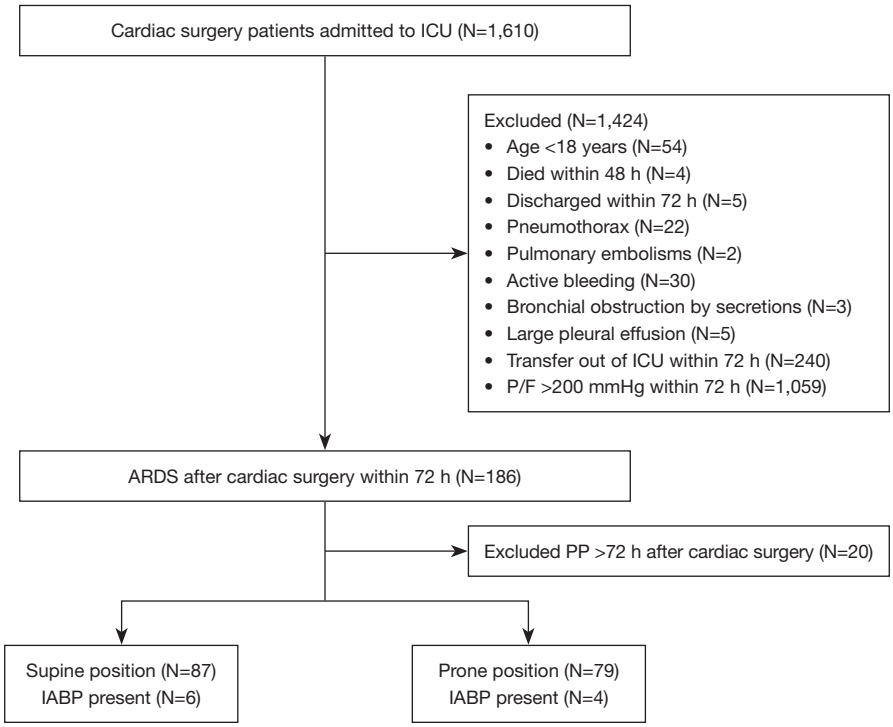

Figure 1 Flow diagram for patient selection. ICU, intensive care unit; P/F, pressure of oxygen to fraction of oxygen ratio; ARDS, acute respiratory distress syndrome; PP, prone positioning; IABP, intra-aortic balloon pump.

the SP group [97.0 (68.0–104.0) *vs.* 187.0 (150.0–307.0) h, P=0.01; 6.0 (6.0–7.0) *vs.* 13.0 (8.0–17.0) days, P=0.02, respectively]. The duration of IABP was shorter in the PP group than in the SP group (39.0±17.0 *vs.* 74.0±22.0 h, P=0.03). We also found that the PP group used norepinephrine and epinephrine for a shorter time than the SP group, and the differences were statistically significant [87.0 (38.0–114.0) *vs.* 125.0 (82.0–180.0) h, P<0.001; 11.0 (0.0–43.0) *vs.* 42.0 (6.0–108.0) h, P<0.001, respectively] (*Table 2*).

We also performed a subgroup analysis between non-IABP and IABP in the PP group; the earliest time to initiate PP in the non-IABP group was 1 h after ICU admission, and the mean time to start PP was 38.0 h, whereas the earliest time to perform PP was 17 h, and the mean time to start PP was 44.0 h in the IABP group. The total number of PP and initiation time of PP between the 2 groups were not significantly different (2.0 (1.0–3.0) *vs.* 2.0 (1.0–2.0) times, P=0.51; 38.0±16.0 *vs.* 44.0±20.0 h, P=0.49, respectively). The duration of MV and ICU stay between the 2 groups were also not significantly different [83.0 (64.0–125.0) *vs.* 97.0 (67.0–103.0) h, P=0.80; 6.0 (5.0–8.0) *vs.* 6.0 (6.0–7.0) days, P=0.72, respectively] (Table S1).

Adverse events

Our study found that there were no serious adverse events associated with PP. One patient developed rapid atrial fibrillation during PP, which disappeared when they converted to the SP, and the arrhythmia did not occur again the next time PP was performed. The incidence of arrhythmias appeared to be lower in the PP group than in the SP group, but there were no statistical differences. One patient in each group had poor wound healing. There were 3 (3.8%) patients in the PP group and 1 (1.1%) case in the SP group who developed mediastinal infection, and 37 (46.8%) patients in the PP group and 34 (39.1%) patients in the SP group who were diagnosed with nosocomial pneumonia, but the differences were not statistically significant. Pressure ulcers, accidental extubation or catheter prolapse, and urgent need for cardiopulmonary resuscitation were not observed during PP of the patients, even among those placed with an IABP (*Table 3*).

