European Review for Medical and Pharmacological Sciences 2023; 27: 5105-5118

Therapeutic effect of micropump intravenous infusion of ambroxol hydrochloride on respiratory distress syndrome in premature infants

J.-S. XU[1], B.-H. LI[2], Y.-Q. XU[3], J. LI[1], Y. LIN[4]

[1]Neonatology Department, Nanjing Jiangbei Hospital, NanJing, China
[2]Radiology Department, Taikang Xianlin Drum Tower Hospital, NanJing, China
[3]Jiangning Hospital affiliated to Nanjing Medical University, NanJing, China
[4]Neonatology Department, Zhongda Jiangbei Hospital Southeast University, NanJing, China

Jinsheng Xu, Baohong Li, Yaqin Xu, and Jun Li have contributed equally as co-first authors

Abstract. – OBJECTIVE: This work aimed to explore the therapeutic effect of micropump intravenous infusion of ambroxol hydrochloride (AH) on respiratory distress syndrome (RDS) in premature infants.

PATIENTS AND METHODS: 56 premature infants from 28 to 34 weeks were recruited for analysis in this work. According to the treatment methods, they were randomly divided into two groups, with 28 patients in each group. Patients in the experimental group were given intravenous AH by micropump, while those in the control group inhaled atomized AH. The therapeutic effects were evaluated by comparing the data after treatment.

RESULTS: The results showed that the serum 8-iso-PGP2α level in the experimental group was 166.32 ± 49.52, which was substantially inferior to that in the control group (183.32 ± 52.54), $p < 0.05$. In the experimental group, PaO_2, SaO_2, and PaO_2/FiO_2 were 95.88 ± 12.82 mmHg, 95.86 ± 2.27%, and 346.81 ± 51.93 mmHg, respectively, after 7 days of treatment. Compared with the control group (88.21 ± 12.82 mmHg, 93.18 ± 3.13%, and 266.83 ± 48.09 mmHg), the difference was statistically significant, $p < 0.05$. The oxygen duration, respiratory distress relief time, and length of stay were 95.12 ± 12.53 h, 4.4 ± 0.6 d, and 19.84 ± 2.8 d, respectively, in the experimental group, while they were 145.92 ± 13.85 h, 6.9 ± 0.9 d, and 28.42 ± 3.7 d, respectively, in the control group, showing great differences ($p < 0.05$).

CONCLUSIONS: Micropump infusion of AH in the treatment of premature RDS patients was more conducive to efficacy. It can alleviate the clinical symptoms of children with RDS, improve their blood gas indicators, relieve and repair the damage to alveolar epithelial cell lipids in children with RDS, and ultimately improve the therapeutic effect, which can be used for the clinical treatment of premature RDS.

Key Words:
Preminfants, Respiratory distress syndrome, Infusion of ambroxol hydrochloride, Micropump iature ntravenous.

Introduction

Neonatal respiratory distress syndrome (RDS), also known as neonatal hyaline membrane disease (HMD), occurs because the lungs of premature infants are not fully developed and lack sufficient pulmonary surfactant (PS), resulting in pulmonary fluid circulation disorder, alveolar atrophy, pulmonary capillary-alveolar high permeability and exosmotic lesions[1]. Most premature infants will suffer from RDS when their organs are not fully developed, which is also one of the factors contributing to the high mortality of premature infants[2]. The most important pathophysiological changes in RDS are PS deficiency, atelectasis, decreased alveolar ventilation/blood flow ratio, and abnormal ventilation function[3]. PS appeared at 18 to 20 weeks of gestational age and reached lung maturity at 35 to 36 weeks of gestational age.

Patients with RDS lack PS, which will lead to reduced lung compliance and alveolar atrophy, resulting in progressive atelectasis[4]. The clinical manifestations of the children were early postnatal onset, with progressive dyspnea aggravation within 4-6 hours after birth, including groans, nasal fans, three depressions, and shortness of breath. Of these, the earliest is exhalatory moaning, and frequent respiratory arrest is the symptom of aggravation. Laboratory tests such as the foam test, suction failure, and chest X-ray can confirm the diagnosis[5].

Corresponding Author: Jun Li, MD; e-mail: junl1977@126.com

At present, many studies[6,7] have shown that the prevention and treatment of RDS by exogenous PS can substantially reduce the morbidity and mortality of children. To date, it has become a consensus that pulmonary surfactant can be used for the clinical treatment of RDS[8]. In addition to the clinical confirmation of the therapeutic effect of PS, abundant data[9] have indicated that oxidation and peroxide have important effects on the emergence and further changes of RDS, and antioxidant treatment and reduction of oxidation can improve the process and prognosis of RDS. Studies[10] have revealed that RDS patients have reduced blood resistance to reactive oxygen species. Excessive oxygen free radicals react with unsaturated fatty acids to form lipid peroxides, resulting in cell damage, apoptosis, DNA damage, protein damage, etc. Studies[11] have also found that the concentration of oxygen free radicals (xanthine and hypoxanthine) in the plasma of RDS patients is much higher than that of normal controls. Therefore, enhancing antioxidant defense may be a treatment for RDS. In neonatal medicine, studies[12] have shown that lipid peroxidation in the blood of premature infants and neonates with hypoxic ischemic encephalopathy (HIE) has achieved good effects by treating RDS and HIE with the antioxidant preparation ambroxol hydrochloride (AH).

AH, as a mucolytic agent, has a half-life of approximately 4-5 h and a stable blood concentration of approximately 24 h after medication[13]. Small-dose AH is utilized in the treatment of chronic obstructive pulmonary disease (COPD) and prevention and treatment of postoperative complications of the lung, with ideal application performance[14]. AH can promote the development of alveolar type II epithelial cells, thereby increasing PS content and reducing the occurrence and mortality of RDS in premature infants[15]. The mechanism of AH may be as follows[16-18]: i. improving the activity of phospholipthalincholine cytoplastase, promoting the synthesis and secretion of PS in alveoli; ii. part of PS can be catabolized by macrophages, and the specificity of AH can hinder the activity of phospholipase A in macrophages; iii. promoting the production of phosphophthalide in PS, reducing the time of mechanical ventilation, and reducing the incidence of RDS complications; iv. it can reduce the prevalence of sepsis and can resist oxidation and inflammation. In recent years, many studies[19,20] have suggested that the application of AH in large doses has a good antioxidant effect, which can remove oxygen free radicals, inhibit the secretion of peroxide, increase antioxidant capacity, protect the enzymatic scavenging function of oxygen free radicals, and help patients recover respiratory function. Clinical studies[21] have found that a large dose of AH can enhance serum SOD activity and improve the blood gas index and lung injury score. Moreover, with the progress of treatment, the activity of SOD in blood increased gradually, suggesting that the application of AH can substantially improve the activity of SOD in the serum of ARDS patients, but it may need a certain course of treatment[22].

In the field of medicine, microdrug injection and delivery need to accurately control the release rate of drugs to achieve microinfusion and continuous infusion of reagents[23]. Microfluidic systems have the advantages of small relative volume, low system energy consumption, and fast response speed, and they have been widely used and have good application prospects[24]. At present, many nonmechanical micropumps are utilized in the driving components of microflow systems. However, since magnetic and electric fields directly act on the fluid, they can only pump the solution of specified components, and their biocompatibility is poor. The micro pump has the advantages of a simple structure, small size, large driving force, and no electromagnetic interference and is widely used in the driving components of micro flow systems. The flow sensor is connected with the electro-hydraulic pump in series, and the closed-loop control system of the electro-hydraulic pump is established, which can improve the control accuracy, expand the application range, and actively participate in the precise control of the output reagent of the electro-hydraulic pump.

