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Study on the effect of phentolamine combined with vitamins A/D on inflammatory responses and humoral immunity in children with severe pneumonia

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Abstract: Pneumonia is a common childhood illness that can become life-threatening if it progresses to severe pneumonia. Currently, there are considerable limitations in the diagnosis and treatment of severe pneumonia in clinical practice, which also leads to a persistently high mortality rate of severe pneumonia. In this study, we first analyzed the related factors for the progression of pneumonia to severe pneumonia and discovered that age, disease duration, infection type, C reactive protein, anemia, malnutrition and underlying diseases were relevant. This suggests that when admitting children with pneumonia in future clinical settings, attention should be paid to these indicators to prevent the progression to severe pneumonia. Subsequently, we explored the therapeutic effect of phentolamine combined with vitamins A/D on severe pneumonia and confirmed the significant clinical efficacy of their combination, which effectively alleviated inflammation in children with severe pneumonia, enhanced immunity and reduced the risk of recurrence of pneumonia, suggesting the extremely high clinical application value of this treatment regimen. These results will provide reliable reference and guidance for the diagnosis and treatment of severe pneumonia in the future, thereby ensuring the prognostic health of children with severe pneumonia.

Keywords: Phentolamine, vitamins A/D, severe pneumonia, inflammatory response, immune function

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INTRODUCTION

Pneumonia is one of the common infectious diseases in clinical settings, especially in children and its occurrence is closely associated with pathogen invasion and allergic reactions (Ding *et al.*, 2024). Statistics indicate that among children aged 6-12, approximately 20-30% have experienced at least one episode of pneumonia (Yan *et al.*, 2024). The incidence of pneumonia has been rising in recent years and is now recognized by the World Health Organization as one of the leading health threats to children's development (Meyer Sauteur, 2024). Children's respiratory systems are not fully developed, making them more vulnerable to infections. Their narrow airways, reduced mucus secretion and impaired ciliary function contribute to the rapid progression of pneumonia to severe forms. Once infected with pneumonia, it may rapidly deteriorate and progress to severe pneumonia (SP) (Yang *et al.*, 2024). According to statistics, the mortality rate of SP is as high as 30-60%, which is one of the main causes of child death at present (Rotini *et al.*, 2024). Therefore, the diagnosis and treatment of SP must draw clinical attention and be handled appropriately.

At present, conventional treatment for SP is still based on antibiotics, antiviral drugs and other conventional symptomatic treatment measures. Nevertheless, the long-term usage of these drugs might cause potential harm to the nervous and blood systems, which is detrimental to the growth of children (Miyoshi & Hisamatsu, 2025). In recent years, phentolamine (PT), as an alpha receptor blocker, has been extensively utilized to address peripheral vascular-related problems and its outstanding effects of relaxing blood vessels and improving pulmonary microcirculation have laid a reliable foundation for its application in SP (Sardana *et al.*, 2023). Moreover, PT plays a remarkable role in enhancing the activity of antibiotics, which undoubtedly contributes to further improvement of the current treatment status of SP (Cui *et al.*, 2023). Vitamins A and D (VA/VD) are among the essential trace elements in the human body and one of the key elements affecting human immune function (Aaseth *et al.*, 2024; Dura-Trave & Gallinas-Victoriano, 2024). Research indicates that VA/VD supplementation therapy also has numerous effects such as improving allergic suppression and antibacterial defense in the human body (Abo-Zaid *et al.*, 2023), which has also received unanimous recognition in the adjuvant treatment of SP in recent years. We believe that the treatment of SP with the combination of PT and VA/VD might yield significant outcomes, but currently, there is no research to substantiate our viewpoint.

Consequently, this study will not only analyze the related factors of pneumonia progressing to SP but also further explore the clinical therapeutic effect of PT combined with VA/VD, offering new references and guidance for the diagnosis and treatment of SP in the future.

