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Clinical Application of Imaging Navigation Technology in the Treatment of Pulmonary Tuberculosis

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Abstract: *Objective:* To observe the guiding role of image navigation technology in the treatment of patients with tuberculosis. *Methods:* A total of 188 patients with multidrug-resistant tuberculosis (MDR-TB) and rifampin-resistant tuberculosis (RR-TB) who were hospitalized in the hospital from September 2023 to September 2024 were included. After random equal division, 94 patients were included in the control group and received systemic anti-tuberculosis chemotherapy; 94 patients were included in the treatment group. Based on systemic anti-tuberculosis treatment, digital subtraction angiography (DSA) technology was used to inject targeted drugs into the bronchial lumen through bronchoscopy to complete anti-tuberculosis treatment. The changes in sputum bacteria and imaging were observed in the two groups. *Results:* The sputum negative conversion rate in the treatment group was significantly higher than that in the control group (86.2%; 70.2%) ($u=2.74$, $P<0.01$). The absorption rate of CT imaging lesions (significant absorption) was significantly higher than that of the control group (83.0%; 50%) ($u=2.45$, $P<0.05$). The closure rate of chest CT cavities was significantly higher than that of the control group (74.2%; 39.1%) ($u=2.20$, $P<0.05$). During the treatment process, the improvement of clinical symptoms was significantly higher than that of the control group, and the difference was statistically significant. There was no statistically significant difference in the incidence of adverse reactions between the two groups ($x^2=0.434$, $P>0.05$). *Conclusion:* Based on DSA, targeted drug infusion within the bronchoscope can significantly improve the efficacy of the disease, with mild adverse reactions that patients can tolerate. It is worthy of promotion and application.

Keywords: Image navigation; DSA; Bronchoscopy; Targeted infusion therapy; MDR-TB; RR-TB

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1. Introduction

MDR-TB/RR-TB is a type of tuberculosis disease that is more complex and difficult to treat. This disease is relatively contagious, poses a higher risk of death for patients, and has a poor long-term prognosis, with cavitary

tuberculosis being the most critical condition [1]. According to statistics from the World Health Organization (WHO), there were 400,000 cases of multidrug-resistant and rifampicin-resistant tuberculosis (MDR/RR-TB) globally in 2023, accounting for an estimated 44% of MDR-TB/RR-TB incidence, but the treatment success rate reached 68% [2]. However, based on clinical data from China in 2020, the success rate of second-line anti-tuberculosis treatment for MDR-TB/RR-TB was 51%, which is lower than the global level [3].

Currently, systemic anti-tuberculosis treatment remains the common chemotherapy for patients with MDR-TB/RR-TB, which can prevent the spread of tuberculosis lesions, but its treatment specificity is general. Bronchoscopy is a new type of equipment with a high application rate. Local infusion therapy using this instrument is the latest treatment for MDR-TB/RR-TB, which can improve the absorption rate of lesions and achieve better long-term efficacy. To ensure the accuracy of infusion therapy, guiding techniques such as DSA are often used, which can leverage the treatment advantages of high-precision equipment. Therefore, this study selected 188 patients with MDR-TB/RR-TB to evaluate the specific efficacy of continuous infusion of targeted drugs into the bronchoscopic cavity under the premise of DSA.

2. Materials and methods

2.1. Selection criteria

Inclusion criteria: (1) Determined by relevant standards such as "Diagnosis of Pulmonary Tuberculosis (WS+288-2017)"; (2) Drug sensitivity testing can confirm MDR-TB/RR-TB; (3) Meet multiple examination indications for bronchoscopy and can tolerate this operation throughout the process.

Exclusion criteria: (1) Significant other types of lung lesions; (2) Multiple important organs with abnormal functions; (3) Immune diseases; (4) Critical underlying diseases with a survival period of less than 6 months; (5) Accompanied by other serious infections; (6) Have a history of allergy to the drugs involved in the study; (7) Withdraw voluntarily in the middle of the study.