In this work, 56 premature infants at 28 to 34 weeks were selected as the research objects. Intravenous infusion of AH with micro pump was used to treat premature infants with RDS, and the therapeutic effects of intravenous infusion of AH with micro pump and aerosol inhalation of AH were analyzed and compared. The therapeutic effect was evaluated by comparing the data after treatment, providing a valuable reference for its clinical application.

Patients and Methods

Research Objects

The retrospective analysis study subjects were 56 premature infants at 28-34 weeks who were

hospitalized in the neonatology Department of Nanjing Jiangbei Hospital from January to July 2021. According to the treatment methods, they were randomly rolled into two groups, with 28 cases in each group. For the experimental group, AH was intravenously injected with a micropump. For the control group, aerosol inhalation AH was adopted.

Inclusion criteria: the patient was singleton pregnancy; 28 weeks < gestational age < 34 weeks; the patient had typical clinical manifestations and was confirmed by chest X-ray examination, and the oxygen concentration during mechanical ventilation was < 60%; the patient had no serious complications. The exclusion criteria were as follows: intrauterine infection, septicemia, congenital malformation, and other serious diseases during pregnancy and a history of alcoholism and smoking.

The parents of the patients included in the work signed informed consent forms, and the process was approved by the Ethics Committee of Nanjing Jiangbei Hospital (Approval Number: 2022011).

Principle of Static Injection of the Micropump

Too much or too little intravenous infusion makes it difficult to achieve the desired goal and even threatens the life of patients. At present, infusion pumps are usually used in clinical transfusion, which can accurately control infusion speed so that drugs can be accurately, uniformly, and safely input into the patient's body and improve the accuracy and safety of infusion. The infusion pump is usually composed of a mechanical system and a microelectronic system, which can control the infusion speed by squeezing the infusion tube[26]. Using SN-2000 V (Shenzhen, China) can communicate with the infusion pump through the RS232 interface to control the infusion pump and read the infusion data. The communication process with the sensor is shown in Figure 1.

The control software is the core of the system. The upper computer software employed in this work is developed and run on the Windows system using C++, which makes full use of the intuitive and friendly interface characteristics of Windows. The upper computer used is to transform the flow sensor and driving power supply according to the parameters set by the user (such as sensor sampling frequency and other information), while receiving the data from the sensor, and using the PID (proportional integral derivative) algorithm in the upper computer to control the work of the voltage pump according to the feedback data. The functions realized by the upper computer are shown in Figure 2.

PID-Based Control Algorithm

The PID control system block diagram is shown in Figure 3. The system is composed of a PID controller and a controlled object.

PID control is a linear control, which constitutes control deviation error(k) according to the given rin(k) and the actual detection value yout(k), as shown in Equation (1).

$$error(k)=rin(t)-yout(k) \tag{1}$$

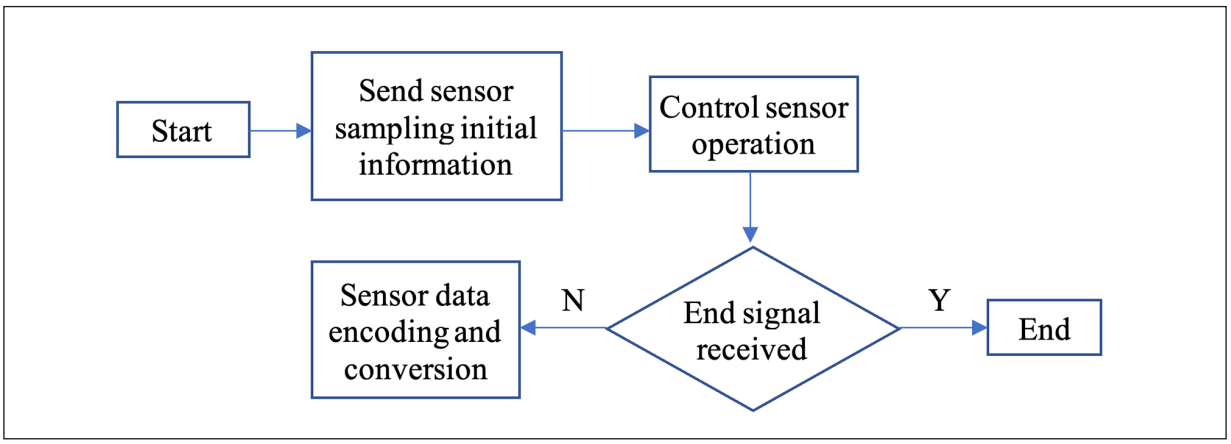

Figure 1. Flow sensor and upper computer communication flow.

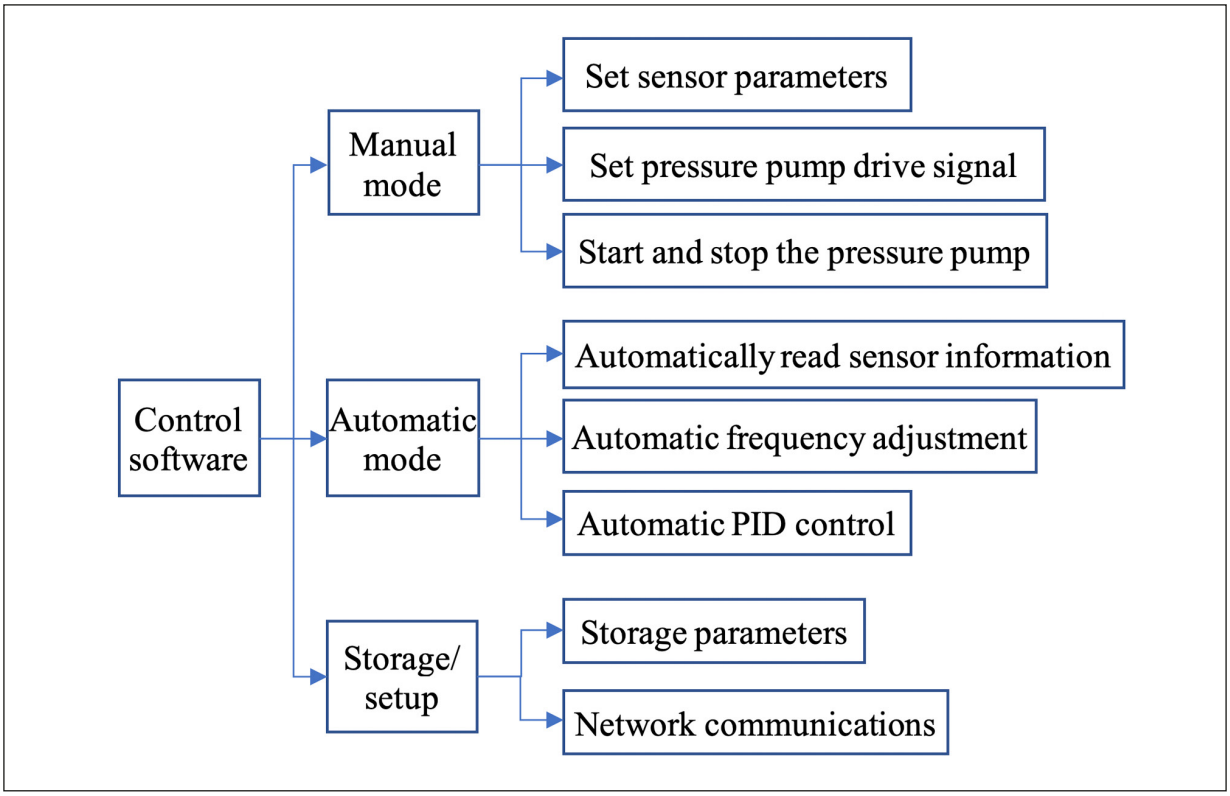

Figure 2. Function diagram of the upper machine position.

