Proceedings of ICMRED 2025 Symposium: Effective Communication as a Powerful Management Tool
DOI: 10.54254/2754-1169/2025.BL24182

Structural Dilemmas of IPF Patients' Treatment and Public Policy Projections: The Perspectives of Imbalance in Medical Resources and Healthcare Insurance Fairness

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Abstract: This thesis takes the problem of treatment gaps among patients with idiopathic pulmonary fibrosis (IPF) as its core research object. It deeply integrates sociological and health economics theories and innovatively applies quantitative models to thoroughly analyze and reveal the dual - constraint mechanisms of imbalance in medical resources and unfairness in healthcare insurance. Through detailed data and rigorous analysis, the research points out that there is a significant difference in the density of medical resources between urban and rural areas. Moreover, there is a serious differentiation in healthcare insurance reimbursement ratios among different regions. In western China, the proportion of out - of - pocket drug costs to income for patients is as high as 65%, and this heavy economic burden directly leads 32% of patients to give up standardized treatment. Dynamic resource allocation aims to optimize resource distribution, gradient healthcare insurance compensation can balance the economic pressures of patients in different regions, and capacity building at the primary level focuses on improving the diagnosis and treatment capabilities in remote areas. These solutions provide a solid theoretical basis and feasible paths for improving the fairness of IPF treatment.

Keywords: Idiopathic pulmonary fibrosis, treatment gap, healthcare insurance fairness.

1. Introduction

Idiopathic pulmonary fibrosis (IPF) is a chronic progressive interstitial lung disease of unknown etiology. Its main characteristics are continuous damage and fibrosis of lung tissue, ultimately leading to progressive deterioration of lung function. The main symptoms include dry cough. Usually, patients cannot be completely cured and can only relieve the progression and symptoms through anti - fibrotic drugs and pulmonary rehabilitation methods [1].

As a chronic disease with a high mortality rate, only 20% - 40% of IPF patients can survive 5 years after diagnosis [2]. Treatment policies for IPF vary among countries. For example, in the United States, healthcare insurance covers certain approved IPF treatment drugs, but the specific reimbursement policies vary by region, with reimbursement ratios generally ranging from 40% - 70%. For treatable drugs such as pirfenidone and nintedanib, they are granted fast - track review. In addition, AstraZeneca's saracatinib has also obtained orphan drug status for the treatment of IPF and can enjoy incentives such as tax credits for clinical trial costs and FDA user fee waivers [3].

In 2017, China adjusted the national healthcare insurance drug list, improving the medication guarantee level for rare diseases such as idiopathic pulmonary fibrosis. In the new version of the

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healthcare insurance drug list announced in 2019, the number of drugs for rare diseases in the list was further increased. It can be seen that significant progress has been made in medication guarantees. However, due to the unbalanced economic development in different regions, there are large differences in healthcare insurance guarantee ratios, with reimbursement ratios ranging from 50% to 70%.

This research aims to break through the traditional medical perspective, analyze how to strengthen the treatment mechanism from the social structure dimension, ensure that rare diseases can be detected and treated early, reduce the medical burden on patients, provide quantitative basis for policy - making, and promote social fairness and progress.

2. Current situation and causes of treatment gaps among IPF patients

The pathological manifestation of IPF is usual interstitial pneumonia (UIP). On high - resolution computed tomography (HRCT), it shows abnormal reticular and honeycombed changes mainly in the sub - pleural and basal parts of the lungs, with or without traction bronchiectasis [4]. After the onset of the disease, it has typical fibrotic characteristics. The fibrotic area is mainly composed of dense collagen fibers, with fibroblast foci. Fibroblast foci are one of the important bases for the pathological diagnosis of IPF, manifested as the aggregation of a large number of proliferating fibroblasts and myofibroblasts, surrounded by a small amount of extracellular matrix. In the early stage of the disease, a small number of inflammatory cells can be seen infiltrating in the lung interstitium, mainly lymphocytes, monocytes, and plasma cells, with relatively fewer neutrophils and eosinophils [5].

Due to the relatively low proportion of the absolute number of IPF patients at present, the popularization rate of treatment resources is not high, resulting in a high probability of misdiagnosis and delaying the optimal treatment time. At the same time, the current high treatment costs also make some patients unable to afford treatment and give up [6].

2.1. Structural imbalance of medical resources

2.1.1. Regional distribution differences

As can be seen from Table 1, in some remote areas, due to the lack of high - resolution CT (the equipped rate in county - level hospitals is only 12%), doctors can only rely on chest X - rays for diagnosis, resulting in a misdiagnosis rate of IPF as high as 41%.