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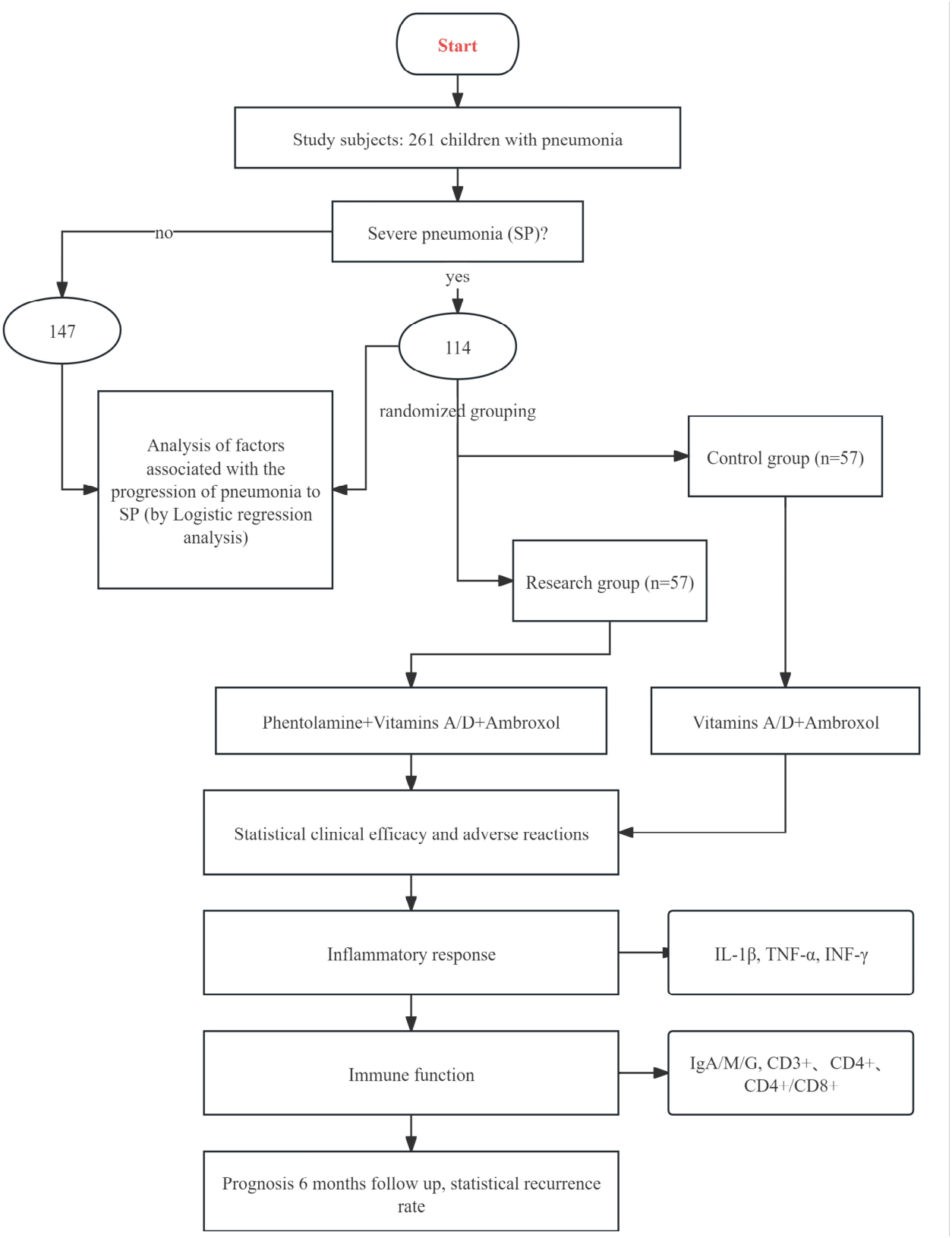

Fig. 1: The flow of this study. 261 children included with pneumonia, of which 114 were SP. After analyzing the relevant factors affecting the progression of pneumonia to SP, divided the 114 children with SP into two groups and further analyzed the therapeutic efficacy of PT combined with VA/VD in SP.

