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Application of artificial intelligence rehabilitation assistance device combined with polymyxin in the treatment of carbapenem resistant Klebsiella pneumoniae infection

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【 **Abstract** 】 **Objective** To investigate the efficacy of artificial intelligence (AI) rehabilitation aids combined with polymyxin in the treatment of carbapenem-resistant Klebsiella pneumoniae (CRKP) infection.**Methods** Ninety cases diagnosed with CRKP infection and treated with sodium polymyxin E methanesulfonate in the Department of Critical Care Medicine of the Affiliated Hospital of Jiangnan University from 2021-12 to 2024-03 were selected and grouped according to different treatment regimens, of which 30 cases were given intravenous infusion of sodium polymyxin E methanesulfonate (Venous group, 2.5 mg/kg, q12h), 30 cases were given sodium polymyxin E methanesulfonateAtomisation group, 75 mg of sodium polymyxin E methanesulfonate was added to 3 ml of saline for inhalation q12h, and Artificial Intelligence Rehabilitation Assistive Devices (AIRAD) combined with sodium polymyxin E methanesulfonate were given to 30 cases (combined group, 75 mg polymyxin E sodium methanesulfonate in 3 ml saline nebulised inhalation, q12h; exercise rehabilitation guided with the aid of AI rehabilitation aids for 4 weeks).Nebulised inhalation, q12h; online video teaching with the help of AI rehabilitation assistive devices to achieve remote-assisted exercises and guide exercise

rehabilitation for 4 weeks), comparing the inflammatory response indexes, arterial blood gas analysis indexes, bacterial clearance rate, prognostic indexes and the occurrence of adverse reactions before and after the treatment in the three groups.**Results** After treatment, the levels of serum WBC, CRP, IL-6, and PCT in the three groups were significantly lower than before treatment (P<0.05), and there was no significant difference between the groups (P<0.05). After treatment, the levels of PaCO2 in all three groups were significantly lower than before treatment (P<0.05), and the levels of PaO2 were significantly higher than before treatment (P<0.05). There was no significant difference between the groups (P>0.05). There was no significant difference in the clearance rates of carbapenem resistant Klebsiella pneumoniae among the three groups (73.33%, 80.00%, 83.33%, respectively) (P>0.05). The duration of ventilator use and ICU hospitalization in the combined group were significantly shorter than those in the intravenous group and the atomization group (P<0.05), and the duration of ventilator use and ICU hospitalization in the atomization group were significantly shorter than those in the vascular group (P<0.05). There was no significant difference in the 28 day incidence rate and mortality (46.67%, 40.00%, 33.33%, respectively), and the incidence of adverse reactions (11.11%, 6.67%, 4.44%, respectively) among the three groups (P>0.05).**Conclusion** Three different protocols for treating CRKP infection can effectively control inflammation, improve blood gas indexes, with better bacterial clearance and less damage to liver and kidney function, which is a better safety; compared with intravenous infusion treatment, nebulised inhalation treatment can significantly shorten the time of ventilator use and the number of days of ICU hospitalisation, which can promote the recovery of the patients; and AI rehabilitation assistive device combined with polymyxin treatment can further shorten the recovery process of the patients.

【**Keywords**】Carbapenem-resistant Klebsiella pneumoniae; polymyxin; lung infection; artificial intelligence; clinical efficacy

In the early 1940s, the birth of penicillin completely changed the situation of mankind's fight against infectious diseases and opened the golden age of antimicrobial drug development.During this period, the application of antimicrobial drugs significantly reduced the mortality rate due to infections [1].However, due to the misuse of antimicrobial drugs, In recent years, the issue of bacterial resistance has gradually attracted people's attention and become a major challenge to public health security in the 21st century. Currently, the spread of bacterial resistance has far

exceeded the development process of new antibiotics, which not only seriously endangers human health but also greatly increases the burden on healthcare. At present, the common drug-resistant bacteria in clinical practice in China mainly include methicillin-resistant Staphylococcus aureus (MRSA), methicillin-resistant coagulase negative Staphylococcus aureus (MRCNS), carbapenem resistant Acinetobacter baumannii (CRAB), and third-generation cephalosporin resistant Escherichia coli. Of particular note is that the detection rate of carbapenem resistant Klebsiella pneumoniae (CRKP) is currently on the rise and has become the leading carbapenem resistant Enterobacteriaceae (CRE) pathogen.Antibiotics available for clinical treatment of infections caused by CRKP strains are scarce, making CRKP infections an important cause of death from hospital-acquired infections[4].

