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A Comparative Analysis of Changes to Intraocular Pressure of ARDS Patients Induced by Prone Position Ventilation

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Abstract

Objective: To investigate the changes of intraocular pressure who is treated with prone position ventilation in ARDS.

Method: 10 patients with ARDS treated in the ICU of the First People's Hospital of Yunnan Province from January 2021 to March 2022 were included, and they were classified as two groups according to whether prone position ventilation was performed daily or not. In the prone position group, the intraocular pressure will be was measure before and after the prone position. Two groups were measured regularly every day.

Result: The overall intraocular pressure level in the prone position group was higher than that in the supine position group. When the patients in the prone position group changed position, the immediate intraocular pressure in prone position was higher than that in supine position, and the increase in intraocular pressure was more pronounced with increasing time in the prone position.

Conclusion: The intraocular pressure changes in the patients who is treated with prone position ventilation in ARDS have exceeded normal physiological criteria, and we should be aware that this group of patients may be at increased risk of developing glaucoma.

Keywords: Acute Respiratory Distress Syndrome (ARDS); Prone position ventilation; Intraocular pressure; Glaucoma

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Introduction

Acute Respiratory Distress Syndrome (ARDS) is a respiratory system disease commonly seen in clinical practice with an acute diffuse pulmonary inflammatory reaction, which features the clinical characteristic of refractory hypoxemia, and in most cases, there are pathological changes such as diffuse alveolar damage, alveolar collapse and reduced pulmonary compliance [1]. According to the statistics by previous scholars, the ARDS patients accounted for 10% of the total patients in ICUs and 24% of mechanical ventilation patients; furthermore, ARDS serious threatens the life and living quality of patients, since the death rate of severe ARDS patients was as high as 40% to 50% [2]. Due to poor prognosis of ARDS, its treatment is forever a topic in ICUs [3]. In recent years, with deepened pathological and physiological knowledge about ARDS and improved clinical respiratory support technologies, mechanical ventilation has become a key measure in treatment of ARDS patients [4]. Among various means of treatment, prone position ventilation is applied in treatment of moderate and severe ARDS more and more widely ever since it was proposed in 1976, because it is able to improve the oxygenation and recruitment maneuver of ARDS patients [5].

However, we all know that the prone position has an effect on intraocular pressure. A large number of studies have shown that the intraocular pressure of a person in lying position is higher than that in the sitting position, and the intraocular pressure will increase rapidly and significantly when the head is at a lower position than the body [6]. Prolonged high IOP or large fluctuations in intraocular pressure due to improper posture is one of the major risk factors for the development and progression of glaucoma disease. Glaucoma is a group of blinding diseases characterized by characteristic optic nerve atrophy and visual field defects [7]. Pathologically increased intraocular pressure is the main risk factor, and the level of elevated intraocular pressure and the tolerance of the optic nerve to pressure damage are related to the occurrence and development of glaucomatous optic nerve atrophy and visual field defects [7]. Therefore, for patients who need to be in prone position for a long duration, in addition to paying attention to the overall prognosis, the change of intraocular pressure should be of concern to clinicians. In this study, the intraocular pressure of ARDS patients in our ICUs during January 2021 to March 2022 was measured for discussion and analysis.

Materials and Method

General materials

The prospective study and analysis were performed on 10 male ARDS patients in the ICU of the First People's Hospital of Yunnan Province for the period from January to March 2022 based on the clinical materials. The patients were aged between 52 to 74 (62.5 ± 8.04 on average). The prone position group consists of 5 patients who were subjected to prone position ventilation for >10 h/day; the supine position group consists of 5 patients without adoption of prone position ventilation. All patients have no eye diseases history. And this study was approved by the Ethics Committee of the First People's Hospital of Yunnan Province (Ethics Number: KHLL2022-KY057).

The criteria of inclusion and exclusion

The criteria of inclusion: Patients in this study met the diagnosis criteria for acute respiratory distress syndrome under the Guide to Diagnosis and Treatment of Acute Pulmonary Injury/Acute Respiratory Distress Syndrome [8].

The criteria of exclusion: All patients with relative contraindications for prone position ventilation such as ventricular arrhythmias and severe hypotension.