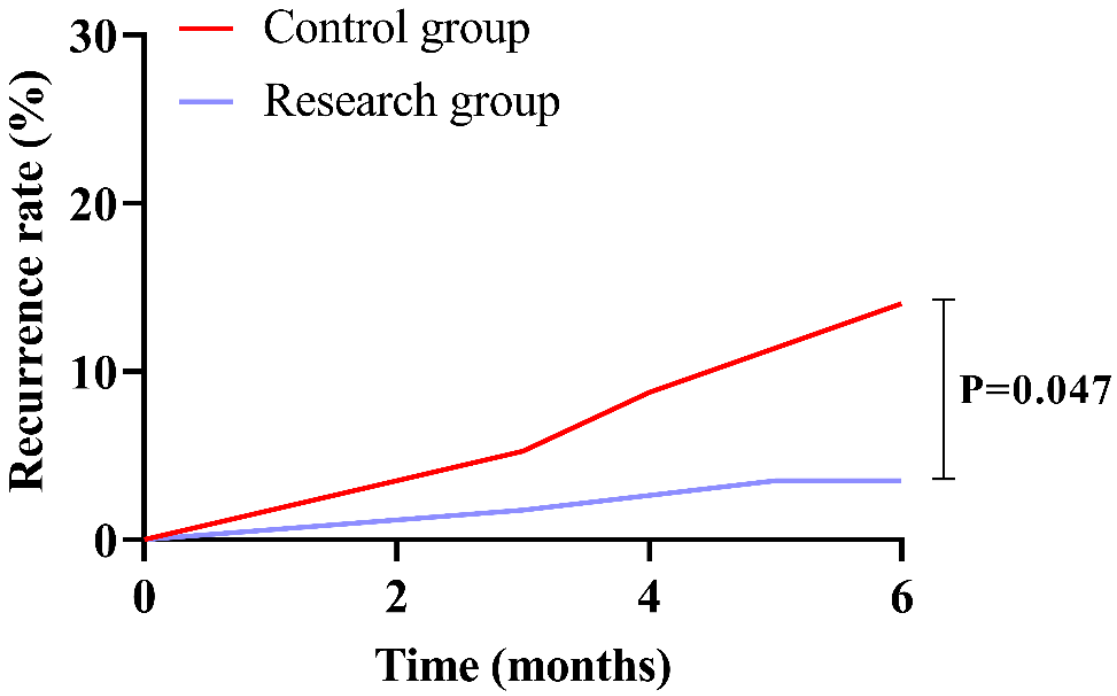

Fig. 2: Prognostic effect of PT combined with VA/VD in the treatment of SP.

Table 1: Univariate analysis of influencing factors affecting the progression of pneumonia to SP.

Indicators	Pneumonia (n=147)	SP (n=114)	t (χ^2)	P
Age	9.89±1.62	8.60±1.95	5.853	<0.001
Sex			0.509	0.476
Male/female	76 (51.70)/71 (48.30)	64 (56.14)/50 (43.86)		
Duration of disease (d)	20.35±6.46	33.59±5.81	17.150	<0.001
Type of infection			33.720	<0.001
Bacteria/virus/bacteria+virus/ mycoplasma	48 (32.65)/52 (35.37)28 (19.05)/19 (12.93)	20 (17.54)/29 (25.44)/14 (12.28)/51 (44.74)		
CRP (mg/L)	16.89±6.81	22.74±7.13	6.744	<0.001
Anemia			24.620	<0.001
Yes/no	18 (12.24)/129 (87.76)	44 (38.60)/70 (61.40)		
Malnutrition			22.550	<0.001
Yes/no	15 (10.20)/132 (89.80)	39 (34.21)/75 (65.79)		
Family history of disease			0.778	0.378
Yes/no	12 (8.16)/135 (91.84)	13 (11.40)/101 (88.60)		
Comorbid underlying disease			0.169	0.681
Yes/no	5 (3.40)/142 (96.60)	5 (4.39)/109 (95.61)		

Table 2: Table of Assignments

Indicators	Assigning
Type of Pneumonia	Pneumonia=1, SP=2
Age	Use of raw data for analysis
Duration of disease (d)	Use of raw data for analysis
Type of infection	Bacteria=1, virus=2, bacteria+virus=3, mycoplasma=4
CRP (mg/L)	Use of raw data for analysis
Anemia	Yes=1, no=2
Malnutrition	Yes=1, no=2