The deviation error(k) is linearly combined into the control quantity u(k) of the system through proportion, several rings, and differentiation, as expressed in Equation (2).

$$u(k) = D_q\left(error(k) + \frac{\int_0^k error(t)dt + \frac{S_I derrer(t)}{dt}}{S_i}\right) \quad (2)$$

Alternatively, it can be expressed as a transfer function as follows:

$$G(j) = \frac{U(j)}{E(j)} = D_q + D_q\left(\frac{1}{S_i j} + S_I j\right) \quad (3)$$

D_q represents the scaling coefficient, S_i is the integral time constant, and S_I is the differential time constant.

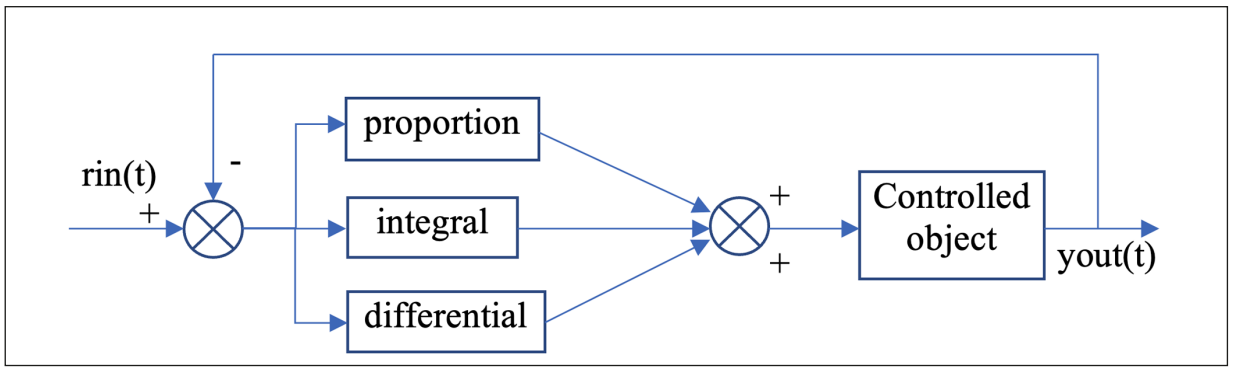

Figure 3. PID control system.

PID control of each calibration link has the following functions:

1. Proportional link: the error signal error(k) of the control system is reflected proportionally. When the error signal appears, the control system runs immediately, thus reducing the system deviation.
2. Integration: this eliminates static differences. The smaller the integral time constant S_i, the stronger the integral effect, and the weaker the integral effect.
3. Differential link reflects the signal change, and before the signal change is too large, the correction signal is introduced to speed up the system operation and shorten the system adjustment time.

A reasonable sampling period for a rotary digital control system is imperative but will be affected by many aspects. If the selected sampling frequency $\varphi = 2\pi/s$ is greater than twice the maximum frequency ω_{max}, the sampled signal can reproduce the original continuous signal. In practice, $S \leq 2\pi/(30\varphi_o)$ can be obtained when the sampling frequency is set to more than 30 times the response of the control system, where φ_o is the cutoff rate of the open-loop frequency characteristic of the system.

Increasing the proportional coefficient D_q can speed up the operation of the system, but if D_q is too large, the number of system oscillations will increase, resulting in a prolonged adjustment time. When D_q is too large, the system cannot perform normal adjustment functions. When the system is stable, increasing D_q can reduce the error but cannot eliminate it completely. The integration link is usually combined with the proportion link or differential link to form PD (proportional derivative) or PID control to play a regulating role. Increasing the integral coefficient S_i in the control system will increase the number of oscillations of the system and then lead to the instability, and vice versa. The differential effect can predict the variation direction of error(k) and eliminate the error before it is formed. Therefore, the dynamic performance of the system can be improved. The algorithm employed by the system is shown in Figure 4. First, Q_t, the target traffic set by the user, is received.

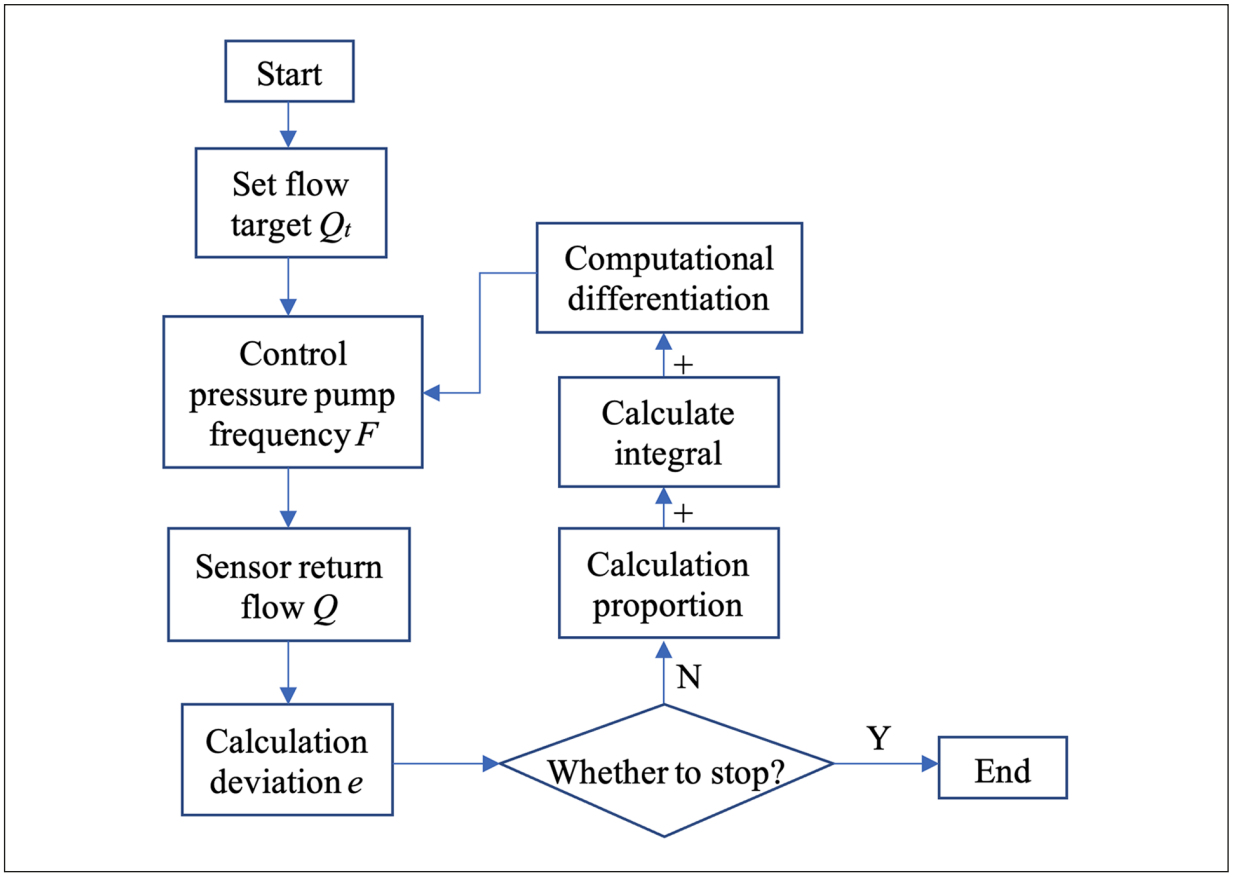

Figure 4. PID algorithm control flowchart.