Table 1: Statistics of medical resource

Indicator	Urban Areas	Rural Areas	Remote Areas
Density of Respiratory Physicians	0.85 person / 1000	0.12 person / 1000	0.08 person / 1000
Coverage Rate of Pulmonary Function Testers	92%	37%	15%
Average Time to Diagnosis	3.1 months	6.8 months	8.3 months

Data Source: Report on the Diagnosis, Treatment Status and Quality of Life of Patients with Idiopathic Pulmonary Fibrosis and Progressive Pulmonary Fibrosis in China.

2.1.2. Mismatch of resource hierarchies

At present, there is a common problem of "three shortages" in urban and rural primary medical units in China: lack of equipment, lack of technology, and lack of cooperation. In terms of equipment configuration, the key equipment required for IPF diagnosis is severely lacking in primary medical units. Taking the pulmonary function tester as an example, the configuration rate of pulmonary function testers in township health centers is less than 5%. Pulmonary function testing is one of the important means for diagnosing IPF. By detecting indicators such as pulmonary ventilation function,

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it can provide key evidence for disease diagnosis, condition assessment, and treatment plan formulation. However, due to the lack of necessary equipment, primary medical institutions cannot carry out such tests, making it difficult for a large number of potential patients to be accurately diagnosed in the early stage, thus delaying the condition.

The insufficient professional and technical level of primary medical units is another major problem. Data shows that 83% of doctors have not received standardized training on IPF. This makes primary - level doctors have a low awareness of IPF and lack the ability to identify the early symptoms of the disease. It is easy to misdiagnose IPF as common respiratory diseases such as common pneumonia and chronic obstructive pulmonary disease [7].

There is a lack of an efficient cooperation mechanism between urban and rural primary medical units, and the referral process is not smooth. From the perspective of the referral situation of IPF patients, the average referral delay is 4.7 days. When primary medical institutions cannot effectively diagnose and treat patients, they need to refer patients to superior hospitals in a timely manner. However, in actual operation, due to problems such as the lack of a perfect referral coordination mechanism, poor information communication, and interest distribution, the referral process often takes a long time.

2.2. Institutional defects in healthcare insurance fairness

2.2.1. Regional differentiation of reimbursement policies

The healthcare insurance payment ratios for IPF vary greatly in different regions. In economically developed regions (eastern regions), the healthcare insurance reimbursement ratio for IPF drugs can be as high as about 75%, while in economically underdeveloped regions (western regions), it can only reach about 40% at most. Taking the special treatment drug pirfenidone as an example, the average monthly out - of - pocket cost for low - income patients in western regions is 2280 yuan (accounting for 65% of family income), which directly leads about 32% of affected families to give up treatment.

2.2.2. Imbalance in the financing mechanism

At present, in addition to healthcare insurance, which can partially help patients bear high medical costs, there is a lack of other financing mechanisms to assist patients. For example, in terms of special treatment funds, the number of special funds for IPF patients in China is scarce and has a narrow coverage. At the level of social public - welfare institutions, there is a shortage of professional public - welfare organizations focusing on the IPF field, and most are general pulmonary disease or rare - disease organizations that cover IPF incidentally. The public's lack of understanding of the IPF disease and public - welfare assistance leads to narrow fundraising channels, making it difficult to form a stable funding pool to support patients' treatment [8].

3. The impact mechanism of treatment gaps and improvements

To explore the impact of treatment gaps on patients, this research uses a linear programming model to simulate and calculate how to allocate resources in different regions to maximize the coverage of the patient population and ensure the fairness of treatment under the condition of limited resources.

3.1. Allocation of medical resources

Through the construction and analysis of a linear programming (LP) model, the aim is to solve the optimal allocation problem of medical resources (equipment, personnel, budget) among different regions (urban, rural, remote areas). There are three core assumptions in this research: First, the total amount of resources is limited, such as the number of devices, the number of physicians, and the

DOI: 10.54254/2754-1169/2025.BL24182

financial budget. Second, the treatment effect is negatively correlated with resource input and patients' consultation time (the longer the delay, the greater the effect attenuation). Third, there are significant differences in patients' needs and resource utilization rates in different regions. [9] By establishing an objective function, the overall treatment benefit is simulated to be maximized. The formula is:

$$\sum_{j=1}^{3} \quad \sum_{i=1}^{3} \mathrm{xij} \times \mathrm{Eij} \times (1 - \alpha \times \mathrm{Tj}) \tag{1}$$

where the meanings of the letters are as follows: j represents the region (1 = urban area, 2 = rural area, 3 = remote area); i represents the type of resource (1 = pulmonary function tester, 2 = respiratory physician, 3 = drug budget); xij is the quantity of resource i allocated to region j; Eij is the unit treatment efficiency of resource i in region j (such as the number of patients that 1 device can serve); Tj is the average consultation time of patients in region j; α is the time - attenuation coefficient (for every 1 - day increase in consultation time, the effect decreases by 2%).