Polymyxins belong to a family of peptide antibiotics that sterilise Gram-negative bacteria by binding to the phosphate portion of the outer membrane and disrupting the integrity of the cell membrane [5].This type of drug mainly includes polymyxin B and polymyxin E. During treatment, polymyxin, its inactive precursor, colistin methanesulfonate (CMS), is administered, which is particularly suitable for the treatment of blood borne infections [6-7]. Polymyxin E has significant therapeutic effects on infections caused by Gram negative aerobic bacteria [8], and its antibacterial spectrum can cover various types such as Clostridium, Klebsiella, and Pseudomonas aeruginosa. Although the efficacy and safety of different administration routes (such as intravenous infusion and nebulization inhalation) have been confirmed by existing research [9], there are still few reports on the effectiveness of this drug in treating carbapenem resistant Klebsiella pneumoniae infection and the liver and kidney damage it causes through different methods. At the same time, the application of artificial intelligence (AI) in the medical field is becoming increasingly widespread and gradually receiving widespread attention. It covers intelligent assisted diagnosis of medical imaging, construction of infectious disease epidemic warning systems, and disease assisted identification and diagnosis systems that integrate clinical data, genetic information, and multidimensional laboratory indicators. It has broad prospects for application in the medical field.The system of differential diagnosis of complex diseases based on clinical diagnosis and treatment data, genetic information and multi-dimensional laboratory test indicators.It is worth noting that AI technology has demonstrated significant clinical value in the field of chronic disease management, which not only optimises the diagnosis and treatment pathway, but also

opens up an innovative application paradigm in the practice of precision medicine through intelligent decision support systems, dynamic follow-up monitoring platforms, and therapeutic prognosis prediction models.Previous studies have pointed out [10] that rehabilitation AI assistive devices can promote patients' rehabilitation by guiding them to remotely assisted exercises to master exercise techniques.However, there is no report on the effect of AI rehabilitation assistive devices combined with polymyxin in the treatment of CRKP infection.In view of this, this study explores this with a view to providing a reference for the choice of treatment options for this disease.

1 Materials and methods

1.1 Basic information Ninety patients who were diagnosed with penicillin-resistant Klebsiella pneumonia and treated with polymyxin E sodium methanesulfonate and had no previous history of renal insufficiency in the Department of Critical Care Medicine of Jiangnan University Hospital from 2021-12 to 2024-03 were selected. Inclusion criteria: (1) age ≥18 years; (2) compliance with the "Diagnostic criteria for hospital-acquired pneumonia" in the 2018 edition of the "Chinese Guidelines for the Diagnosis and Treatment of Hospital-acquired and Ventilator-associated Pneumonia in Adults" [11] and confirmation of carbapenem-resistant Klebsiella pneumoniae by sputum culture; and (3) drug sensitivity tests showing resistance to Polymyxin E sodium methanesulfonate; (4) receiving polymyxin E sodium methanesulfonate treatment for ≥7d; (5) signing the informed consent form. Exclusion criteria: (1) the presence of heart, liver, kidney and other important organs serious damage; (2) serious infections; (3) the presence of central neuropathy, immunodeficiency, or previous history of seizures; (4) before enrollment in other drug regimens; (5) pregnant or lactating women and other special groups. According to the different treatment plans, 30 cases were treated with intravenous infusion of polymyxin E sodium methanesulfonate (Venous group), 30 cases were treated with nebulised inhalation of polymyxin E sodium methanesulfonate (Atomisation group), and 30 cases were treated with artificial intelligence rehabilitation assistive device combined with nebulised inhalation of polymyxin E sodium methanesulfonate (combined).The Venous group consisted of 17 males and 13 females, with ages ranging from 22 to 78 (49.93±3.52) years old; body mass index (BMI) of (22.71±2.82) kg/m2; and comorbidities: chronic obstructive pulmonary disease (COPD) in 11 cases, cerebrovascular disease in 7 cases, diabetes mellitus in 5 cases, lung cancer in 4 cases, and