At the beginning, the driving frequency of the piezoelectric pump is set to the upper frequency limit, and the flow value Q feedback from the flow sensor is received. Then, the deviation E is calculated, and the proportion, integral, and differential part of the response in PID is calculated according to the deviation.

Closed-Loop Control Experiment

1. Piezoelectricity pump open-loop experiment. During the experiment, the working frequency of the piezoelectric pump is set as 50 Hz, the driving power is 100 V, and the flow rate is recorded after stable operation.
2. Closed-loop control experiment without pulsation elimination. Based on an open loop, a thermal flow sensor is added at the outlet of the piezoelectric pump to form a closed-loop control system. The output flow of the piezoelectric pump is controlled by the PID algorithm, and the target flow rate is set at 700 μL/min. Because the data collected by the flow sensor fluctuate greatly, the flow values collected in multiple sampling periods are processed by mean filtering.
3. Closed-loop control experiment based on pulsation elimination. A fluid filter and flow sensor are added to the back end of the piezoelectric pump to form a closed-loop system. The PID algorithm is employed to control the output flow of the pump, and the target flow rate is set at 700 μL/min.

Therapeutic Methods

Children in the control group received AH atomization inhalation by conventional continuous positive airway pressure ventilation, mask, or nasal catheter oxygen inhalation. Children with severe breathing were treated with endotracheal intubation, and ventilators were used to maintain the effect of respiration. The children needed to be kept warm. The children were placed in a thermal box with an appropriate temperature to maintain the appropriate skin humidity (55-65%) and keep the skin temperature at 36.5-37°C. If necessary, anti-infection treatment, hypoglycemia correction, and acidosis treatment were given. The treatments of the experimental group were the same as those of the control group except for intravenous infusion of AH with a micropump. After dilution of 30 mg/(kg·d) AH with 20 mL 5% glucose solution, the patients were treated by intravenous infusion with a micropump 4 times per day.

Evaluation Methods

1. Serum cytology: 2 mL of arterial heparin sodium anticoagulant blood was extracted at the same time before treatment, 5 days after treatment, and 7 days after treatment for blood gas analysis. 4 mL of venous blood was collected, and ELISA kits were from by Beijing Jinmei Bioengineering Co., Ltd. The concentrations of cytokines in serum, including interleukin (IL)-1β, IL-6, IL-8, tumor necrosis factor alpha (TNF-α), GM-CSF (granulocyte macrophage colony stimulating factor), and IL-10, were measured by double-antibody sandwich ELISA.
2. 8-iso PGF2α detection: the collection time was the same as above. 1 mL of venous blood was collected and placed at room temperature for approximately 2 hours, followed by centrifugation (3,000 r/min) for 10 minutes. The supernatant was placed in the EP (eppendorf) tube, and all blood samples were stored in the refrigerator at -80°C until 8-iso PGF2α was determined by ELISA in the same batch.
3. Blood gas analysis: $PaCO_2$, PaO_2, and other blood gas indexes were compared between the two groups at different periods after treatment.
4. Others: the oxygen inhalation time, respiratory distress relief time, and length of stay were compared and analyzed between the two groups.

After treatment, if the symptoms of the newborn disappeared and the newborn could be discharged, the effect was classified as significant. If the symptoms of the newborn were relieved after treatment and it was necessary to stay in the hospital for observation, it was classified as effective. If the symptoms of the newborn did not change after treatment and leisure became more serious, it was classified as invalid.

Statistical Analysis

SPSS 22.0 (IBM Corp., Armonk, NY, USA) was employed for analysis. Measurement data were indicated as the mean ± standard deviation ($\bar{x} \pm s$). Independent sample *t*-test was adopted for comparison between the two groups. One-way ANOVA was adopted for comparison of means among multiple groups, and the Q test was used for comparison of means between groups. $p < 0.05$ suggested a statistically significant difference.

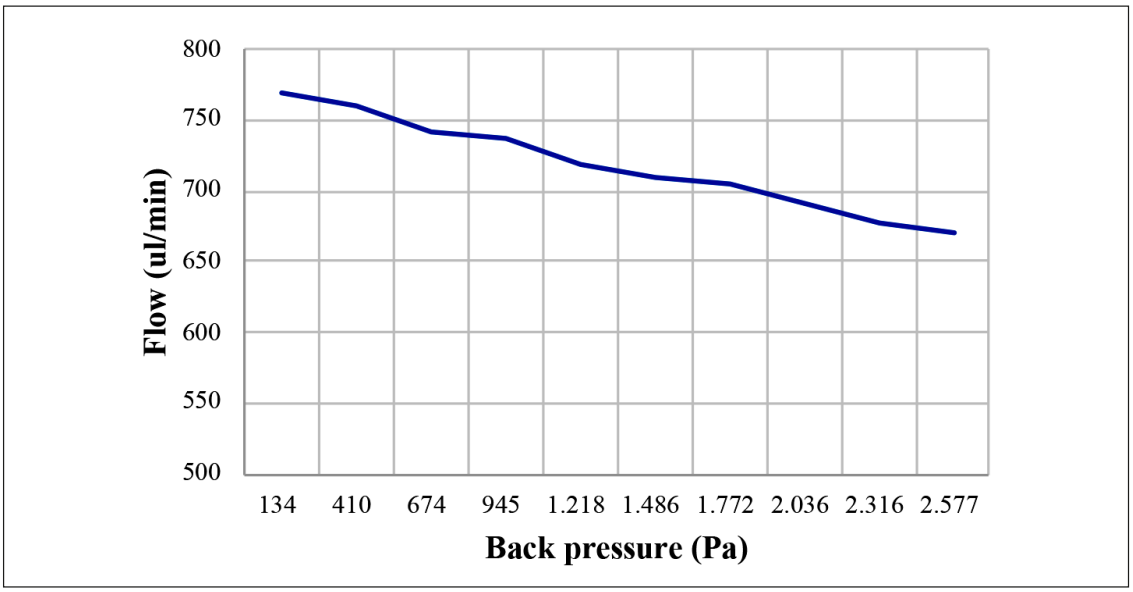

Figure 5. Results of the pressure pump open-loop experiment.

Results

Experimental Results of the Micropump Control System

With increasing back pressure, the output flow of the piezoelectric pump also decreased (Figure 5).