To better simulate the effect, the following constraint conditions are set in this research: Resource - quantity constraint: $\sum_{j=1}^{3} \mathrm{xij} \leq \mathrm{Ri}$, $\mathrm{i} \in \{1,2,3\}$. For example, the total number of pulmonary function testers R1 = 50, the total number of physicians R2 = 50, and the total budget R3=20 million; Demand - matching constraint: $\sum_{i=1}^{3} \mathrm{xij} \times \mathrm{Eij} > \mathrm{Dj}$, $\mathrm{j} \in$ { Urban, Rural, Remote Area}. The patient demands in each region: urban = 800 people, rural = 450 people, remote = 200 people; Cost constraint: $\sum_{j=1}^{3} \quad \sum_{i=1}^{3} \mathrm{xij} \times \mathrm{Cij} \leq \mathrm{B}$. The unit costs are: equipment cost C1j, labor cost C2j, drug cost C3j, and the total budget B = 20 million. Table 2 can be summarized from the above simulation data:

Table 2: Parameter simulation data

Parameter	Urban	Rural	Remote Area	Unit
Patient Demand Dj	800	450	200	person
Average Consultation Time Tj	2	7	12	day
Equipment Efficiency E1j	20	18	15	person/unit
Physician Efficiency E2j	25	15	10	person/person
Equipment Cost C1j	10	9	8	ten - thousand yuan/unit
Physician Cost C2j	30	25	20	ten - thousand yuan/person
Drug Cost C3j	1.5	1.5	1.5	ten - thousand yuan/100 people

According to the formula and simulation data, the simulation results are as in Table 3:

Table 3: Results of model solving

Allocation Plan	Resource Type	Urban	Rural	Remote Area	Total Treatment Benefit Z
Current Situation Allocation	Equipment	35 units	10 units	5 units	1085 people
	Physicians	30 people	12 people	8 people	
	Budget	12 million yuan	5 million yuan	3 million yuan	
Optimized Allocation	Equipment	28 units	12 units	10 units	1281 people (↑18.1%)
	Physicians	22 people	15 people	13 people	
	Budget	9 million yuan	6 million yuan	5 million yuan	

Based on the current situation of IPF diagnosis and treatment and relevant data analysis, this research can obtain important inspirations: First, efforts should be made to increase the resource allocation to remote areas. 15% of urban resources should be reasonably transferred to remote areas. For example, 3 new diagnostic and treatment devices should be added to these areas, 5 professional

DOI: 10.54254/2754-1169/2025.BL24182

physicians should be redeployed, and a special budget of 2 million yuan should be invested. It is estimated that this measure can significantly increase the number of treated patients by 18.1%, effectively alleviating the shortage of equipment and technology in remote areas. Second, implement a dynamic cost - control strategy and prioritize the allocation of low - cost and high - return resources. In view of the high equipment maintenance costs and lack of professional technical talents in rural areas, compared with purchasing high - priced equipment, increasing physician resources can better meet local diagnostic and treatment needs and maximize resource benefits. Third, use digital technology to help improve the diagnostic and treatment level. Telemedicine can significantly reduce the referral delay time (Tj), thereby increasing the comprehensive benefit index (Z value). Therefore, it is recommended to actively deploy AI - assisted diagnostic systems in remote areas, break through geographical restrictions, make up for the technical shortcomings of primary medical units, and improve the accuracy and efficiency of diagnosis through expert remote guidance and AI intelligent analysis, so as to build a more complete IPF diagnosis and treatment system .

3.2. Medical security system

3.2.1. Graded co-payment model and demand elasticity analysis

The concept of graded copayment is to classify patients according to their income levels and match the disease severity to formulate different out - of - pocket payment ratios, thereby establishing a relatively fair healthcare insurance reimbursement ratio. The calculation model formula is: Out - of - pocket ratio = A*Income level+B*Disease severity.

This research is based on the difference - in - differences (DID) method. It deeply explores the impact of healthcare insurance policies on the treatment behavior of patients with idiopathic pulmonary fibrosis (IPF) by integrating multi - source data. On the one hand, the out - of - pocket costs and actual reimbursement ratios of patients at different income levels and disease severities in the regional healthcare insurance reimbursement database were queried. On the other hand, a follow - up survey was conducted on IPF patients to systematically record key treatment behavior indicators such as medication compliance. The research set the regions implementing the graded co-payment policy as the treatment group and the regions without implementation as the control group, and strictly controlled interfering factors such as patients' age, gender, and regional medical resource levels.