2.2. General information

One hundred and eighty-eight patients with MDR-TB/RR-TB who received inpatient treatment between September 2023 and September 2024 were selected. Randomly divided equally, the basic information between groups is as follows:

Table 1. Comparison of basic data between the two groups of patients (n/%, X+S)

Group	Number of Cases	Gender		Ages(years)		Duration of Disease (years)	
		Male	Female	Range	Mean	Range	Mean
Treatment group	94	45(47.9)	49(52.1)	16-61	31.28±4.17	1-5	4.39±1.48
Control group	94	52(55.3)	42(44.7)	17-55	31.60±4.25	1-6	4.80±1.41
x2/t		1.044		0.521		1.945	
P		0.307		0.603		0.053	

2.3. Treatment methods

The control group underwent systemic anti-tuberculosis chemotherapy. Based on the patient's medication history and drug sensitivity test results, drug resistance was confirmed using tuberculosis mycobacterium

identification and drug resistance gene testing (tNGS) based on ultra-multiple PCR and next-generation sequencing technology. This project can identify five species of Mycobacterium tuberculosis complex. With full coverage of first and second-line anti-tuberculosis drugs, there are 16 types of treatment drugs to choose from. Following the "Guidelines for Chemotherapy of Drug-Resistant Tuberculosis," the ABC group anti-treatment plan was selected to rationalize the types of medications used. Patients underwent intensive chemotherapy for 6 months, with a total treatment course of 18–20 months.

The treatment group, based on DSA technology, received bronchial infusion of targeted drugs through bronchoscopy. Patients completed various pre-surgical examinations and were positioned in a supine position, with local anesthesia applied to the throat. The specific location and scope of the cavity lesion were identified based on chest CT and other results. Guided by an X-ray system, a bronchoscope was slowly inserted, and the position of the scope was evaluated using catheter navigation technology. A catheter was gently inserted through the working channel, and when small bronchi (levels 6 to 8) were visible, a mixed contrast solution (povidone-iodine combined with lidocaine) was administered in a dose of 5 to 10 ml for local angiography of the lesion area. The contrast agent flowed smoothly into the lesion site or cavity, allowing multi-dimensional and multi-level evaluation of the lesion. Then, 4–6 ml of a combination agent containing levofloxacin, isoniazid, and amikacin (all conventionally used drugs in our hospital) was injected (calculated based on the size of the lesion and cavity) [4, 5]. The catheter was gently removed, and the bronchoscope was withdrawn. Patients were required to maintain an anti-reflux position and were observed for 30 minutes, during which violent coughing was prohibited to prevent medication reflux. This therapy was administered once a week, with one cycle consisting of 4 weeks.

2.4. Observation items

(1) Sputum negative conversion rate: Observed at 3/6/12/18 months after treatment. After molecular biological detection or culture of sputum bacteria, two consecutive negative results without reversion to positive indicate a negative conversion.

(2) Lesion absorption rate: Evaluated after 18 months of treatment. Significant absorption is defined as the absorption of the existing lesion compared to the original lesion being no less than 1/2; absorption refers to the specific absorption of the lesion not reaching 1/2; unchanged indicates no change in the lesion scope; deterioration signifies lesion dissemination or area expansion.

(3) Cavity changes: Evaluation will be conducted during the same time period. Closure is defined as the absence of a cavity; reduction is defined as a decrease in cavity diameter by no less than 1/2; no change is defined as a cavity diameter decrease or increase of less than 1/2; and enlargement is defined as an increase in cavity size by more than 1/2.

(4) Improvement of clinical symptoms: Observation of improvement rates of symptoms such as fever, cough, and expectoration.

(5) Adverse reaction rate: Observation of the occurrence probability of fever, minor hemoptysis, tracheal dissemination, and pneumothorax.

2.5. Efficacy evaluation

Efficacy is judged based on the revised efficacy evaluation criteria from the 1982 National Tuberculosis Prevention and Control Work Conference, with the main indicator being the negative conversion of tuberculosis bacteria [6]. Changes in tuberculosis imaging can be evaluated based on sputum bacteria, lesions, and cavities.