With increasing back pressure, the output flow of the piezoelectric pump also decreased. Experimentally obtained flow rates were measured by an electronic balance at different back pressures. The experimental results deviated greatly from the target flow rate of 700 μL/min (Figure 6).

Due to the closed-loop control, the flow rate measured by different back pressure electronic balances was 700 μL/min, and the error was within 30 μL/min. After the addition of the fluid filter, the flow sensor can improve the accuracy of flow rate detection of the piezoelectric pump and improve the closed-loop control accuracy of the piezoelectric pump (Figure 7).

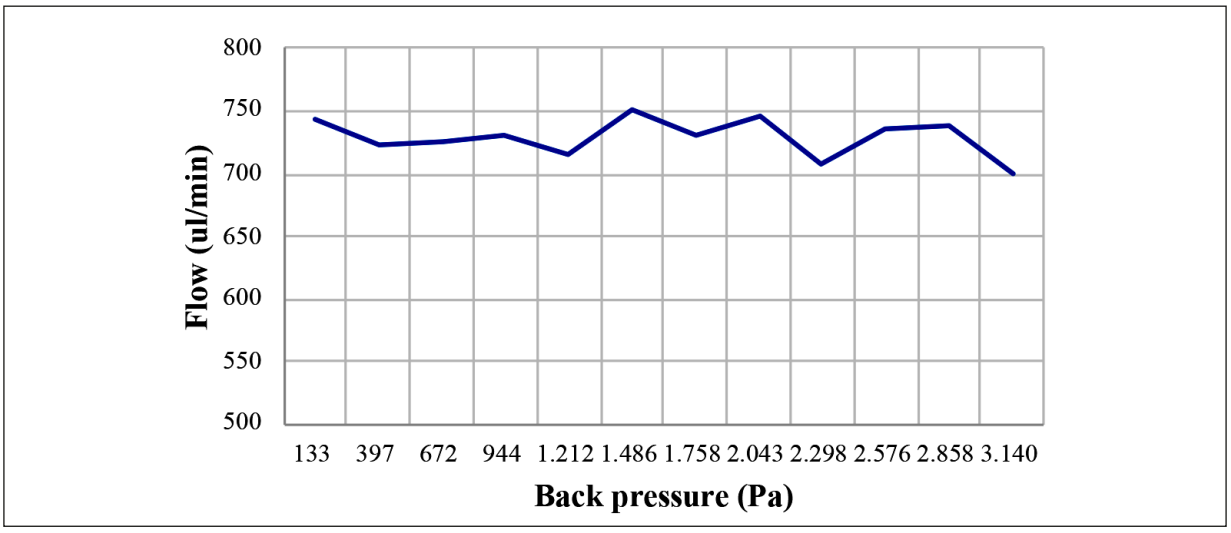

Figure 6. Experimental results of closed-loop control without pulsation.

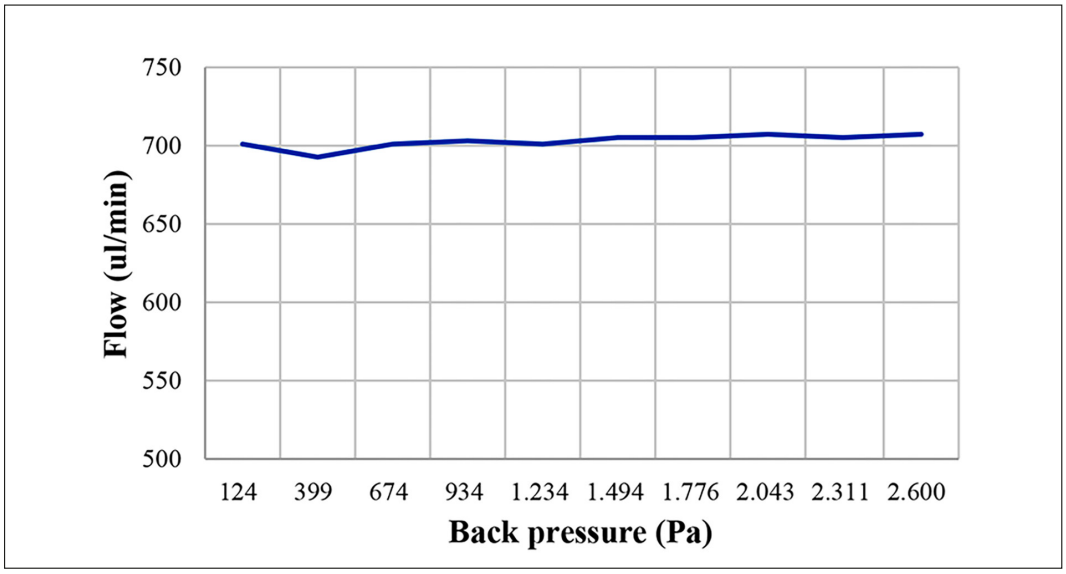

Figure 7. Experimental results of closed-loop control based on pulsation elimination.

Results of Serum Cytology

Serum test results showed that there was no considerable difference in cytokine levels between groups before treatment ($p > 0.05$). After five days of treatment, serum IL-1β, IL-6, IL-8, TNF-α, GM-CSF, and IL-10 were changed to varying degrees, but the differences were not substantial ($p > 0.05$). After seven days of treatment, serum IL-1β, IL-6, IL-8, TNF-α, GM-CSF, and IL-10 in the experimental group were 1,037.98 ± 19.64 pg/mL, 368.47 ± 84.29 pg/mL, 692.42 ± 27.92 pg/mL, 129.53 ± 28.52 pg/mL, 254.86 ± 11.4 pg/mL, and 543.73 ± 38.13 pg/mL, respectively; while those in the control group were 1,048.17 ± 19.35 pg/mL, 425.36 ± 88.22 pg/mL, 713.48 ± 25.25 pg/mL, 141.88 ± 26.84 pg/mL, 262.92 ± 12.5 pg/mL, and 529.14 ± 38.22 pg/mL, respectively. The serum levels of IL-1β, IL-6, IL-8, TNF-α, and GM-CSF in the experimental group were notably increased, while the levels of IL-10 were decreased ($p < 0.05$, Figure 8).

After five days of treatment, the level of serum 8-iso PGP2α in the experimental group was 212.66 ± 62.83, which was lower than that in the control group (220.45 ± 58.96) but without a great difference ($p > 0.05$). After seven days of treatment, the serum 8-iso PGP2α level in the experimental group was 166.32 ± 49.52, which was greatly inferior to that in the control group (183.32 ± 52.54) ($p < 0.05$, Figure 9).

Blood Gas Analysis Results

Before treatment, blood gas analysis showed little difference between groups, $p > 0.05$. Five days and seven days after treatment, blood gas analysis results of the two groups showed that all data showed an upward trend to varying degrees, and the difference was remarkable ($p < 0.05$). In the experimental group, PaO_2, SaO_2, and PaO_2/FiO_2 were 95.88 ± 12.82 mmHg, 95.86 ± 2.27%, and 346.81 ± 51.93 mmHg, respectively, after seven days of treatment. Compared with 88.21 ± 12.82 mmHg, 93.18 ± 3.13%, and 266.83 ± 48.09 mmHg in the control group, the recovery range of the experimental group was more prominent, showing a better recovery and a considerable difference ($p < 0.05$, Figure 10).