interstitial pneumonitis in 3 cases.The Atomisation group had 18 males and 12 females, aged 27-74 (50.32±3.45) years, with a BMI of (23.05±2.77) kg/m2, and comorbidities: chronic obstructive pulmonary disease (COPD) in 12 cases, cerebrovascular disease in 8 cases, diabetes mellitus in 5 cases, lung cancer in 3 cases, and interstitial pneumonitis in 2 cases.The combined group had 19 males and 11 females, aged 28-72 (50.32±3.45) years, with a BMI of (23.05±2.77) kg/m2.In the combined group, there were 19 male and 11 female patients; their ages ranged from 28 to 72 (50.45±3.61) years; their BMIs were (23.24±2.69) kg/m2; and their comorbidities were: chronic obstructive pulmonary disease (COPD) in 13 cases, cerebrovascular disease (CVD) in 8 cases, diabetes mellitus (DM) in 4 cases, lung cancer (LCC) in 3 cases, and interstitial pneumonitis in 2 cases.The difference between the general information of the three groups was not statistically significant (P>0.05) and was comparable (Table 1).The study was reviewed and approved by the Medical Ethics Committee of Jiangnan University Hospital.

Table 1 Comparison of general information between the three groups

groups	Sex (m/f)	Age (years)	BMI （kg/m^2）	complication				
				COPD	cerebrovascular disease	diabetes	lung cancer	interstitial pneumonia
Venous group （n=30）	17/13	49.93±3.52	22.71±2.82	17	7	5	4	3
Atomisation group （n=30）	18/12	50.32±3.45	23.05±2.77	12	8	5	3	2
combined group （n=30）	19/11	50.45±3.61	23.24±2.69	13	8	4	3	2
χ^2/F	0.278	0.177	0.284			0.219		
P	0.870	0.838	0.754			0.956		

1.2 methods Collate all patients' basic information (including age and gender), clinical

information (e.g., history of traumatic surgery, hospitalisation within 90 days, history of antibiotic use, use of immunosuppressive therapies, retention of central venous catheters, retention of urinary catheters, haemodialysis and continuous renal replacement therapy, history of mechanical ventilation, length of time from admission to positive sputum culture), complications (e.g., diabetes, cardiovascular disease, vital organ-related diseases, central nervous system diseases, malignancy, etc.), and laboratory tests (e.g., diabetes, cardiovascular disease, vital organ-related diseases, central nervous system diseases, malignancy).(length of time, as well as length of antibiotic course and length of hospital stay), complications (e.g., diabetes mellitus, cardiovascular diseases, diseases related to vital organs, diseases of the central nervous system, malignant tumours, etc.), as well as data from laboratory tests and microbiological examinations.In the intravenous group, polymyxin E sodium methanesulfonate (Zhengda Tianqing Pharmaceutical Group Co., Ltd., State Pharmaceutical License No. H20213773, specification: 150 mg) was given to the intravenous infusion treatment, with the dosage method: 2.5 mg/kg, q12h; the nebulisation group was given to the nebulisation inhalation treatment of polymyxin E sodium methanesulfonate, with the dosage method: 75 mg of polymyxin E sodium methanesulfonate added to 3 ml of saline nebulisation and inhalation, q12h.The combination group was given artificial intelligence rehabilitation assistive device combined with polymyxin E sodium methanesulfonate nebulised inhalation treatment.Sodium polymyxin E methanesulfonate nebulised inhalation treatment was the same as that in the nebulised group.Artificial intelligence rehabilitation aids were adopted from the AI rehabilitation aids researched by the Affiliated Hospital of Xuzhou Medical University, including smart bracelets, Bluetooth transmission devices and camera equipment, and the use of this equipment for exercise rehabilitation adhered to the principle of phased rehabilitation: (1) bed rest was the mainstay during the acute infection period, and combined with respiratory training to prevent the decline of lung function.(2) Gradually increase low-intensity aerobic exercise (seated resistance training) during the recovery period, and control the heart rate at 50-70% of the maximum heart rate.(3) Strengthen muscle strength and endurance training during the stabilisation period, combined with balance training to prevent falls.With the help of AI rehabilitation assistive devices, the patients were instructed to carry out abdominal breathing, sitting resistance training, muscle strength and endurance training, and balance training through online video teaching for 4 weeks.During the training process, the AI bracelet combines abdominal breathing training, sitting