Table 3: Multivariate analysis of factors affecting the progression of pneumonia to SP

Indicators	Regression coefficient (β)	Standard Error (S.E.)	Wald χ^2	P	Odds ratio (OR)	95% Confidence interval (95% CI)
Age	1.024	0.226	28.642	<0.001	1.642	1.192-2.462
Duration of disease (d)	1.462	0.184	22.846	<0.001	4.264	2.842-6.064
Type of infection	0.574	0.134	16.264	<0.001	1.762	1.342-2.842
CRP (mg/L)	0.642	0.108	26.542	<0.001	1.840	1.242-2.334
Anemia	0.841	0.264	15.164	<0.001	2.224	1.514-3.706
Malnutrition	0.952	0.194	20.870	<0.001	2.184	1.542-3.942

Table 4: Clinical efficacy of PT combined with VA/VD in the treatment of SP

Indicators		Control group (n=57)	Research group (n=57)	t (χ^2)	P
Clinical data	Age	8.53±1.99	8.67±1.92	0.383	0.703
	Sex			0.570	0.450
	Male/female	34 (59.65)/23 (40.35)	30 (52.63)/27 (57.37)		
	Duration of disease (d)	33.67±5.24	33.51±6.37	0.145	0.885
	Type of infection			1.416	0.702
	Bacteria/virus/bacteria +virus/mycoplasma	12 (21.05)/13 (22.81)/6 (10.53)/26 (45.61)	8 (14.04)/16 (28.07)/8 (14.04)/25 (43.86)		
	CRP (mg/L)	22.02±7.58	23.47±6.64	1.088	0.279
	Anemia			0.592	0.442
	Yes/no	24 (42.11)/33 (57.89)	20 (35.09)/37 (64.91)		
	Malnutrition			0.351	0.554
	Yes/no	18 (31.58)/39 (68.42)	21 (36.84)/36 (63.16)		
	Family history of disease			0.781	0.377
	Yes/no	5 (8.77)/52 (91.23)	8 (14.04)/49 (85.96)		
	Comorbid underlying disease			0.209	0.647
	Yes/no	2 (3.51)/55 (96.49)	3 (5.26)/54 (94.74)		
Time to disappearance of symptoms (d)	Cough	4.68±0.74	3.89±0.77	5.589	<0.001
	High fever	3.84±0.84	2.95±0.93	5.376	<0.001
	Shortness of breath	4.42±0.84	5.44±1.04	5.751	<0.001
Clinical efficacy	Markedly effective	20 (35.09)	31 (54.39)		
	Effective	25 (43.86)	22 (38.60)		
	Ineffective	12 (21.05)	4 (7.02)		
	Total effective rate	78.95	92.98	4.653	0.031

Table 5: Impact of PT combined with VA/VD on inflammatory responses in SP

Groups	INF-γ (ng/L)		IL-1β (ng/L)		TNF-α (ng/L)	
	Before	After	Before	After	Before	After
Control group (n=57)	41.16±10.54	53.77±7.87*	27.60±7.28	19.54±4.65*	48.26±5.78	33.73±3.82*
Research group (n=57)	40.25±10.28	57.54±8.92*	27.88±5.57	16.51±3.76*	48.05±4.88	29.80±4.56*
t	0.468	2.393	0.225	3.832	0.212	4.987
P	0.641	0.018	0.822	<0.001	0.833	<0.001

Note: * indicates *P<0.05* compared to the same group before treatment.

MATERIALS AND METHODS

Research subjects

The sample size needed for this study was calculated by G*Power software with effect size=0.5, alpha err prob=0.05 and power=0.8, which showed that a minimum of 96 subjects (48 in each group) were needed. On this basis, 261 children with pneumonia admitted to our hospital from February 2022 to January 2024 were selected as the research subjects. Among them, 114 children developed SP and were randomized into a research group and a control group, with 57 cases in each group. The control group was given VD combined with routine treatment, while the research group was given VD combined with PT treatment. The flowchart of this study can be found in fig. 1.