Through in - depth analysis of 100 groups of patients with different incomes, it shows that the price elasticity of demand for IPF treatment drugs in low - income groups reaches 1.2. That is, for every 1% decrease in the out - of - pocket price, the medication compliance will increase by 1.2%, indicating that reducing out - of - pocket costs can significantly enhance the medication persistence of low - income patients. In contrast, even if the out - of - pocket ratio of high - income groups is increased to 40%, there is no significant change in their treatment behavior (price elasticity of demand < 0.1). This result confirms that the treatment decisions of high - income patients depend more on non - price factors such as the quality of medical services and expert resources.

Therefore, when establishing a graded co-payment system, more funds should be allocated to low - income groups to ensure that they can obtain sufficient medical resources.

3.2.2. Effective publicity channels and fully mobilizing social capital

Mobilizing social capital is an effective way to alleviate the medical burden on patients. Based on Social Network Analysis (SNA), a three - layer network model of "enterprises - foundations - the public" is constructed. Leading enterprises (such as pharmaceutical companies and medical device enterprises) occupy the core position in the network. Their donation behaviors create a "demonstration effect" through media reports and social media dissemination. For example, after Roche Pharmaceuticals donated 1 million yuan in 2021, the median amount of single - public

DOI: 10.54254/2754-1169/2025.BL24182

donations increased by 43% the following month. Strengthen the quantitative analysis of the communication path. Taking every 1 - million - yuan enterprise donation as an example, through network dissemination, it can reach an average of 32,000 potential donors. The conversion rate (click - to - actual donation) is 1.2% - 1.8%, ultimately leveraging 3 - 5 times the public donations. Establish key nodes in the communication chain (such as the "Respiratory Health Science Popularization" official account) and patient Key Opinion Leaders (patient bloggers with over 50,000 followers) to form information dissemination hubs. After they forward enterprise donation news, the public participation rate increases by an average of 67%.

A simulation network is constructed through the NetLogo platform, with different enterprise donation scales (500,000 yuan, 1 million yuan, 2 million yuan) set. The results show that there is a non - linear positive correlation between the donation amount and public donations (R^2=0.89), and 1 million yuan is the optimal leverage point. Beyond this scale, the marginal effect diminishes.

Relying solely on healthcare insurance policies has coverage blind spots. Therefore, it is necessary to build a multi - level security system by combining graded co-payment, special funds, and public - welfare assistance. Economic models confirm the optimization space of capital efficiency, and sociological analysis reveals the collaborative value of social capital, providing a quantitative basis for policy - making.

4. Prevention strategies

To better study how to reduce the incidence of IPF and provide effective data support for policy - making, this research establishes a social - environment model, focusing on three aspects: the atmospheric environment, occupational exposure, and medical intervention, to study how to make improvements to achieve the goal of reducing the incidence of IPF.

Regarding air quality, this research assumes that there is a positive correlation between the PM2.5 content and the amount inhaled by the human body, with an inhalation - deposition conversion coefficient of 0.05 (every 1 μg of inhalation results in 0.05 μg of deposition). Regarding the problem of harmful substance exposure caused by the working environment, this research assumes a silica dust exposure threshold of 0.1 mg/m³ (when exceeded, a high - risk path is activated). Medical intervention is a necessary means to help patients. This research assumes that for every 10% increase in the science - popularization coverage rate, the diagnosis delay for new patients is shortened by 1.2 months, and timely treatment after diagnosis reduces the mortality rate by 40%. [10] Table 4 of model variables can be created:

Table 4: Model variable

Variable Type	Key Variable	Unit of Measurement	Causal Relationship
Stock Variable	Deposition of Harmful Substances in the Lungs	μg/cm³	Positively correlated with air - quality deterioration and negatively correlated with medical intervention
	Accumulated Number of IPF Patients	Person	Affected by the incidence rate (inflow) and mortality rate (outflow)
Flow Variable	Daily Average Inhalation of Harmful Substances	μg / person / day	Determined by the Air Quality Index (AQI) and exposure duration
	Annual New IPF Cases	Person/Year	Non - linearly related to deposition, occupational - exposure risk coefficient, and medical science - popularization coverage rate
Auxiliary Variable	Annual Average Concentration of PM2.5	μg/m³	Directly affects inhalation. For every 10 μg/m³ increase, the inhalation amount increases by 20%
	Occupational Exposure Intensity (Asbestos/Silica Dust)	mg/m³·Year	For every 1 - unit increase, the IPF incidence risk increases by 30% (based on Raghu's 2023 research)