Discussion

In this cohort, we retrospectively analyzed all patients

Table 1 Baseline parameters and details of surgery

Variables	PP (n=79)	SP (n=87)	P value
Age (years)	60 (54–66)	63 (54–69)	0.06
Male	55 (69.6)	62 (71.3)	0.73
BMI (kg/m^2)	26.73±3.91	25.47±3.89	0.32
APACHE II	14.0 (12.0–18.0)	16.0 (13.0–20.0)	0.053
NYHA class			0.24
Grade 1	19 (24.1)	11 (12.6)	
Grade 2	38 (48.1)	44 (50.6)	
Grade 3	20 (25.3)	28 (32.2)	
Grade 4	2 (2.5)	4 (4.6)	
P/F (mmHg)	160.0 (127.8–184.3)	155.3 (142.5–176.3)	0.99
VT (mL/kg/PBW)	7.0 (6.0–7.0)	7.0 (6.0–7.0)	0.58
PEEP (mmHg)	8 (6–8)	7 (6–8)	0.16
FiO_2 (%)	40 (40–50)	45 (40–50)	0.39
Pmean (mmHg)	11.0 (10.0–12.0)	10.0 (9.0–12.0)	0.055
CVP (mmHg)	8 (7–10)	9 (8–10)	0.052
CO_2-GAP (mmHg)	6.357±2.7584	6.826±2.7205	0.27
$ScVO_2$ (%)	72.5 (65.4–79.9)	74.1 (68.1–79.5)	0.33
Lactic acid (mmol/L)	3.9 (2.6–6.7)	6.2 (3.1–9.7)	0.002
Co-morbidities			
Arterial hypertension	42 (53.2)	47 (54.0)	0.91
Diabetes	14 (17.7)	25 (28.7)	0.10
Chronic kidney disease	4 (5.1)	7 (8.0)	0.44
Hyperlipidemia	20 (25.3)	18 (20.7)	0.48
Arrhythmia	9 (11.4)	17 (19.5)	0.15
COPD	2 (2.5)	3 (3.4)	>0.99
Pulmonary hypertension	5 (6.3)	10 (11.5)	0.25
Live disease	4 (5.1)	4 (4.6)	>0.99
Cerebrovascular disease	13 (16.5)	11 (12.6)	0.49
Details of surgery			0.45
CABG	24 (30.4)	29 (33.3)	
Valve surgery	17 (21.5)	27 (31.0)	
CABG and valve surgery	7 (8.9)	5 (5.7)	
Congenital heart disease surgery	4 (5.1)	1 (1.1)	
Pericardial peel surgery	2 (2.5)	5 (5.7)	
Pulmonary endarterectomy surgery	4 (5.1)	1 (1.1)	
Surgery for heart tumors	6 (7.6)	5 (5.7)	
Repair of aortic dissection	8 (10.1)	6 (6.9)	
Valve surgery and repair of aortic dissection	3 (3.8)	2 (2.3)	
CABG and/or valve surgery and IABP	4 (5.1)	6 (6.9)	

Data are presented as medians (25th–75th percentiles), absolute numbers (percentages) or mean ± SD. PP, prone position; SP, supine position; BMI, body mass index; APACHE II, Acute Physiology and Chronic Health Evaluation II; NYHA, New York Heart Association; P/F, partial pressure of arterial oxygen to inspired fraction of oxygen ration; VT, tidal volume; PBW, predicted body weight; PEEP, positive end-expiratory pressure; FiO_2, fraction of inspiration of O_2; Pmean, mean airway pressure; CVP, central venous pressure; CO_2-GAP, arterio-venous carbon dioxide partial pressure difference; $ScVO_2$, central venous oxygen saturation; COPD, chronic obstructive pulmonary disease; CABG, coronary artery bypass graft; IABP, intra-aortic balloon pump; SD, standard deviation.