Method

Description of body position: (1) Supine position: The patient is face up with their head resting on a 13 cm thick soft pillow, with whose arms in neutral position on two sides and legs stretch flatly. The patients in the prone position group were in supine position for 12 h to 14 h, while those in the supine position group were in supine position for the whole day. (2) Prone position: The patient is positioned face-down with whose arms in a neutral position on two sides and legs stretch flatly. A soft pillow is placed under the chest and hip respectively and a 13-cm thick ring pad is placed under the face. The patients in prone position group changed from supine position to prone position once and then from prone position to supine position once every day, with a 10-h time in prone position, while the patients in supine position were not adopt a prone position.

Measure method: The intraocular pressure of two eyes was measured independently by an ophthalmologist using icare hand-held portable rebound tonometer (Model: TA011). For the prone position group, the intraocular pressure before adoption prone position, the instant intraocular pressure when changing from supine position to prone position, the intraocular pressure before adoption of supine position, and the instant intraocular pressure when changing form prone position to supine position were measured. For supine position group, the intraocular pressure was measured once to twice/day at 9:00 and 17:00. Each intraocular pressure measurement was taken three times and the average was taken.

Statistical method

The statistical software R (Version 4.1.1; R Core Team, 2021) was used for statistical description and deduction. The quantitative data was expressed with mean and standard deviation, while qualitative data was expressed with frequencies and percentage. The comparison of intraocular pressure between patients in prone position group and supine position group was subject to *t* test using independent samples. For the same patient, the comparison of intraocular pressure when changing between prone position and supine position, the comparison of intraocular pressure between the start and end of prone position, and the intraocular pressure in the left eye and the right eye at the same time were subject to t test using matched pair design. When α=0.05 and P<0.05, it was considered that there was statistically significant difference.

Result

Comparison of overall intraocular pressure between the two groups

The right intraocular pressure of patients in prone position group was 18.31 ± 5.60 mmHg which was higher than 14.43 ± 2.83 mmHg in the supine position group, suggesting statistically significant difference with t=4.345 and P<0.001. The left intraocular pressure of patients in prone position group was 18.22 ± 5.81 mmHg which was higher than 14.24 ± 2.78 mmHg in the supine position group, suggesting statistically significant difference with t=4.353 and P<0.001. And in each group, no statistically significant differences were found between the left intraocular pressure and the right intraocular pressure, as shown in Table 1.

The comparison of intraocular pressure when there was change of body position in prone position group (from prone position to supine position)

The right intraocular pressure of patients in prone position was 20.92 ± 3.53 mmHg which was higher than 16.00 ± 4.39 mmHg in supine position, suggesting statistically significant difference with t=3.024 and P=0.006. The left intraocular pressure of patients in prone position was 21.33 ± 2.10 mmHg which was higher than 15.58 ± 5.18 mmHg in the supine position, suggesting statistically significant difference with t=3.564 and P=0.002. And there was no statistically significant difference between the left intraocular pressure and the right intraocular pressure before and after the postural change, as

Table 1: The comparison of overall intraocular pressure between the prone position group and supine position group.

Intraocular Pressure	Prone position group (N=54)	Supine position group (N=37)	t	P value
Right Eye	18.31 ± 5.60	14.43 ± 2.83	4.345	<0.001
Left Eye	18.22 ± 5.81	14.24 ± 2.78	4.353	<0.001
t	0.379	0.672		
P value	0.706	0.506		

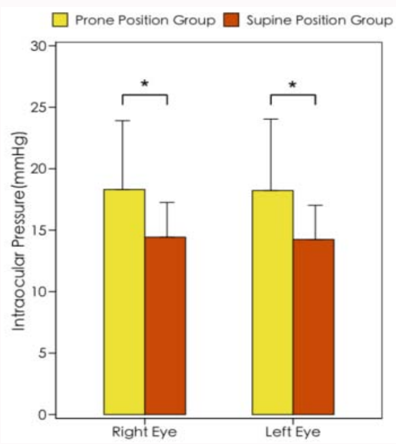

Figure 1: The comparison of overall intraocular pressure between the prone position group and supine position group.

Table 2: The comparison of intraocular pressure when there was change of body position in prone position group (from prone position to supine position).