Table 6: Impact of PT combined with VA/VD on humoral immunity in SP

Indicators		Control group (n=57)	Research group (n=57)	t	P
IgA (g/L)	Before	1.32±0.25	1.39±0.31	1.414	0.160
	After	1.97±0.37*	2.33±0.46*	4.585	<0.001
IgG (g/L)	Before	7.61±1.59	7.14±1.89	1.436	0.154
	After	9.42±1.57*	10.99±1.66*	5.165	<0.001
IgM (g/L)	Before	1.52±0.43	1.52±0.34	0.039	0.969
	After	1.79±0.42*	2.05±0.28*	3.884	<0.001
CD3+ (%)	Before	56.50±6.72	56.17±7.32	0.251	0.803
	After	61.48±7.25*	66.97±8.46*	3.721	<0.001
CD4+ (%)	Before	33.62±6.43	34.61±6.14	0.836	0.405
	After	39.13±6.53*	44.02±4.67*	4.604	<0.001
CD8+ (%)	Before	32.64±5.39	32.85±7.13	0.172	0.864
	After	25.97±3.19*	22.66±3.84*	4.990	<0.001
CD4+/CD8+	Before	1.06±0.26	1.10±0.29	0.870	0.386
	After	1.52±0.28*	2.00±0.38*	7.496	<0.001

Note: * indicates *P<0.05* compared to the same group before treatment.

Table 7: Safety effect of PT combined with VA/VD in the treatment of SP

Groups	Heart failure	Diarrhea	Bloating	Rash	Vomiting	Total Incidence
Control group (n=57)	1 (1.75)	2 (3.51)	1 (1.75)	1 (1.75)	2 (3.51)	12.28
Research group (n=57)	1 (1.75)	2 (3.51)	1 (1.75)	2 (3.51)	2 (3.51)	14.04
χ^2						0.077
P						0.782

This study adhered to the principles outlined in the Declaration of Helsinki and was approved by the Ethics Committee of our hospital (No.2022142). All subjects and members of the research team who collected the data were unaware of their subgroups.

Inclusion and exclusion criteria

Inclusion criteria: (1) Age 6-12 years (2) Diagnosis of pneumonia or SP through observation of symptoms and signs, imaging examinations, laboratory tests, etc. (Martin-Loeches & Torres, 2021). (3) High compliance and active cooperation with investigation and research. (3) Provision of written informed consent by the guardians of the children. Exclusion criteria: (1) Liver and renal dysfunction. (2) Autoimmune system and blood system disorders. (3) Malignant tumors. (4) Severe cardio-cerebrovascular diseases such as myocardial infarction and stroke. (5) Drug allergies. (6) Death during treatment or follow-up.

METHODS

The data such as age, gender and disease course of all children were collected. Subsequently, all children with SP were instructed to rest in the supine position and were provided with basic treatments such as oxygen inhalation, anti-shock, cardiotonic measures, diuretics, correction of acid-base imbalance and adrenocortical hormones. Treatment plan for the control group: 7.5 mg of ambroxol hydrochloride (Hubei Kelun Pharmaceutical Co, Ltd, H20183050) was added into 50 mL of 5% glucose injection, thoroughly mixed and then intravenously infused; the infusion was completed within 30 minutes, twice a day, for 7 consecutive days. In addition, oral VA/VD capsules (Zhejiang Medicine Co., Ltd. Xinchang Pharmaceutical Factory, H20058460), 1 capsule/day, for 15 days. Research group: Based on the above treatment, 0.15 mg/kg of PT injection (Shanghai Xudong Haipu Pharmaceutical Co., Ltd, H31020589) was added into 100 mL of 10% glucose injection for intravenous drip completed within 30 minutes, twice a day, for 7 consecutive days.