resistance training, balance training, and muscle strength and endurance training, and provides action comparison feedback to improve the patient's learning efficiency.The Bluetooth transmission device is used to unite the bracelet with the cloud/local device to achieve real-time data transmission and remote monitoring.It also supports cross-platform operation (e.g., Android, iOS), ensuring that healthcare professionals can access data via mobile or PC.Uses a camera to capture patient training movements, combines with AI vision algorithms to analyse movement standards and provide real-time corrective feedback.The virtual trainer instructs the patient in the form of a sketch of the human body structure, avoiding the risk of privacy leakage.

1.3 Observation indicators (1) Inflammatory indicators. Five millilitres of peripheral venous blood was drawn from all patients before treatment and one week after the end of treatment, and serum was separated using a centrifuge at room temperature. A fully automatic biochemical analyser was used to determine the white blood cell count (WBC), an enzyme-linked immunosorbent assay (ELISA) kit and a multifunctional enzyme marker were used to detect and calculate the expression level of interleukin-6 (IL-6) in the patients' serum, and the level of C-reactive protein (CRP) in the patients was determined using immunoturbidimetric assay, and the level of procalcitoninogen (PCT) was determined using immunofluorescence. (2) Arterial blood gas indicators. Arterial blood was drawn before and after treatment and the levels of arterial partial pressure of carbon dioxide (PaCO2) and arterial partial pressure of oxygen (PaO2) were determined by clinical blood gas analysis. (3) Bacterial clearance rate. Based on the results of bacterial culture through sputum or bronchoscopic lavage fluid samples in the post-treatment review, the assessment criteria were divided into three cases: clearance, non-clearance and replacement. Clearance refers to the failure to culture CRKP after treatment; uncleared means that CRKP can still be cultured after treatment; and replacement refers to the culture of new causative organisms even though CRKP cannot be detected. (4) Prognostic indicators. The duration of ventilator use, 28-day morbidity and mortality rate, and ICU stay were recorded in both groups. (5) Adverse reactions. Record any abnormal changes in liver and kidney function related indicators such as nausea, vomiting, elevated transaminase or creatinine levels.

1.4 statistical processing SPSS26.0 statistical software was used to process the data. Measurement data were expressed as（$\bar{x} \pm s$）, Perform independent sample t-test between groups

and paired sample t-test within groups; The count data is analyzed using the chi square test, while the stratified data is analyzed using the rank sum test. P<0.05 is considered statistically significant.

2 Results

2.1 Comparison of the levels of inflammatory indexes between the three groups the levels of serum WBC, CRP, IL-6 and PCT in the three groups after treatment were significantly reduced compared with those before treatment ($P<0.05$) See Table 2.