Table 2 Primary outcomes

Variables	PP (n=79)	SP (n=87)	P value
Length of MV (h), median (IQR)	84.0 (64.0–122.0)	120.0 (97.0–182.0)	<0.001
Length of ICU stay (days), median (IQR)	6.0 (5.0–8.0)	8.0 (6.0–12.0)	<0.001
Duration of norepinephrine (h), median (IQR)	87.0 (38.0–114.0)	125.0 (82.0–180.0)	<0.001
Duration of epinephrine (h), median (IQR)	11.0 (0.0–43.0)	42.0 (6.0–108.0)	<0.001
Subgroup analysis (with IABP)			
Patients, n	4	6	
Length of MV (h), median (IQR)	97.0 (68.0–104.0)	187.0 (150.0–307.0)	0.01
Length of ICU stay (days), median (IQR)	6.0 (6.0–7.0)	13.0 (8.0–17.0)	0.02
Duration of postoperative IABP (h), mean ± SD	39.0±17.0	74.0±22.0	0.03

PP, prone positioning; SP, supine positioning; MV, mechanical ventilation; IQR, interquartile range; ICU, intensive care unit; IABP, intra-aortic balloon pump; SD, standard deviation.

Table 3 Adverse events

Variables	PP (n=79)	SP (n=87)	P value
Nosocomial pneumonia, n (%)	37 (46.8)	34 (39.1)	0.31
Arrhythmia, n (%)	30 (38.0)	41 (47.1)	0.23
Poor wound healing, n (%)	1 (1.3)	1 (1.1)	>0.99
Mediastinal infection, n (%)	3 (3.8)	1 (1.1)	0.55
Pressure ulcers, n (%)	0 (0.0)	0 (0.0)	–
Accidental extubation or catheter prolapse, n (%)	0 (0.0)	0 (0.0)	–
Urgent need for cardiopulmonary, n (%)	0 (0.0)	0 (0.0)	–
Chest-CT (sternal contusion-poor bone healing sign), n (%)	0 (0.0)	0 (0.0)	–

PP, prone positioning; SP, supine positioning; CT, computed tomography.

with ARDS who had been admitted to the ICU after cardiac surgery for the past 5 years and found that PP can significantly improve oxygenation and shorten the duration of MV and ICU stay. We also found that the PP group had a shorter duration of using IABP, as well as norepinephrine and epinephrine, than did the SP group. There were no adverse events such as poor wound healing, pressure ulcers, unintended extubation, and urgent need for cardiopulmonary resuscitation observed during PP of the patients, even those placed with an IABP.

The risk of ARDS after cardiac surgery is associated with the use of cardiopulmonary bypass (CPB), direct surgical insult, MV, and the need for blood product transfusion and large volume shifts. In fact, ARDS in the cardiac population affects not only survival but also the length of ICU and in-hospital stay, and long-term physical and psychological morbidity (20). PP has been used since the 1970s to treat severe hypoxemia in patients with ARDS and has a positive effect on ventilation, regardless of the etiology of ARDS (19). However, PP has not been widely adopted in postoperative cardiac patients owing to physicians being reluctant to implement PP in patients with a recent sternotomy because of complications of PP including poor wound healing, pressure ulcers, arrhythmia, and unintended extubation (17). Clinicians may attempt to use recruitment maneuvers to reopen collapsed alveoli, thereby decreasing shunt fraction and improving hypoxemia (4), but the response of patients with ARDS to recruitment maneuvers is extremely variable, improvement in oxygenation is transient, and increase in pulmonary compliance has not

been seen (21); moreover, more than 20% of patients who undergo recruitment maneuvers experience adverse events including transient oxygen desaturation, hypotension, arrhythmias, and pneumothorax (22). Meanwhile, with the accumulation of experience, our study and other published studies (12,14-16) have found that PP can significantly improve oxygenation in patients after cardiac surgery. The main physiological purposes of the prone position are as follows: (I) improve respiratory mechanics; (II) homogenize the pleural pressure gradient, alveolar inflation, and ventilation distribution; (III) increase lung volume and reduce the number of atelectasis areas; (IV) facilitate the discharge of secretions; (V) improve oxygenation. Thus, we can conclude that PP can improve P/F ratio in patients with ARDS after cardiac surgery. The essence of ARDS is a pathophysiological alteration characterized by damage to pulmonary capillary endothelial cells and alveolar epithelial cells (18,23), resulting in diffuse effusion in both lungs, decreased lung compliance, and increased pulmonary artery pressure, which increases the right heart afterload and leads to a decrease in the preload of the left heart, and an increase in the volume or pressure of the right heart is transmitted to the left heart through the ventricular septum, resulting in a sharp decrease in left heart output, causing or aggravating shock (24). However, patients who undergo cardiac surgery often have underlying pulmonary hypertension, which results in a higher risk of acute right heart failure for those who develop ARDS after cardiac surgery. PP can reopen the collapsed alveoli and some compressed blood vessels, make the lung ventilation more uniform, improve oxygenation, reduce the plateau pressure and driving pressure, and improve the compliance of the respiratory system. This results in a decrease in pulmonary vascular resistance, a decrease in pulmonary circulatory resistance, and ultimately a reduction in the afterload of the right ventricle (25,26), facilitating the correction of right heart failure (27). PP can reduce the inflammation of the lungs and even the whole body, thereby reducing the cardiac damage related to the release of cytokines (28). Therefore, it is theoretically possible that PP may be more conducive to the recovery of cardiac function in patients with ARDS after cardiac surgery. This theory echoes our results that the PP group used norepinephrine and epinephrine for a shorter time than the SP group. We also performed a subgroup analysis of patients who had an IABP placed intraoperatively and found that the duration of using IABP was significantly shorter in the PP group than in the SP group, and the difference was statistically significant. IABP is used in patients with low cardiac output after cardiac surgery to help them safely survive the perioperative period. For patients with intraoperative IABP placement who have poor basic cardiac function, postoperative ARDS may further deteriorate cardiac function; based on the role of protecting lung and right heart function in the prone position, and improving cardiac function while improving oxygenation and lung compliance at the same time, theoretically, PP may shorten the duration of necessity for IABP, which is consistent with our results. Due to the small number of patients included in this study, further validation by randomized controlled trials (RCTs) with large samples is needed.