Clinical efficacy evaluation

Efficacy assessment was made by referring to the pneumonia treatment guidelines (Oliveira *et al.*, 2023). Markedly effective: After treatment, symptoms such as cough and fever completely disappeared and blood gas indicators returned to normal. Effective: Symptoms were relieved and blood gas indicators improved. Ineffective: Symptoms remained unchanged or even worsened. Total effective rate = (markedly effective +effective) / total number of people ×100%.

Sample collection and testing

Fasting venous blood of children with SP was collected before and after treatment and divided into two portions. One portion was used for detecting inflammatory factors and the other for measuring immune function indicators. Detection of inflammatory factors: Serum was separated

from blood samples by centrifugation to measure interleukin-1β (IL-1β), tumor necrosis factor-α (TNF-α) and interferon-γ (INF-γ) following enzyme linked immunosorbent assay (ELISA) kit instructions and to quantify C-reactive protein (CRP) using a hematology analyzer (Mindray BC-5390). Immune function test: T lymphocyte subsets ($CD3^+$, $CD4^+$, $CD8^+$ and $CD4^+/CD8^+$) were determined by flow cytometry and *immunoglobulin A/M/G (IgA/M/G) were quantified with an electrophoresis analyzer.*

Prognostic follow-up

All SP cases underwent a 6-month prognostic follow-up. The follow-up was conducted through regular re-examinations (once a month) and the recurrence of pneumonia in the prognosis of children was recorded.

Endpoints

(1) The relevant factors influencing the progression of pneumonia to SP were determined. (2) The clinical efficacy of PT combined with VA/VD in the treatment of SP was discussed and the disappearance time of cough, high fever and shortness of breath in children was statistically analyzed. (3) The impact of PT combined with VA/VD on the inflammatory response and immune function of children with SP was investigated. (4) The safety of PT combined with VA/VD in the treatment of SP was analyzed. (5) The control effect of PT combined with VA/VD on the prognostic recurrence of pneumonia in children with SP within 6 months was analyzed.

STATISTICAL ANALYSIS

Data were imported into SPSS23.0 for statistical analysis. The Chi-square test was employed for the comparison of all count data [n (%)] and the Fisher's precision probability test was utilized for verification when the theoretical frequency in each cell of the fourfold table was less than 5. The Shapiro-Wilk test was adopted to test the normality of the measurement data. The normal distribution data (χ±s) were compared using the independent sample t-test and paired t-test and the non-normal distribution data [median (interquartile range)] were compared using the Mann-Whitney U test and the Willcoxon rank sum test. Logistic regression analysis was utilized to analyze related factors. The recurrence rate was calculated using the Kaplan-Meier method and the comparison was conducted using the Log-rank test. A $P<0.05$ was regarded as statistically significant.

RESULTS

Univariate analysis of influencing factors affecting the progression of pneumonia to SP

Comparing the data of children with pneumonia and children with SP, it was seen that there was no statistically significant difference in gender and family history of disease between the two groups ($P>0.05$). The age of children with SP was lower than that of children with pneumonia, while the duration of disease and CRP were higher than that of children with pneumonia ($P<0.05$). Meanwhile, the number of mycoplasma infection, anemia and malnutrition was more in children with SP than in children with pneumonia ($P<0.05$) (table 1).

Multivariate analysis of factors affecting the progression of pneumonia to SP

Values were assigned to the above indicators with differences (table 2), followed by logistic regression analysis with pneumonia and SP as independent variables and other indicators as covariates. The output showed that age (OR: 1.642, 95%CI: 1.192-2.462), duration of disease (OR: 4.264, 95%CI: 2.842-6.064), type of infection (OR: 1.762, 95%CI: 1.342-2.842), CRP (OR: 1.840, 95%CI: 1.242-2.334), anemia (OR: 2.224, 95%CI: 1.514-3.706) and malnutrition (OR: 2.184, 95%CI: 1.542-3.942) were the relevant factors affecting the progression of pneumonia to SP (table 3).

Clinical efficacy of PT combined with VA/VD in the treatment of SP

To ensure the reliability of the research results, we compared the clinical data of children in the research group and the control group again. The two groups were not markedly different in age, sex and disease course ($P>0.05$), confirming their comparability. Regarding symptom alleviation, the disappearance time of cough, high fever and shortness of breath in the research group was shorter compared to the control group ($P<0.05$). Additionally, the total effective rate of treatment in the research group was 80%, higher than that in the control group ($P<0.05$) (table 4).