Intraocular Pressure	Prone position (N=12)	Supine position (N=12)	t	P Value
Right Eye	20.92 ± 3.53	16.00 ± 4.39	3.024	0.006
Left Eye	21.33 ± 2.10	15.58 ± 5.18	3.564	0.002
t	0.553	0.834		
P Value	0.591	0.421		

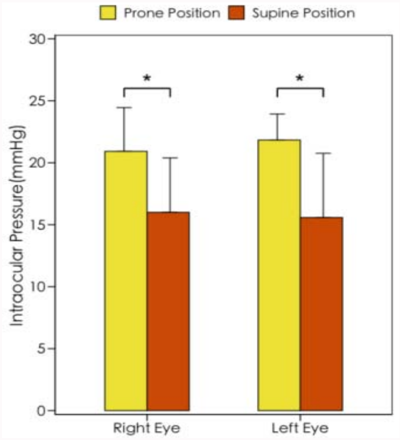

Figure 2: The comparison of intraocular pressure when there was change of body position in prone position group (from prone position to supine position).

Table 3: The comparison of intraocular pressure when there was change of body position in prone position group (from supine position to prone position).

Intraocular Pressure	Supine position (N=9)	Prone position (N=8)	t	P Value
Right Eye	16.00 ± 3.50	21.38 ± 2.45	3.622	0.003
Left Eye	15.78 ± 5.17	21.75 ± 2.43	2.981	0.009
t	0.316	0.893		
P Value	0.76	0.402		

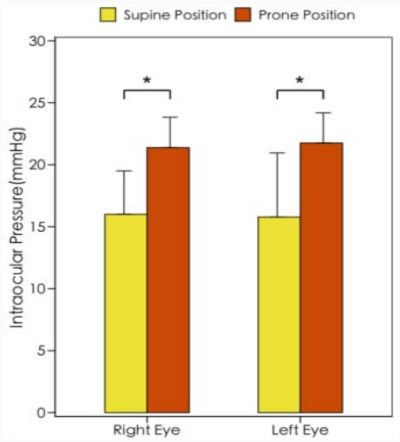

Figure 3: The comparison of intraocular pressure when there was change of body position in prone position group (from supine position to prone position).

shown in Table 2 and Figure 2.

The comparison of intraocular pressure when there was change of body position in prone position group (from supine position to prone position)

The right intraocular pressure of patients in supine position was 16.00 ± 3.50 mmHg which was lower than 21.38 ± 2.45 mmHg in prone position, suggesting statistically significant difference with t=3.622 and P=0.003. The left intraocular pressure of patients in supine position was 15.78 ± 5.17 mmHg which was lower than 21.75 ± 2.43 mmHg in the prone position, suggesting statistically significant difference with t=2.981 and P=0.009. And there was also no statistically significant difference between the left and right eye

Table 4: The comparison of intraocular pressure between the start and end of prone position.

Intraocular Pressure	Start of prone position (N=10)	End of prone position (N=10)	t	P Value
Right Eye	19.90 ± 2.85	25.00 ± 3.89	3.348	0.004
Left Eye	20.80 ± 1.62	24.60 ± 4.20	2.672	0.016
t	1.304	0.937		
P Value	0.225	0.373		

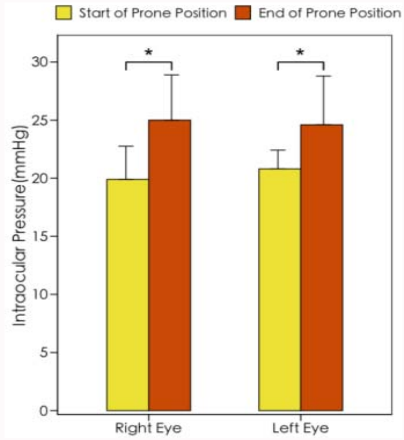

Figure 4: The comparison of intraocular pressure between the start and end of prone position.

Table 5: The comparison of intraocular pressure at the end of supine position and at the end of prone position.

Intraocular Pressure	End of supine position (N=13)	End of prone position (N=12)	t	P Value
Right Eye	14.23 ± 2.31	25.17 ± 3.56	9.173	<0.001
Left Eye	14.15 ± 2.85	24.50 ± 3.90	7.618	<0.001
t	0.221	1.232		
P Value	0.809	0.244		

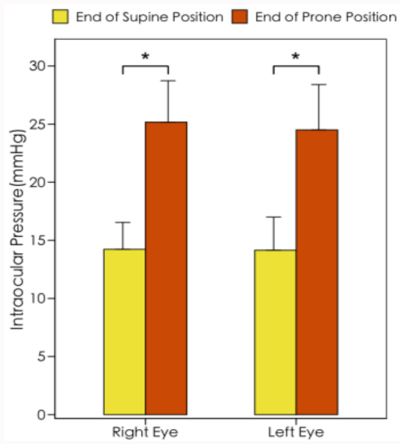

Figure 5: The comparison of intraocular pressure at the end of supine position and at the end of prone position.