Currently, the initiation time of PP is one of the most controversial issues (16). According to the guidelines of the Intensive Care Society (www.ics.ac.uk), PP is an absolute contraindication for the first 24 hours after thoracotomy cardiac surgery (17). Guérin *et al.* reported that PP can lower the mortality rate in severe ARDS, but their study excluded patients who underwent sternotomy within the last 15 days (11). Meanwhile, it has been reported that for patients with acute respiratory failure (ARF), it is most beneficial to start the PP early, particularly before day 3, when the main pathophysiology is exudate, congestion, and compressive atelectasis; with the progression of ARDS (1 week and above), the main pathophysiological factors are fibrosis and type II cell proliferation, in which the effectiveness of the prone position has been shown to be limited (19). von Wardenburg *et al.* (16) initiated PP of postoperative days (PODs) 3–4 and found that PP can reduce ventilation-induced lung injury in patients undergoing cardiac surgery in ARF. Saha *et al.* (15) included 24 patients with ARF after cardiac surgery and found that the median time to carry out PP was the fourth POD, with a total of 5 patients undergoing PP within the first 24 h after cardiac surgery. In our study, we included patients with ARDS after cardiac surgery within 72 h and found that PP was performed on a mean time of 38 h postoperatively, with a total of 21 patients undergoing PP within the first 24 hours after cardiac surgery, of which the earliest time was 1 h post-surgery. We found that the PP group had a significant improvement in P/F ratio after 1 session of PP treatment and had the shorter duration of MV and ICU stay compared with the SP group. According to an official American Thoracic Society Clinical Practice Guideline for intubated ARDS, PP for more than 12 h/day is valid (29). In our cohort, the median duration of PP was 15.0 h and no complications associated with PP were identified. Finally,

we summarized all PP patients and found that early prone ventilation can benefit patients with PEEP ≥5 cmH_2O, FiO_2 ≥40%, P/F ≤200 mmHg and for whom lung ultrasonography or chest-CT showed consolidation of both lower lungs.

Although Maillet *et al.* (12) found that PP caused facial edema, it regressed rapidly after assuming a SP, 5 patients developed pressure scores on the chin, cheekbone, or knee without persistent esthetic facial sequelae. PP after cardiac surgery implies presumed risk of sternal wound infection. Maillet *et al.* (12) included 16 patients undergoing cardiac surgery, 2 (12.5%) of whom developed superficial sternal wound infection. von Wardenburg *et al.* (16) recorded only 5 (3.9%) patients who developed sternal wound infection. In our population, we placed foam pads in all vulnerable areas and turned the patients over every 2 hours to avoid pressure ulcers. In order to avoid compression and poor healing of the chest wound, we fixed the ribcage with an elastic chest strap and placed a water pad under the compressed chest; there was only 1 (1.3%) patient who experienced poor wound healing in the PP group, suggesting that PP is not a real risk factor for sternal complications compared with rates reported in SP cardiac surgery patients (30). Further, no complications associated with prone ventilation were observed in the studies of von Wardenburg *et al.* (16), Zhang *et al.* (31), and Saha *et al.* (15) when PP was performed by experienced and highly trained staff, which were consistent with our findings that there were no pressure ulcers, unintended extubation, or urgent need for cardiopulmonary resuscitation during PP, even in patients placed with IABP. Our study found that 3 cases of mediastinal infection occurred in PP group, compared with only 1 case in the SP group, although there was no statistically significant difference in our conclusions; the sample size was small and a larger sample size will be needed to validate this issue.