Impact of PT combined with VA/VD on inflammatory responses in SP

As presented in table 5, there was no statistically significant difference in the comparison of inflammatory factor detection results between groups before treatment ($P>0.05$); after treatment, IL-1β and TNF-α in both groups decreased significantly ($P<0.05$), with their levels in the research group being (16.51±3.76) ng/L and (29.80±4.56) ng/L, respectively, all of which were lower compared to the control group ($P<0.05$). Whereas INF-γ was elevated in both groups after treatment, it was higher in the research group than in the control group ($P<0.05$).

Impact of PT combined with VA/VD on humoral immunity in SP

In terms of immune function, there was no significant inter-group difference in the detection results of immunoglobulins and T lymphocyte subsets before treatment ($P>0.05$). After treatment, both groups showed a significant increase in immunoglobulin levels, with even higher levels of IgA, IgG and IgM in the research group

($P<0.05$). The T lymphocyte subsets $CD3^+$, $CD4^+$ and $CD4^+/CD8^+$ of both groups increased after treatment, with those in the research group being higher compared to the control group, while CD8+ decreased and was even lower in the research group ($P<0.05$) (table 6).

Safety and prognostic effect of PT combined with VA/VD in the treatment of SP

Finally, there was no notable inter-group difference in the comparison of the incidence of adverse reactions during the treatment process ($P>0.05$). In the prognostic follow-up (all research subjects were followed up successfully), the prognostic recurrence rate of the research group was 3.51%, lower than that of the control group ($P<0.05$) (table 7 and fig. 2).

DISCUSSION

To offer more reliable references and guidance for the diagnosis and treatment of SP in the future, we first explored the related factors for the progression of pneumonia to SP. The results indicated that age, disease course and infection type were all independent factors. Analyzing the reasons one by one, we hold that: (1) The younger the child, the immature the immune system, the weaker the respiratory function and respiratory mucosal barrier function, the more rapid progression of the disease after infection and the higher risk of developing SP if not treated effectively and promptly (Schuller *et al.*, 2024). (2) After children are infected with pneumonia, the body's inflammatory response keeps increasing. This process will continue to intensify as the disease course lengthens, leading to dehydration and electrolyte imbalance and aggravating lung injury and systemic symptoms (Wang *et al.*, 2024). Thus, longer disease duration increases the risk of progression to SP. (3) Compared with common pneumonia pathogens such as bacteria and viruses, mycoplasma infection is more likely to lead to severe illness. This is mainly because the clinical symptoms of mycoplasma infection are diverse and lack typical manifestations, which is prone to misdiagnosis, mistreatment and consequently delayed treatment (Poddighe *et al.*, 2022). (4) CRP is a sensitive indicator produced by the body in response to inflammatory stimuli such as microbial invasion or tissue damage; its level is positively correlated with the severity of the infection. Clinically, the CRP level is commonly used as a reference for evaluating the severity of pneumonia (Xu & Han, 2023). Although there are variations in the critical value of CRP in predicting SP due to individual differences (Ma *et al.*, 2023; Zhu *et al.*, 2023), an elevated CRP level often indicates a more severe inflammatory response and greater lung damage. (5) Children with anemia and malnutrition have lower immune functions and are more susceptible to infection. Once infected with pneumonia, the disease is easy to spread and difficult to cure and may lead to heart failure and other extrapulmonary diseases, increasing the risk of severe illness (Kulkarni *et al.*, 2021). In this regard, we believe that in the future when children with pneumonia are admitted, it is necessary to promptly clarify the infection type and take symptomatic treatment, especially for infants and young children as well as those with anemia, malnutrition, or underlying diseases. Once there are symptoms of pneumonia such as fever, wheezing and cough, timely medical treatment should be sought to avoid delaying treatment. Meanwhile, children's physical exercise should be strengthened to enhance immunity and reduce the risk of infection.