Analysis of Treatment Results

The duration of oxygen inhalation, respiratory distress relief, and length of stay were 95.12 ± 12.53 h, 4.4 ± 0.6 d, and 19.84 ± 2.8 d in the experimental group and 145.92 ± 13.85 h, 6.9 ± 0.9 d, and 28.42 ± 3.7 d in the control group, respectively. It suggested that the methods in the experimental group greatly shortened the treatment period of patient ($p < 0.05$, Figure 11).

In the experimental group, a significant treatment effect accounted for 53.60%, a general effect accounted for 39.30%, and an invalid effect accounted for 7.10%. In the control group, sig-

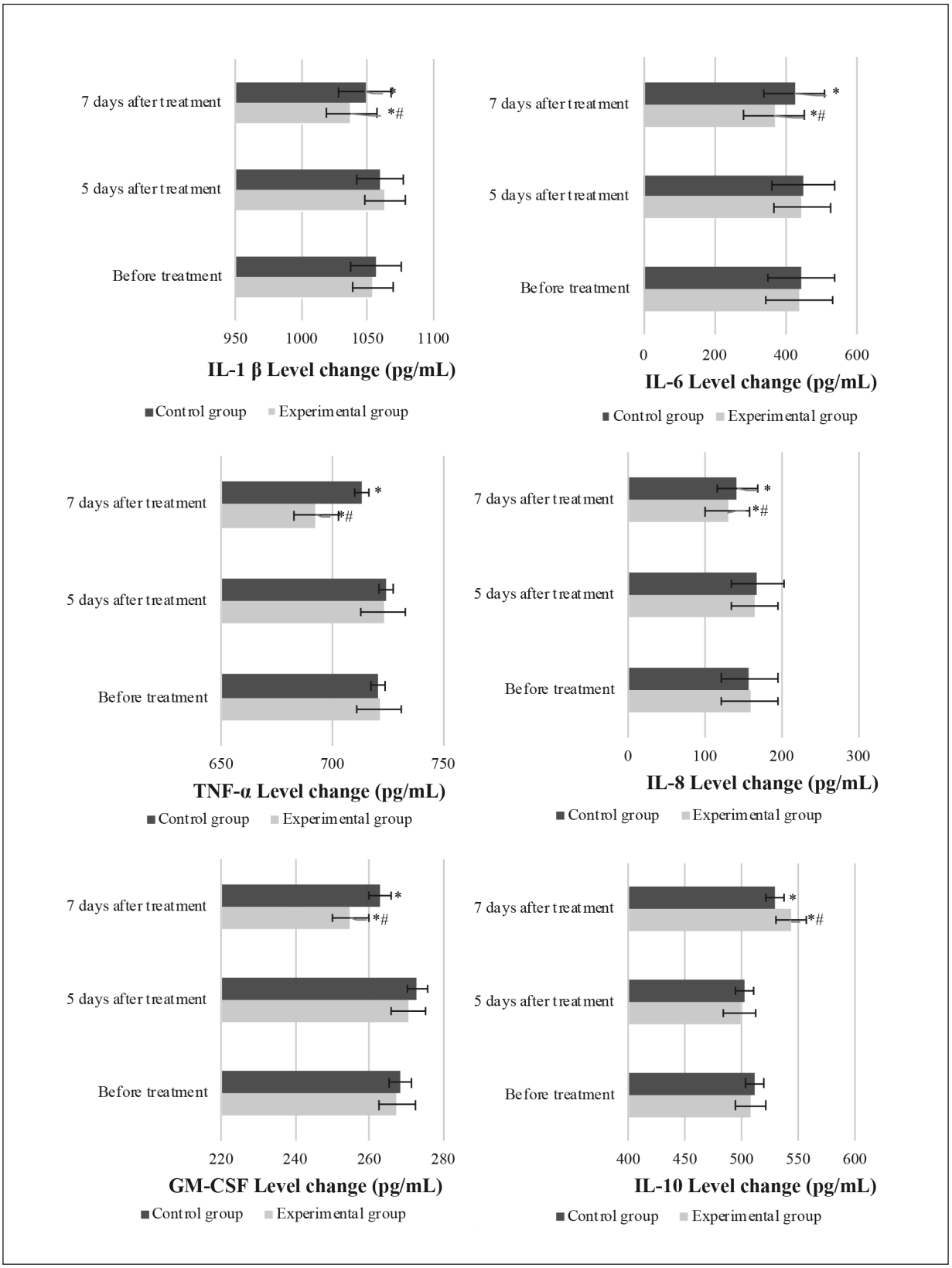

Figure 8. Results of cytokine level detection. (*compared with before treatment, $p < 0.05$; #compared with control group, $p < 0.05$).

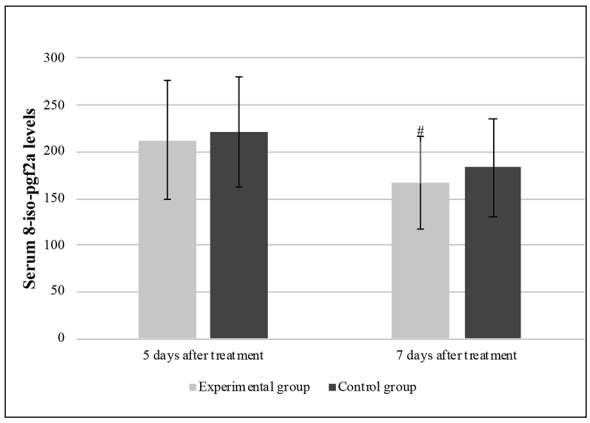

Figure 9. Results of serum 8-iso PGP2α level detection (*compared with control group, $p < 0.05$).

nificant treatment effect accounted for 28.60%, general effect accounted for 46.40%, and invalid accounted for 25%. The treatment effect of the experimental group was obviously better ($p < 0.05$, Figure 12).

Discussion

The high-precision, continuous, and stable supply of biological reagents is an indispensable experimental means in the fields of life science and drug development. With the progress of science and technology, there are higher requirements for continuous fluid transportation[27]. In this work, an SN-2000 V infusion pump was applied, and the system was composed of a PID controller and a controlled object. The experimental results