This study also has several limitations: (I) this was a retrospective, single-center design with a low power of statistical analyses. (II) The number of patients included in the IABP subgroup analysis was too small to be directly conclusive. (III) Hemodynamic parameters or cardiac function or echocardiography were not investigated daily. (IV) We did not further investigate the difference in length of hospital stay, mortality, and long-term physical and psychological morbidity between patients with ARDS in the PP and SP groups. This study has several strengths: (I) this is currently the study with the largest number of patients who underwent PP for ARDS after cardiac surgery currently, and the results are more reliable than those of others conducted previously. (II) Currently, there are unclear conclusions such as ICU stay and duration of MV between PP and SP after cardiac surgery. This study is the first to clearly conclude that ICU stay and duration of MV between PP and SP after cardiac surgery. (III) This study has important guiding significance for future practice that patients with ARDS after cardiac surgery or even placed with IABP can also be ventilated in the prone position at an early stage.

Conclusions

Early PP treatment is effective and safe for patients with moderate to severe ARDS after cardiac surgery and it is even safe in a subgroup placed with IABP. Considering this as a retrospective cohort study, a large multicenter RCT is needed to validate the findings.

Acknowledgments

Funding: This work was supported by National High-Level Hospital Clinical Research Funding (Nos. 2022-PUMCH-D-005 and 2022-PUMCH-B-115) and CAMS Innovation Fund for Medical Sciences (CIFMS) (No. 2023-I2M-CT-B-031).

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-323/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-323/dss

Peer Review File: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-323/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-323/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki

(as revised in 2013). Informed consent was not applicable for the retrospective study and waived by the Institutional Research and Ethics Committee of Peking Union Medical College Hospital. This is a retrospective observation study, which exempted ethics after we consulted to the Ethics Committee of Peking Union Medical College Hospital.

References

1. Milot J, Perron J, Lacasse Y, et al. Incidence and predictors of ARDS after cardiac surgery. Chest 2001;119:884-8.
2. Gajic O, Dabbagh O, Park PK, et al. Early identification of patients at risk of acute lung injury: evaluation of lung injury prediction score in a multicenter cohort study. Am J Respir Crit Care Med 2011;183:462-70.
3. Huffmyer JL, Groves DS. Pulmonary complications of cardiopulmonary bypass. Best Pract Res Clin Anaesthesiol 2015;29:163-75.
4. Stephens RS, Shah AS, Whitman GJ. Lung injury and acute respiratory distress syndrome after cardiac surgery. Ann Thorac Surg 2013;95:1122-9.
5. Rubenfeld GD, Caldwell E, Peabody E, et al. Incidence and outcomes of acute lung injury. N Engl J Med 2005;353:1685-93.
6. Bienvenu OJ, Colantuoni E, Mendez-Tellez PA, et al. Depressive symptoms and impaired physical function after acute lung injury: a 2-year longitudinal study. Am J Respir Crit Care Med 2012;185:517-24.
7. Ajibowo AO, Kolawole OA, Sadia H, et al. A Comprehensive Review of the Management of Acute Respiratory Distress Syndrome. Cureus 2022;14:e30669.
8. Gattinoni L, Busana M, Giosa L, et al. Prone Positioning in Acute Respiratory Distress Syndrome. Semin Respir Crit Care Med 2019;40:94-100.
9. Gattinoni L, Tognoni G, Pesenti A, et al. Effect of prone positioning on the survival of patients with acute respiratory failure. N Engl J Med 2001;345:568-73.
10. Munshi L, Del Sorbo L, Adhikari NKJ, et al. Prone Position for Acute Respiratory Distress Syndrome. A Systematic Review and Meta-Analysis. Ann Am Thorac Soc 2017;14:S280-8.
11. Guérin C, Reignier J, Richard JC, et al. Prone positioning in severe acute respiratory distress syndrome. N Engl J Med 2013;368:2159-68.
12. Maillet JM, Thierry S, Brodaty D. Prone positioning and acute respiratory distress syndrome after cardiac surgery: a feasibility study. J Cardiothorac Vasc Anesth 2008;22:414-7.
13. Eremenko AA, Egorov VM, Levikov DI. Results of the treatment of cardiac surgery patients with postoperative acute respiratory distress syndrome by prone-position pulmonary ventilation. Anesteziol Reanimatol 2000;(5):42-5.
14. Brüssel T, Hachenberg T, Roos N, et al. Mechanical ventilation in the prone position for acute respiratory failure after cardiac surgery. J Cardiothorac Vasc Anesth 1993;7:541-6.
15. Saha S, Jebran AF, Leistner M, et al. Turning Things Around: The Role of Prone Positioning in the Management of Acute Respiratory Failure After Cardiac Surgery. J Cardiothorac Vasc Anesth 2020;34:1434-8.
16. von Wardenburg C, Wenzl M, Dell'Aquila AM, et al. Prone Positioning in Cardiac Surgery: For Many, But Not for Everyone. Semin Thorac Cardiovasc Surg 2016;28:281-7.
17. Santarpino G, Bonifazi R, Albanese M, et al. Prone Positioning in Postoperative Cardiac Surgery Patients: A Narrative Review. J Cardiothorac Vasc Anesth 2022;36:2636-42.
18. ; Ranieri VM, Rubenfeld GD, et al. Acute respiratory distress syndrome: the Berlin Definition. JAMA 2012;307:2526-33.
19. Kallet RH. A Comprehensive Review of Prone Position in ARDS. Respir Care 2015;60:1660-87.
20. Kogan A, Preisman S, Levin S, et al. Adult respiratory distress syndrome following cardiac surgery. J Card Surg 2014;29:41-6.
21. Brower RG, Morris A, MacIntyre N, et al. Effects of recruitment maneuvers in patients with acute lung injury and acute respiratory distress syndrome ventilated with high positive end-expiratory pressure. Crit Care Med 2003;31:2592-7.
22. Fan E, Checkley W, Stewart TE, et al. Complications from recruitment maneuvers in patients with acute lung injury: secondary analysis from the lung open ventilation study. Respir Care 2012;57:1842-9.