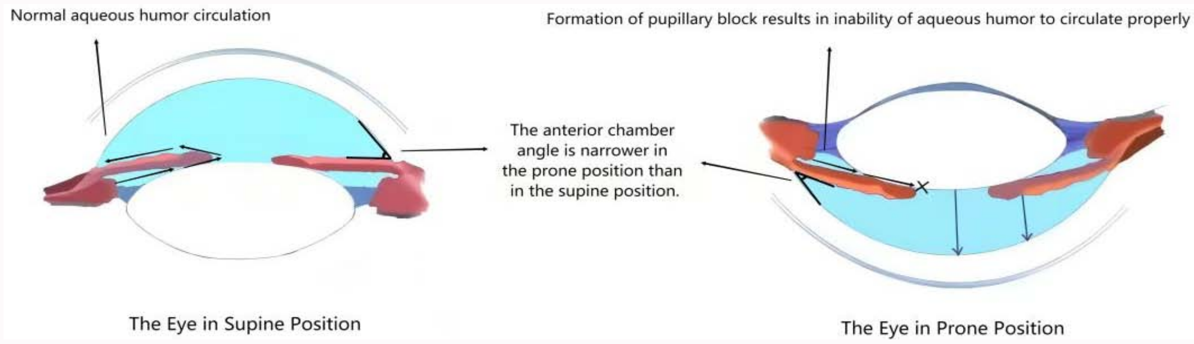

Figure 6: The eye conditions in supine position and prone position.

pressures, as shown in Table 3 and Figure 3.

The comparison of intraocular pressure between the start and end of prone position

The right intraocular pressure of patients at the start of prone position was 19.90 ± 2.85 mmHg which was lower than 25.00 ± 3.89 mmHg at the end of prone position, suggesting statistically significant difference with t=3.348 and P=0.004. The left intraocular pressure of patients at the start of prone position was 20.80 ± 1.62mmHg which was lower than 24.60 ± 4.20 mmHg at the end of prone position, suggesting statistically significant difference with t=2.672 and P=0.016. And the difference in intraocular pressure between the left eye and the right eye was not statistically significant, as shown in Table 4 and Figure 4.

The comparison of intraocular pressure at the end of supine position and at the end of prone position

The right intraocular pressure of patients at the end of supine position was 14.23 ± 2.31 mmHg which was lower than 25.17 ± 3.56 mmHg at the end of prone position, suggesting statistically significant difference with t=9.173 and P<0.001. The left intraocular pressure of patients at the end of supine position was 14.15 ± 2.85 mmHg which was lower than 24.50 ± 3.90 mmHg at the end of prone position, suggesting statistically significant difference with t=7.618 and P<0.001. Also, there was no statistical difference between the both eyes intraocular pressures, as shown in Table 5 and Figure 5.

Discussion

In recent, the use of prone position ventilation is becoming more widespread as an important measure in the treatment of ARDS. Upon meta-analysis of 8 randomized controlled trials over 12 years, Munshi et al. [9] found that prolonged prone position ventilation (at least 12 h, or even longer than 16 h) reduced death rate of patients with moderate to severe ARDS (oxygenation index <200 mmHg) and that prone position ventilation was safe and feasible. However, during their treatment, changes in intraocular pressure due to prone position and even the resulting development and progression of glaucoma disease should be of concern to the majority of intensivists and ophthalmologists.

Glaucoma is a group of eye diseases characterized by irreversible optic nerve damage and visual field defects that can lead to permanent impairment of visual function and even blindness in patients [7]. Studies have found that optic nerve damage caused by glaucoma is mainly because of mechanical compression and ocular blood supply disorder induced by pathological increased intraocular pressure [10]. In the long-term high intraocular pressure or large fluctuations in intraocular pressure, patients may have different degrees of eye distension, vision loss, headache on one side, and even nausea and vomiting, and in the advanced stage, patients may have irreversible visual field narrowing in the affected eye, tubular vision, night blindness, which will seriously affect patients' lives [11]. Intraocular pressure refers to the tissue pressure against the wall of the eyeball, and under normal physiological conditions, the intraocular pressure of most people is maintained at 10 mmHg to 21 mmHg, with a difference between left and right eyeballs that is not greater than 5 mmHg and a fluctuation between day time and night time that is not greater than 8 mmHg [12]. The stability of intraocular pressure is mainly dependent on the dynamic homeostasis between production and drainage of aqueous humor, and both increased production or obstruction of aqueous humor can cause increased intraocular pressure.