Table 2 Comparison of the levels of inflammatory indicators between the three groups（$\bar{x}\pm s$）

groups	example	WBC（10^9/L）		CRP（mg/L）		IL-6（pg/ml）		PCT（ng/ml）	
		pre-treatment	post-treatment	pre-treatment	post-treatment	pre-treatment	post-treatment	pre-treatment	post-treatment
Venous group	30	19.63±8.74	12.31±4.28*	74.81±9.78	25.64±3.50*	41.56±5.67	15.36±3.20*	7.35±1.08	1.04±0.15*
Atomisation group	30	18.67±5.24	11.90±3.97*	75.04±8.96	24.71±3.42*	42.15±4.98	14.97±3.15*	7.29±1.06	1.02±0.13*
combined group	30	18.92±7.85	11.34±4.15*	75.25±9.37	23.97±3.28*	42.20±5.19	14.75±4.07*	7.33±1.10	1.00±0.12*
F		0.135	0.416	0.017	1.816	0.136	0.234	0.024	0.669
P		0.874	0.661	0.984	0.169	0.873	0.792	0.976	0.515

Note: Comparison with pre-treatment.*$P<0.05$

2.2 Comparison of arterial blood gas analysis indexes between the three groups PaCO2 levels in both groups in post-treatment were significantly lower than those in pre-treatment (P<0.05), and PaO2 levels were significantly higher than those in pre-treatment (P<0.05). elevated (P < 0.05), and no significant difference was seen in the comparison between groups (P > 0.05). See Table 3.

Table 3 Comparison of arterial blood gas analysis indicators between the three groups（$\bar{x}\pm s$，mmHg）

groups	examples	$PaCO_2$		PaO_2	
		pre-treatment	post-treatment	pre-treatment	post-treatment
Venous group	30	55.10±8.23	47.56±6.78*	69.53±13.85	84.97±8.62*
Atomisation group	30	54.78±7.86	46.91±6.55*	70.14±12.69	85.32±9.04*
combined group	30	55.24±9.24	46.28±6.37*	70.26±12.58	86.12±10.20*
F		0.023	0.285	0.027	0.120
P		0.977	0.753	0.973	0.887

Note: Comparison with pre-treatment.*$P<0.05$

2.3 Comparison of bacterial clearance rate between the three groups The clearance rate of the intravenous injection group was 73.33% (22/30), the nebulization group was 80.00% (24/30), and the combination group was 83.33% (25/30). There was no significant difference in the total clearance rate among the three groups ($P>0.05$). See Table 4.

Table 4 Comparison of bacterial clearance rates between the three groups

groups	examples	get rid of	as yet unsettled	interchangeability	Clearance（%）
Venous group	30	22	8	0	73.33
Atomisation group	30	24	6	0	80.00
combined group	30	25	5	0	83.33
χ^2					0.934
P					0.627

2.4 Comparison of prognostic indicators between the three groups The ventilator use and hospitalization time in ICU of the combined group were shorter than those of the intravenous group and the atomization group (P<0.05). The ventilator use and hospitalization time of the atomization group were significantly faster than those of the intravenous group (P<0.05). There was no significant difference in the 28 day incidence rate and mortality of the three groups (P>0.05). See Table 5.

Table 5 Comparison of prognostic indicators between the three groups

groups	examples	Duration of ventilator use (d)	Length of ICU stay （d）	28-day morbidity and mortality rate[n(%)]
Venous group	30	18.42±3.30	19.64±4.15	14（46.67）
Atomisation group	30	15.89±2.94*	16.52±3.68*	12（40.00）
combined group	30	11.91±3.05*#	12.83±3.41*#	10（33.33）
F/χ^2		33.615	24.672	1.111
P		＜0.001	＜0.001	0.574

Note: Comparison with intravenous group, *P<0.05; comparison with nebulised group, #P<0.05

2.5 Comparison of the occurrence of adverse reactions in the three groups There were 3 cases of liver dysfunction and 2 cases of kidney dysfunction in the intravenous injection group, 2 cases of liver dysfunction and 1 case of kidney dysfunction in the nebulization group, and 2 cases of liver dysfunction in the combination group, but there was no significant difference between the groups (P>0.05). See Table 6.