23. Sigurdsson MI, Sigvaldason K, Gunnarsson TS, et al. Acute respiratory distress syndrome: nationwide changes in incidence, treatment and mortality over 23 years. Acta Anaesthesiol Scand 2013;57:37-45.
24. Matthay MA, Zemans RL. The acute respiratory distress syndrome: pathogenesis and treatment. Annu Rev Pathol 2011;6:147-63.
25. Jozwiak M, Teboul JL, Anguel N, et al. Beneficial hemodynamic effects of prone positioning in patients with acute respiratory distress syndrome. Am J Respir Crit Care Med 2013;188:1428-33.
26. Girdauskas E, Kuntze T, Borger MA, et al. Acute respiratory dysfunction after surgery for acute type A aortic dissection. Eur J Cardiothorac Surg 2010;37:691-6.
27. Vieillard-Baron A, Charron C, Caille V, et al. Prone positioning unloads the right ventricle in severe ARDS. Chest 2007;132:1440-6.
28. Bianchi AM, Reboredo MM, Lucinda LM, et al. The Effects of Prone Position Ventilation on Experimental Mild Acute Lung Injury Induced by Intraperitoneal Lipopolysaccharide Injection in Rats. Lung 2016;194:193-9.
29. Fan E, Del Sorbo L, Goligher EC, et al. An Official American Thoracic Society/European Society of Intensive Care Medicine/Society of Critical Care Medicine Clinical Practice Guideline: Mechanical Ventilation in Adult Patients with Acute Respiratory Distress Syndrome. Am J Respir Crit Care Med 2017;195:1253-63. Erratum in: Am J Respir Crit Care Med 2017;195:1540.
30. Lemaignen A, Birgand G, Ghodhbane W, et al. Sternal wound infection after cardiac surgery: incidence and risk factors according to clinical presentation. Clin Microbiol Infect 2015;21:674.e11-8.
31. Zhang Y, Zhou W, Ma J. The effects of prone position ventilation on patients with acute respiratory distress syndrome after cardiac surgery. Perfusion 2024. [Epub ahead of print]. doi: 10.1177/02676591241228972.

(English Language Editor: J. Jones)

Cite this article as: Su L, Zhang J, Zhao H, Li Z, Luo H, Liu J, Miao Q, Deng H, Cui N, He H, Chai W, Long Y. Efficacy and safety of early prone position in postoperative cardiac surgery adults with acute respiratory distress syndrome: a single-center retrospective cohort study. J Thorac Dis 2024;16(8):4967-4976. doi: 10.21037/jtd-24-323