In the above test results, it can be seen that there is a statistical difference between the intraocular pressure measured in the prone groups and supine groups. In the study of intraocular pressure during position change in the prone group, patients in the prone group had lower intraocular pressure when changing from prone to supine position and higher intraocular pressure when changing from supine to prone position. Also, during the period when the patients were in the prone position, the intraocular pressure increased further with the prolongation of the prone position. And the range of intraocular pressure changes caused by patients in prolonged prone position exceeds the physiological data in the 2017 Glaucoma Diagnosis and Consensus [12].

According to current studies, the main factors of changes of intraocular pressure caused by postural changes may include advancement of iridolenticular diaphragm, venous pressure of episclera, blood pressure, ocular perfusion pressure and hormones [13]. The patients in this testing process were all severe ARDS patients in our ICU. In treatment, the blood pressure and hormones were controlled stably. The venous pressure of episcleral, however, is mainly dependent on the relative position between eyes and heart [14]. In this experiment, due to the illness of patients, all patients in the two groups were always in lying position, the relative position between eyes and heart at supine position and prone position was virtually the same? Therefore, there was no clinical difference in terms of venous pressure of episcleral. So, we considered that the difference of intraocular pressure between the two groups and the change of intraocular pressure within the same group after change of body position were mainly caused by obstruction of aqueous humor due to anterior displacement of the crystalline iris septum in the prone position. When a patient is at prone position, there is anterior displacement of crystalline lens because of gravity which causes anterior displacement of the crystalline iris septum and reduced the depth of anterior chamber. As a result, the anterior chamber angle is narrowed and the lens is widely and tightly connected to the iris forming a pupillary block caused obstruction of aqueous humor, resulting in increased intraocular pressure, as shown in Figure 6.

There was also similar report of this idea in the study by Anderson et al. [15], who also found higher intraocular pressure and shallower the anterior chamber depth in the prone position compared to the supine position, the same results as our test, and they found no significant change in the anterior chamber depth between the supine and prone position. Prior to this, Lam et al. [16] considered that the prone position did not last long enough (4 min) to cause changes in the anterior chamber depth. But in our study, some patients with ARDS have to be ventilated in prone position ventilation for a long time due to the necessity of their treatment, it means they had to suffer high intraocular pressure for a long term but cannot avoid the significant fluctuation of intraocular pressure caused by change of body position. Although the body maintains hemodynamic stability after a change in body position through a series of regulatory mechanisms, including self-regulation and venous and arterial systems, and neurological reflexes, which regulate intraocular pressure to some extent [17]. However, prolonged exposure to such pathologically high intraocular pressure and frequent large fluctuations in intraocular pressure may cause damage to the optic nerve cells, affecting visual acuity and visual function and causing irreversible glaucoma damage. And in the treatment of ARDS patients, besides paying attention to the systemic prognosis, their long-term complications and quality of life are also something we cannot ignore. Therefore, for ARDS patients who have to receive prone position ventilation and patients with high risk of glaucoma, early predication and diagnosis of eye diseases should be performed before serious visual impairment is caused, so as to give corresponding treatment [18].

In summary, throughout the testing process, some ARDS patients have had their intraocular pressure altered beyond normal physiological standards due to the need to maintain a special body position for long periods of time. Since the increased intraocular pressure and its significant fluctuation caused by unfavorable body positions cannot be avoided, it's a major problem to be addressed in guaranteeing effective treatment to patients while reducing or avoiding increased intraocular pressure and the irreversible impairment to optic nerves and visual field. At last, we hope that this study will provide some reference for clinicians to alert relevant departments that need to perform prone ventilation on patients, so that more physicians will be aware of the changes in intraocular pressure and the increased risk of glaucoma in these patients.

Author Contributions

BL and ZC planned and designed the study. SJ, YW, ZL, and DZ contributed to data collection, data analysis, and data interpretation. BL played a leading role in writing the manuscript. ZC revised the manuscript. All authors read and approved the final manuscript.

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