Table 6 Comparison of the incidence of adverse reactions between the three groups [n (%)]

groups	examples	ALT overload	AAT exceeded	Cr exceeded	rate of occurrence
Venous	30	2（4.44）	1（2.22）	2（4.44）	5（11.11）

group					
Atomisation group	30	1（2.22）	1（2.22）	1（2.22）	3（6.67）
combined group	30	1（2.22）	1（2.22）	0（0.00）	2（4.44）
χ^2					0.129
P					0.720

3 Discussion

Klebsiella pneumoniae (CRKP) can cause serious hospital-acquired infections, especially respiratory tract infections.In the past, carbapenem antibiotics were regarded as the last resort for the treatment of this bacterium, but with the overuse of antibiotics, drug-resistant strain CRKP has gradually increased and become epidemic in multiple outbreaks.It is now believed that controlling CRKP infection is difficult and the morbidity and mortality rates are high, making it an important risk factor for nosocomial mortality.The mechanisms of resistance of CRKP to carbapenem antibiotics are complex and varied[12].Due to the complexity and diversity of resistance mechanisms, it is necessary to pay timely attention to the characteristics of local resistance mechanisms of CRKP to guide clinical medication.

Currently, treatment options for CRKP strains are quite limited.CRKP has shown resistance to almost all antibiotics except tigecycline and polymyxin.The use of single agents remains limited due to renal and neurotoxicity issues; also, unsuccessful tigecycline therapy has been reported.Polymyxin, an early non-ribosomal antibiotic, was widely used in clinical treatment against gram-negative bacteria.Its main antimicrobial mechanism is to achieve bactericidal effect by binding to lipoproteins on the bacterial cell membrane and destroying the integrity of the cell [13].However, due to its narrow antibacterial spectrum and obvious toxic side effects, it has been gradually replaced by other drugs.However, with the increase of multi-drug resistant gram-negative bacterial infections globally, polymyxins have received renewed attention as the last line of defence in the treatment of gram-negative bacteria.Overseas studies have found [14] that even if in vitro drug sensitivity tests show resistance to polymyxins, polymyxin-based combination therapy is still an effective treatment option.Polymyxin-based antimicrobials include

polymyxin B sulfate, polymyxin E sodium methanesulfonate, and polymyxin E sulfate [15-16].

This study found that after treatment, the levels of serum white blood cells, CRP, IL-6, and PCT in the three groups were significantly lower than before treatment, while the levels of PaCO2 were significantly reduced and the levels of PaO2 were significantly higher than before treatment. Further research found that the clearance rate of carbapenem resistant Klebsiella pneumoniae in the intravenous injection group was 73.33%, the clearance rate of carbapenem resistant Klebsiella pneumoniae in the atomization group was 80.00%, and the clearance rate of carbapenem resistant Klebsiella pneumoniae in the combined group was 83.33%. There was no significant difference in the total clearance rate, 28 day incidence rate and mortality among the three groups. The above treatment plans for carbapenem resistant Klebsiella pneumoniae infection can control inflammation, improve blood gas indicators, and have better bacterial clearance effects, with comparable efficacy.The reason for this may be related to the fact that all three groups of patients were treated with the same drug, so there was no significant difference in the effects of different administration methods on the control of inflammation, the improvement of blood gas indexes and bacterial clearance effects.However, this study found that the ventilator use time and ICU hospitalisation time of the combined group and nebulised group were significantly shorter than those of the intravenous group, in which the ventilator use time and ICU hospitalisation time of the combined group were significantly shorter than those of the other two groups, suggesting that the rehabilitation effect of AI rehabilitation assistive device combined with nebulised use of polymyxin in the treatment of carbapenem-resistant Klebsiella pneumoniae infections is most ideal, and that the rehabilitation of polymyxin E sodium methanesulphonate nebulised inhalation treatmenteffect was superior to intravenous administration.The reasons for the analysis are: (1) Nebulised inhalation therapy uses a nebulising device to convert the drug (solution or powder) into tiny droplets or particles, so that it is suspended in the gas and enters the respiratory tract and lungs to achieve the therapeutic purpose.Compared with the traditional method of medication administration, the administration of medication by nebulisation inhalation enables the medication to reach the affected area directly, which can achieve a higher concentration of medication in the lungs, and the medication can act rapidly and directly on the lesion, which not only can effectively control the infection and colonisation, but also avoids a variety of adverse reactions that may be caused by systemic medication [17].The concentration of polymyxin in sputum specimens given by