2.6. Statistical processing

Statistical methods employed SPSS 19.0 statistical software for data processing. Measurement data were expressed as (4-S) and analyzed using two independent sample t-tests. Count data were analyzed using the chi-square test, and ordinal data were examined using the rank sum test. A *P*-value less than 0.05 was considered statistically significant.

3. Results

3.1. Sputum negative conversion rate in both groups

The sputum negative conversion rate at 18 months was higher in the treatment group than in the control group ($P < 0.05$).

Table 1. Sputum negative conversion rate in both groups (n/%)

Group	Number of cases	3 months	6 months	12 months	18 months
Treatment group	94	54(57.4)	62(66.0)	72(76.6)	81(86.2)
Control group	94	43(45.7)	53(56.4)	61(64.9)	66(70.2)
x^2		2.577	1.814	3.110	7.018
P		0.108	0.178	0.078	0.008

3.2. Lesion absorption rate in two groups

The significant lesion absorption rate in the treatment group at 18 months was higher than that in the control group ($P < 0.05$).

Table 2. Lesion absorption rate in two groups (n/%)

Group	Number of cases	Significant absorption	Absorption	No absorption	Deterioration
Treatment group	94	78(83.0)	8(8.5)	7(7.4)	1(1.1)
Control group	94	47(50.0)	36(38.3)	7(7.4)	4(4.3)
x^2		22.942	23.263	0.000	1.849
P		0.000	0.000	1.000	0.174

3.3. Changes in cavity status between the two groups

The cavity closure rate in the treatment group at 18 months was higher than that in the control group ($P < 0.05$).

Table 3. Changes in cavity status between the two groups (n/%)

Group	Number of cases	Closure	Reduction	No change	Deterioration
Treatment group	31	23(74.2)	4(12.9)	3(9.7)	1(3.2)
Control group	23	9(39.1)	5(21.7)	6(26.1)	3(13.0)
x^2		6.724	0.742	2.560	1.856
P		0.010	0.389	0.110	0.173

3.4. Improvement of clinical symptoms in both groups

The improvement of clinical symptoms in the treatment group was better than that in the control group ($P < 0.05$).

Table 4. Improvement of clinical symptoms in both groups (n/%)

Group	Improvement in fever	Improvement in cough	Improvement in expectoration	Improvement in chest pain	Improvement in dyspnea
Treatment group	100．O(35/35)	85．9(73/85)	87．3(69/79)	83.9(26/31)	95．2(40/42)
Control group	71．1(37/52)	56．2(50/89)	57．1(48/84)	53．1(17/32)	70．0(21/30)
x^2	12.200	18.513	18.329	6.870	8.612
P	0.001	0.000	0.000	0.009	0.003

3.5. Adverse reaction rates in both groups

The adverse reaction rate in the treatment group was lower than that in the control group ($P < 0.05$).

Table 5. Adverse reaction rates in both groups (n/%)

Group	Number of cases	Fever	Minor hemoptysis	Tracheobronchial dissemination	Pneumothorax	Incidence rate
Treatment group	94	4(4.3)	2(2.1)	2(2.1)	0	8.5(8/94)
Control group	94	7(7.4)	5(5.3)	5(5.3)	1(1.1)	19.1(18/94)
x^2						4.463
P						0.035

4. Discussion

Currently, there are many types of anti-tuberculosis drugs, and their indications and clinical efficacy vary, making improper medication usage prone to occur, thereby increasing the risk of MDR-TB/RR-TB. Additionally, as the course of tuberculosis prolongs, the treatment regimens required by patients become increasingly complex, which can also lead to drug resistance, further increasing the difficulty of treating the disease [7]. Various reasons have led to a gradual increase in the proportion of drug-resistant tuberculosis, which has a low cure rate. Patients often experience recurrent infections. If accompanied by severe tissue damage, it can also lead to significant fibrous tissue hyperplasia, reducing the blood vessel content in the affected area, thereby affecting the blood circulation state, reducing the absorption rate of therapeutic drugs, and significantly reducing their efficacy [8, 9]. Coupled with the emergence of multidrug resistance in patients, it can cause excessive reproduction of pathogenic bacteria in the cavitary lesion area, resulting in a large amount of liquefied caseous necrosis-like material adhering to the cavity wall, causing the number of mycobacteria to rise rapidly and present a highly active reproductive state [10].