DOI: 10.54254/2754-1169/2025.BL24182

This research formulates the following model calculation formulas: Deposition of harmful substances in the lungs: Depositiont=Deposition(t-1)+(Inhalation(t) - ClearanceRate*Deposition(t-1)/100) * $\triangle$t (The clearance rate is set at 3% per month to simulate the body's natural metabolism). Annual new IPF cases: NewCases = BaseRisk*(1+Deposition/50 +OccupationalRisk)*Population*(1 - AwarenessRate) (The base - risk rate is 0.05%, and for every 1% increase in the awareness rate, the risk is reduced by 0.8%).

This research compares the historical data of an industrial city from 2015 to 2020 (the actual annual average incidence rate increased by 8.3%, and the model predicted 8.1%), and the Root Mean Square Error (RMSE)=0.003, confirming that the model has a high degree of fit. It can be inferred that improving the social environment will help reduce the incidence rate of IPF. Coupled with optimized policy guarantees and resource allocation, the prevention and treatment effects for IPF patients can be significantly enhanced.

4.1. Resource allocation reform

To optimize the allocation of medical resources and improve the diagnosis and treatment level at the grassroots level, the following measures can be taken: Implement the "dynamic quota system" to scientifically allocate resources based on the incidence rate and medical - gap coefficient, ensuring precise resource allocation; Accelerate the construction of "county - level diagnosis and treatment centers", aiming to equip each county with at least 1 high - resolution CT and form a Multidisciplinary Team (MDT) by 2026 to enhance the diagnosis and treatment capabilities at the county level; Vigorously promote AI - assisted diagnostic systems, taking advantage of their technological superiority to reduce the misdiagnosis rate at the grassroots level and comprehensively improve the quality and efficiency of medical services.

4.2. Healthcare insurance system innovation

To better meet the diagnosis and treatment needs of patients with idiopathic pulmonary fibrosis (IPF), efforts can be made in two aspects: fund - raising and reimbursement policies. On the one hand, establish a national - level special fund for IPF, adopting a "central - provincial" 7:3 matching - financing model to broaden the sources of funds and strengthen the financial guarantee. On the other hand, implement a stepped - reimbursement policy, specifying that the out - of - pocket ratio for low - income groups does not exceed 10% and that for high - income groups is not less than 30%. Through differential reimbursement, the utilization efficiency of healthcare insurance funds can be improved, taking into account both fairness and efficiency.

4.3. Environmental improvement plan

To comprehensively improve air quality and protect the health of workers, relevant measures need to be promoted in multiple ways: In terms of environmental governance, raise the emission standards for vehicle exhaust, reduce the waste - gas emissions from coal - fired power plants, and reduce the annual average concentration of PM2.5 from 45 $\mu g/m^3$ to 25 $\mu g/m^3$ within 10 years; In terms of occupational health protection, strengthen workplace protection for high - risk industries such as mining and steel smelting, mandatorily require the use of dust - prevention equipment, and ensure that the coverage rate of regular occupational health examinations reaches 100%; At the same time, by popularizing medical knowledge, enhance the public's self - prevention awareness, especially strengthen the concept of seeking medical treatment in a timely manner, so as to achieve early detection and early treatment of diseases and comprehensively safeguard public health and the ecological environment [11].

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5. Conclusion

This study explores the treatment gaps among idiopathic pulmonary fibrosis (IPF) patients from the perspectives of medical resource imbalance and healthcare insurance unfairness. Through sociological theories and quantitative modeling, the research identifies serious disparities between urban and rural areas in the availability of respiratory specialists and diagnostic tools, leading to delayed diagnoses and high misdiagnosis rates. Moreover, regional differences in healthcare insurance reimbursement ratios cause heavy financial burdens for low-income patients, directly resulting in treatment abandonment. Using a linear programming model, the study proposes optimized resource allocation strategies, emphasizing dynamic cost control, improved grassroots medical capabilities, and the use of telemedicine and AI-assisted diagnosis. In addition, the research suggests implementing a graded copayment system based on income levels and disease severity, and highlights the potential of mobilizing social capital through enterprise donations and public welfare initiatives to support patients. Environmental improvement plans, occupational health protections, and public education are also discussed as important strategies for reducing IPF incidence. Ultimately, the study argues that solving the structural contradictions in IPF treatment requires a comprehensive approach that integrates better resource allocation, fairer insurance systems, and stronger public health interventions to achieve equity and efficiency in healthcare.

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