Next, we further explored the clinical therapeutic effect of PT combined with VA/VD on SP to provide a more reliable guarantee for the prognosis of children. First, we observed that the symptom relief time in the research group after treatment was significantly shorter compared to the control group and the clinical efficacy was superior, suggesting that PT combined with VA/VD has excellent therapeutic effects on SP. Previous studies have also reported the efficacy of PT in treating coronary syndrome (Hamila *et al.*, 2022), supporting our hypothesis. PT is an α-receptor blocker with β-adrenergic stimulating properties, which can effectively counter the effects of epinephrine and norepinephrine in the blood (Van Demark *et al.*, 2021), resulting in a decrease in peripheral vascular resistance, vasodilation, enhanced myocardial contraction and alleviated pulmonary edema (Hersh *et al.*, 2019). Additionally, it reduces the cardiac load by alleviating pulmonary artery pressure and promoting blood circulation (Lazari J *et al.*, 2021). Therefore, with the assistance of VA/VD, PT can not only play a role in promoting the differentiation of respiratory epithelial cells and assisting in the recovery of respiratory epithelium, but also resist the invasion of external pathogenic bacteria, improve the functions of T and B lymphocytes, regulate immune function and resist the infection of pathogenic bacteria, thus inhibiting the progression of inflammatory responses. When comparing the inflammatory factors and humoral immunity of the two groups before and after treatment, we found better performance in the research group after treatment, corroborating this view. Similarly, Gago-García A *et al*. verified that PT could reduce inflammation and stress reactions after anesthesia (Gago-Garcia *et al.*, 2021). Recently, in a basic studyit was shown that the use of PT after induction of neonatal pneumonia cell model by lipopolysaccharide and found that PT could improve apoptosis and inflammatory response of pneumocytes by regulating the TrkA/Akt signaling pathway (Liu *et al.*, 2024), which also and can support our view. However, since the present study was not conducted in vitro, further studies on the specific mechanism of action of PT are needed. However, the use of PT in implant surgeries has been associated with increased cardiac stress and potential safety concerns, including heightened risks of adverse cardiovascular effects (Vintanel-Moreno *et al.*, 2021). Therefore, we also tallied the adverse reactions during the

treatment process and found no statistical difference between the two groups. It can be seen that PT combined with VA/VD is also a safe SP treatment scheme. Of course, in future applications, we also need to strictly control the dosage of PT to avoid drug toxicity and side effects. In a meta-analysis by Vinnakota DN, he analyzed the safety of PT as an anesthetic reversal agent for endodontic and soft tissue surgery and the results also showed that PT does not increase the incidence of any adverse events (Vinnakota & Kamatham, 2019), which could also support the results of the current study. Finally, in the prognostic follow-up, the prognostic recurrence rate of the research group was also lower than that of the control group, indicating that the combination of PT and VA/VD also has an excellent and stable long-term control effect on SP. This is because by regulating human immune function, VA/VD can enhance the body's autonomous disease resistance, resist the invasion of external pathogens and reduce the disease recurrence rate (Lv *et al.*, 2024). PT can reduce pulmonary circulation resistance and arterial pressure, release norepinephrine and improve vasoconstriction and velocity, thereby ensuring smooth blood circulation and enhancing resistance to pathogens (Li *et al.*, 2020).

Of course, given the limited number of cases included in this study, it is still necessary to further increase the number of cases for validation. Besides, we need to incorporate more clinical data to further confirm the related factors influencing the progression of pneumonia to SP. Finally, a longer-term follow-up of the subjects in this study is also required to obtain the long-term prognostic impact of PT combined with VA/VD on SP.

CONCLUSION

Age, disease duration, infection type, CRP, anemia, malnutrition and underlying diseases are the relevant factors influencing the progression of pneumonia to SP. In the future, clinicians need to pay heed to these indicators when admitting children with pneumonia to prevent the progression to SP. The combination of PT and VA/VD is an effective treatment for SP, improving inflammatory responses and immune function in affected children. This approach shows promise for widespread clinical use and offers reliable long-term prognostic benefits.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of interest

There is no conflict of interest.

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