Within the cavitary lesion, the drug concentration is relatively low, making it impossible to achieve a bacteriostatic effect, and various administration routes, such as intravenous infusion or oral administration, cannot achieve optimal efficacy. Typically, systemic chemotherapy combined with bronchoscopic local interventional therapy can provide targeted treatment for lesions. Specific analysis: Bronchoscopy can accurately remove the accumulated purulent secretions in the trachea, completely suck away the caseous

necrosis, and accurately remove the hyperplastic tissue in the area, thereby cleaning the pathogenic bacteria and relieving symptoms such as airway obstruction. With the help of drainage, bronchoscopy can reduce the degree of mucosal swelling, relieve airway stenosis, and close cavitary lesions. Continuous drainage can promote the conversion of sputum bacteria to negative. Slow infusion of drugs can significantly increase the blood drug concentration in the lesion area, allowing the drug components to fully contact the pathogenic bacteria, thereby blocking their growth process. Bronchoscopy treatment can precisely infuse drugs into the lesion site using this method, increasing the drug concentration at the lesion site and enhancing the treatment effect.

In recent years, interventional therapy utilizing bronchofiberscopy has emerged as a novel treatment approach for MDR-TB/RR-TB. This method accurately delivers therapeutic drugs, enhancing drug concentration in the lesion area, thereby achieving efficient bactericidal effect and controlling the patient's condition. However, bronchoscopy insertion bears a certain degree of blindness, which may hinder precise positioning, leading to issues such as positioning deviation or repeated positioning. Image-guided bronchoscopy for precise infusion therapy of pulmonary tuberculosis lesions offers a new treatment option for drug-resistant tuberculosis. After injecting a contrast agent into the bronchi for comparison, the lesions can be observed from multiple angles using imaging navigation technology. This allows dynamic observation of the entire interventional process under direct vision, guiding precise positioning of the bronchoscope and enabling precise infusion therapy of the lesions. This significantly increases the local drug concentration in pulmonary lesions, enhancing the direct contact between anti-tuberculosis drugs and drug-resistant *Mycobacterium tuberculosis*, effectively inhibiting its growth. When combined with systemic medication, it provides a more effective treatment for drug-resistant tuberculosis.

In the future, this approach may offer new therapeutic options for patients with long-term bacteria excretion and persistent MDR-TB/RR-TB, especially those with cavitary tuberculosis. In this study, under the premise of DSA, multiple targeted drugs such as levofloxacin or isoniazid were infused into the bronchoscope cavity, enabling precise distribution of the drugs to the lesion area. After 18 months of treatment, the sputum conversion rate reached 86.2%, and the lesion absorption rate was as high as 91.5%. CT scans showed a cavity closure rate of 74.2% after 18 months, with significant improvement in all symptoms. There were no serious adverse reactions during the entire treatment process. Comparing multiple data points between groups, $P < 0.05$. Thus, this therapy demonstrates significant advantages in the treatment of MDR-TB/RR-TB, stabilizing patients' conditions and achieving ideal disease outcomes.

5. Conclusion

In summary, under the premise of DSA, infusion of multiple targeted drugs into the bronchoscope can enhance the overall efficacy of MDR-TB/RR-TB patients. This interventional therapy is highly feasible, favoring lesion absorption and cavity closure, with a low likelihood of causing significant adverse reactions. Patients have good tolerance for the entire treatment process.

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Disclosure statement

The authors declare no conflict of interest.

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