nebulisation with sodium polymyxin methanesulphonate for inhalation is relatively higher than that of intravenous drip, and the therapeutic utilisation and drug targeting index of nebulised inhalation with sodium polymyxin methanesulphonate for inhalation are significantly greater than 1 [18], resulting in a more desirable drug efficacy.In addition, nebulised inhalation therapy has the advantage of a small dose of medication [19].Intravenous infusion is a traditional way of drug delivery, and due to the physicochemical properties of the drug and the characteristics of the host's anatomical structure, the infected site often fails to achieve an effective antimicrobial concentration, which in turn affects the therapeutic efficacy or even leads to therapeutic failure [20].(2) AI can play an important role in rehabilitation process assessment, respiratory function assessment, respiratory exercise modelling and personalised rehabilitation programme design [21], and can dynamically assess the recovery of lung function in CRKP-infected patients by analysing their physiological data (e.g. heart rate, oxygen saturation) and exercise performance (e.g. gait, respiratory pattern); at the same time, an AI-supported respiratory training system can be used to analyse patients'At the same time, the AI-supported respiratory training system can quantify the improvement of lung capacity by analysing the depth and frequency of the patient's abdominal breathing and lip-contracted breathing; with the help of AI rehabilitation assistive devices to achieve remote assisted exercise, the online video teaching to guide patients to carry out abdominal respiration, seated resistance training, muscular strength and endurance training as well as balance training not only remotely monitors the patient's exercise data and physiological indexes, providing real-time feedback, but also plays a role in assisting to improve the respiratory function, reduce the long-termIt can also assist in improving respiratory function, reducing long-term bed-ridden complications, regulating patients' immune status, and predicting the risk of immune diseases [22], all of which can play an auxiliary role in the recovery of CRKP infections, thus improving the rehabilitation effect, shortening the rehabilitation process, and improving the prognosis.This study also found that all three groups of patients had a small number of adverse reactions, mainly manifested as liver and kidney function impairment, but the incidence of adverse reactions was low in all three groups, suggesting that the safety of all of them was satisfactory.(3) AI rehabilitation assistive device combined with nebulisation using polymyxin to treat carbapenem-resistant Klebsiella pneumoniae infection can reduce the side effects of antibiotics, shorten the duration of the patient's illness and prevent recurrence.On the basis of drug treatment,

combined with AI exercise rehabilitation can enhance the anti-infection ability by regulating the state of the whole body, in which the strength training and balance training can improve the muscle strength and cardiopulmonary endurance, reduce the risk of lung infection caused by long-term bed rest, and the flexibility training can improve the blood circulation and promote the penetration of drugs in the infected area and tissue repair.Exercise with the help of AI rehabilitation assistive devices can relieve anxiety and depression by releasing endorphins, enhance patients' adherence to treatment, and thus improve the therapeutic effect, thus playing a synergistic role.In addition, with the help of AI rehabilitation assistive device to carry out exercise can formulate individualised rehabilitation plan for CRKP infected patients, for patients in the acute stage can be combined with drugs, supplemented by low-intensity exercise (e.g., bed activities) to maintain the basic metabolism; for patients in the recovery stage can gradually increase aerobic and strength training, combined with drug adjustments in order to consolidate the efficacy of the treatment, so there is a synergistic effect.

In summary, three different protocols for the treatment of CRKP infection can effectively control inflammation, improve blood gas indexes, with better bacterial clearance and less damage to liver and kidney functions, which is a better safety profile; compared with intravenous infusion treatment, nebulised inhalation treatment can significantly shorten ventilator use time and ICU hospital days, which can promote patients' recovery; and AI rehabilitation assistive device combined with polymyxin treatment can promote patients' recovery by reducing the number of antibioticThe combination of AI rehabilitation assistive device and polymyxin therapy can further improve the rehabilitation effect by reducing antibiotic side effects, shortening the duration of disease and preventing recurrence, so it has a synergistic effect and is worth promoting.

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