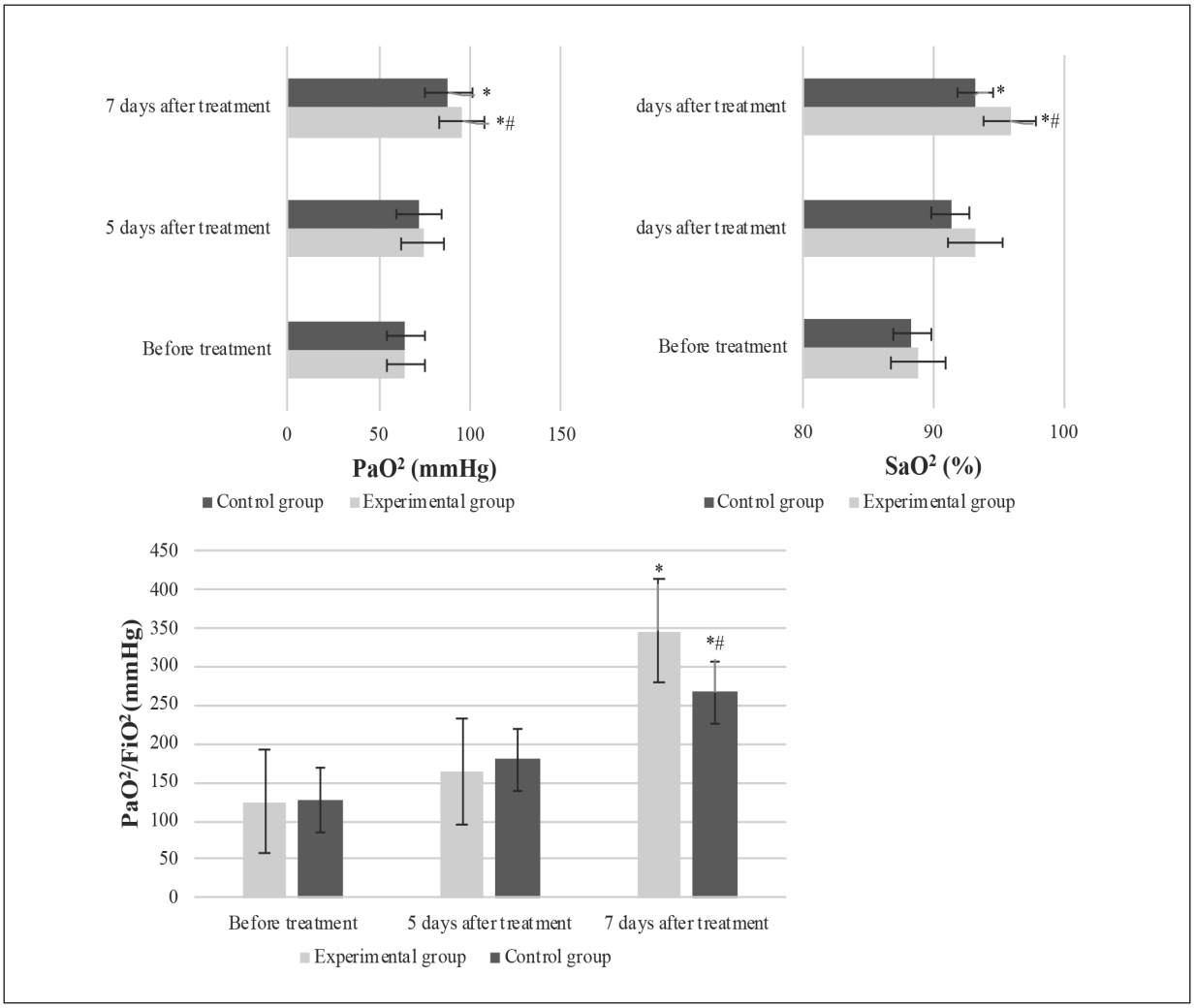

Figure 10. Blood gas analysis results (*compared with before treatment, $p < 0.05$; #compared with control group, $p < 0.05$).

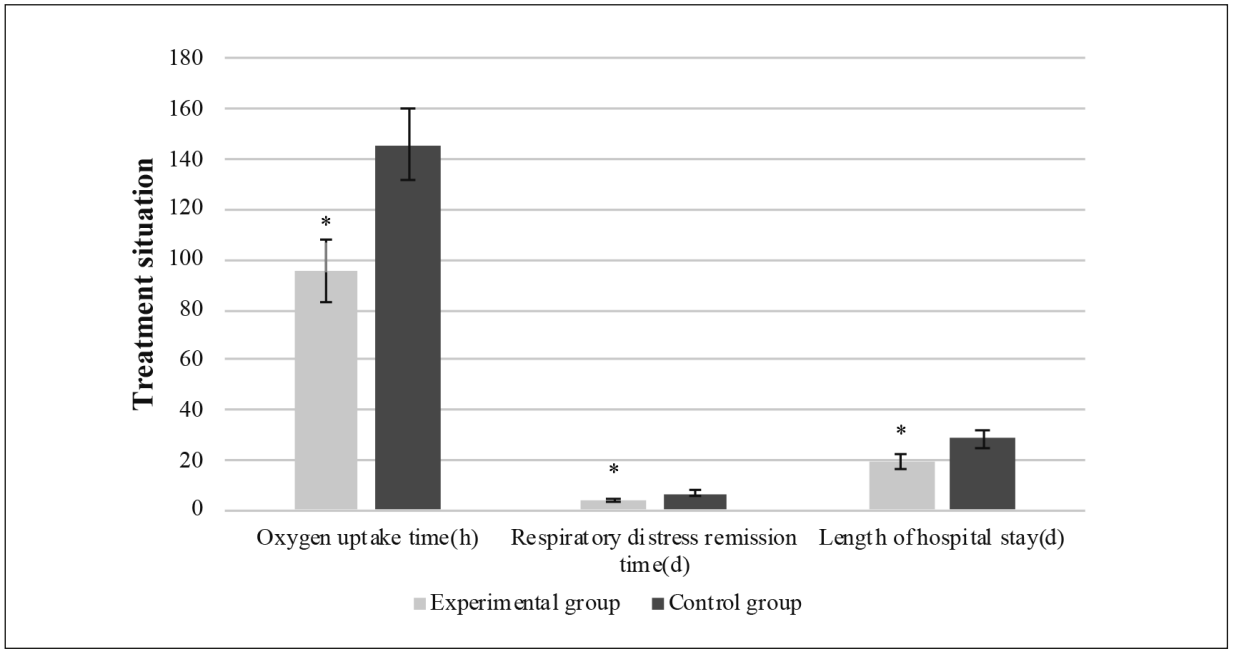

Figure 11. Results of treatment analysis (*compared with control group, $p < 0.05$).

showed that due to the closed-loop control, the flow rate measured by different back pressure electronic balances was 700 μL/min, and the error was within 30 μL/min. After the addition of the fluid filter, the flow sensor can improve the accuracy of the flow rate detection of the piezoelectric pump and improve the closed-loop control accuracy of the piezoelectric pump. The system employed the PID algorithm to realize high-precision control of hydraulic pump flow.

To explore the therapeutic effect of micropump AH infusion on RDS in premature infants, 58

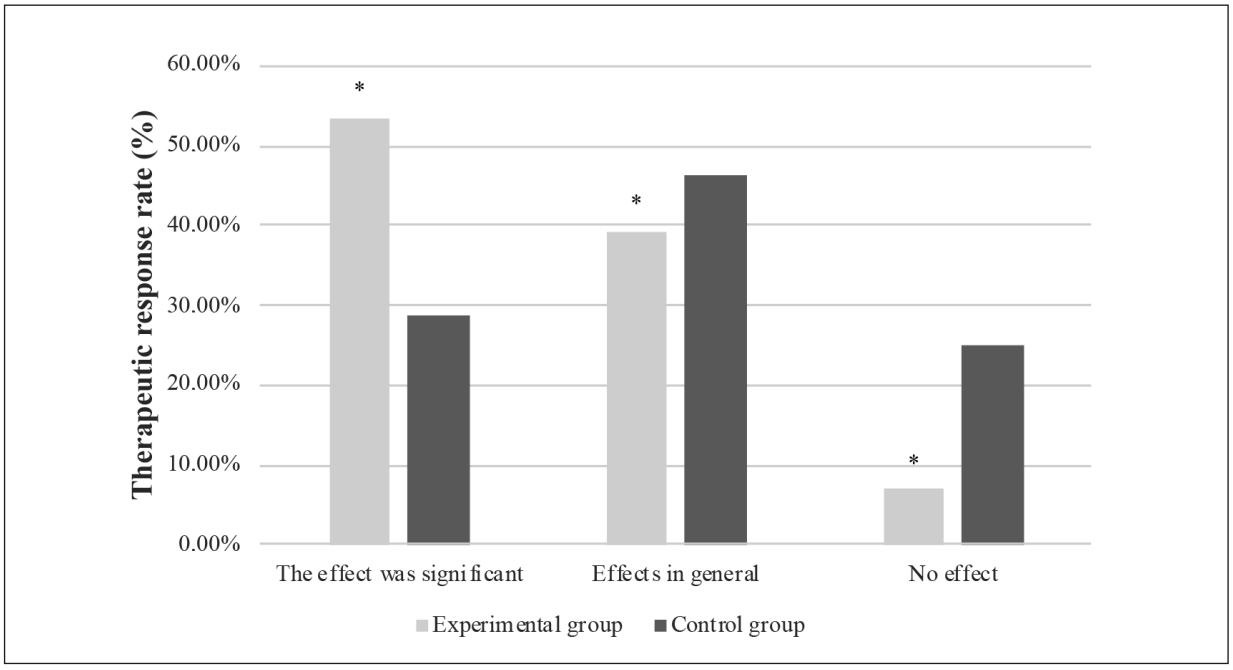

Figure 12. Evaluation of therapeutic effect (*compared with control group, $p < 0.05$).

premature infants with RDS were selected for the experiment. When RDS is metabolized in the body, it cannot reduce oxygen to water with enough electrons under hypoxic conditions, and free radicals increase and accumulate, producing excessive free radicals. Free radicals react with various cellular components to cause cellular structural damage and functional metabolic disorders, among which lipid peroxidation causes the most obvious damage. Studies[28] have proven that patients with diseases of the respiratory system, cardiovascular system, and nervous system have the pathological process of ischemia-reperfusion, resulting in an increase in oxygen free radicals and lipid peroxidation. Thus, there is an increase in 8-iso PGF2α levels, and the level of 8-iso PGF2α is positively correlated with the severity of the disease[29]. The results showed that after five days of treatment, the level of serum 8-iso PGP2α in the experimental group was 212.66 ± 62.83, which was inferior to that in the control group (220.45 ± 58.96), but the difference was not notable, $p > 0.05$. After seven days of treatment, the serum 8-iso PGP2α level in the experimental group was 166.32 ± 49.52, which was greatly lower than that in the control group (183.32 ± 52.54) ($p < 0.05$). These results suggested that intravenous infusion of AH *via* micropump can reduce lipid peroxidation damage in premature infants and play a good adjuvant role in RDS children.

Recently, it was found[30] that the balance between cytokines, especially proinflammatory factors and anti-inflammatory factors, plays a crucial role in the occurrence and development of RDS. After seven days of treatment, serum IL-1β, IL-6, IL-8, TNF-α, GM-CSF, and IL-10 in the experimental group were 1,037.98 ± 19.64 pg/mL, 368.47 ± 84.29 pg/mL, 692.42 ± 27.92 pg/mL, 129.53 ± 28.52 pg/mL, 254.86 ± 11.4 pg/mL, and 543.73 ± 38.13 pg/mL, respectively. The levels in the control group were 1,048.17 ± 19.35 pg/mL, 425.36 ± 88.22 pg/mL, 713.48 ± 25.25 pg/mL, 141.88 ± 26.84 pg/mL, 262.92 ± 12.5 pg/mL, and 529.14 ± 38.22 pg/mL, respectively. The serum levels of IL-1β, IL-6, IL-8, TNF-α, and GM-CSF in the experimental group were notably increased, while the levels of IL-10 were decreased ($p < 0.05$). Elfarargy et al[31] suggested that reducing the concentration of proinflammatory cytokines can alleviate excessive and uncontrolled inflammatory responses in patients with RDS to a certain extent and reduce tissue and organ damage, which is conducive to the treatment of RDS. Blood gas analysis results of the two groups showed little difference and no statistical significance ($p > 0.05$), indicating comparability. Five and seven days after treatment, blood gas analysis results of the two groups showed that all data showed an upward trend to varying degrees, and the difference was dramatic ($p < 0.05$). In the experimental group, PaO_2, SaO_2, and PaO_2/FiO_2 were 95.88 ± 12.82 mmHg, 95.86 ± 2.27%, and 346.81 ± 51.93 mmHg, respectively, after seven days of treatment. Compared with 88.21 ± 12.82 mmHg, 93.18 ± 3.13%, and 266.83 ± 48.09 mmHg in the control group, the recovery range of the experimental group was more prominent, and the recovery was better, with considerable differences ($p < 0.05$). It also indicated that AH treatment by micropump can effectively improve the oxygenation index and antioxidant capacity of children.

Finally, a summary of the treatment showed that the duration of oxygen inhalation, respiratory distress relief, and hospital stay were 95.12 ± 12.53 h, 4.4 ± 0.6 d, and 19.84 ± 2.8 d in the experimental group and 145.92 ± 13.85 h, 6.9 ± 0.9 d, and 28.42 ± 3.7 d in the control group, respectively. Compared with the control group, the treatment time of the experimental group was notably shortened. In the experimental group, a significant treatment effect accounted for 53.60%, a general effect accounted for 39.30%, and an invalid effect accounted for 7.10%. In the control group, significant treatment effect accounted for 28.60%, general effect accounted for 46.40%, and invalid accounted for 25%. The treatment effect in the experimental group was obviously better ($p < 0.05$). The results showed that micropump infusion of AH was more beneficial to the recovery of RDS than conventional aerosol inhalation of AH.

Conclusions

At present, most patients with RDS are treated by intravenous infusion or atomized inhalation of AH in clinical practice, and there are few literature reports on the use of micropump infusion for RDS. To study its improvement effect in treatment, AH infusion with a micropump was applied to treat children with RDS, and its effect was compared with conventional atomization therapy. The results showed that micropump infusion of AH in the treatment of premature RDS patients was more conducive to the play of drug efficacy, which can alleviate the clinical

symptoms of RDS children, improve their blood gas indicators, slow down and repair the damage of alveolar epithelial cell lipids in RDS children, and thus improve the therapeutic effect. It has an important influence on improving the symptoms of children and restoring normal lung function and can be used for the clinical treatment of premature RDS. However, due to the limitation of conditions, the sample size is small, and some results have some errors, which need further study and confirmation.

Conflict of Interest
The Authors declare that they have no conflict of interests.

Acknowledgements
We would like to thank Nanjing Jiangbei Hospital for support.

Informed Consent
The parents of the patients included in the work signed informed consent forms.

Ethics Approval
The process was approved by the Ethics Committee of Nanjing Jiangbei Hospital (Approval Number: 2022011).

ORCID ID
Jun Li: 0000-0002-3852-2256.

Funding
None.

Authors' Contribution
J.-S. Xu was responsible for manuscript writing, patient information collection and quality control. B.-H. Li was responsible for the overall planning of the study. J. Li was responsible for the final editing. Y.-Q. Xu is responsible for language polishing. Y. Lin was responsible for statistical analysis.

Data Availability
The data used to support the findings of this study are available from the corresponding author upon request.

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