REVIEW

Establishment of tiered diagnosis and treatment system and prevention and control framework for chronic obstructive pulmonary disease

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ABSTRACT

Chronic obstructive pulmonary disease (COPD), the third leading cause of death globally, is characterized by persistent airflow limitation. In China, the prevalence among individuals aged 40 and above reaches 13.7%, with a noticeable trend toward younger groups. However, inadequate screening rates at the primary healthcare level and delayed diagnosis pose significant challenges. Researches have indicated that standardized screening questionnaires combined with AI-assisted lung function interpretation technology can enhance the efficiency of early diagnosis. Treatment requires individualized medication combined with non-pharmacological interventions (health education, telemedicine, and smart inhalation devices) to enhance the adherence and the symptom control. In terms of management, the community-based primary healthcare system, home oxygen therapy, and multidisciplinary pulmonary rehabilitation programs can shorten the hospitalization duration during acute exacerbations and then improve outcomes. The findings indicate that an integrated strategy combining early screening, tiered diagnosis and treatment, digital management and community-family collaboration is key to reducing disability and mortality rates from COPD. In the future, it is needed to focus on strengthening primary healthcare capabilities and implementing evidence-based precision interventions to drive a shift from "passive treatment" to "proactive healthcare management," thereby alleviating socioeconomic burdens.

Key Words: Chronic obstructive pulmonary disease, Tiered diagnosis, Screening questionnaires, Telemedicine, Pulmonary rehabilitation

1. INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a progressive chronic inflammatory respiratory disease characterized by airflow limitation, presenting with persistent respiratory symptoms and airflow obstruction.[1,2] COPD, a common and frequently occurring condition, is primarily characterized by persistent wheezing and coughing with phlegm. It is progressive and persistent in nature. Without timely treatment, as the disease advances, it can develop into cor pulmonale, affecting multiple systems throughout the body and even becoming life-threatening.[3,4] The Global Burden of Disease report indicates that 4.41 million patients died from chronic respiratory diseases in 2021, with COPD accounting for 3.719 million of these deaths.[5] Globally, the incidence of

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COPD has been rising year by year.[6] According to relevant statistics from the World Health Organization (WHO), the prevalence rate of COPD stands at 8.9%. It is projected that by 2060, over 5.4 million people worldwide will die from COPD and related complications, which will also increase the global economic and social burden to a certain extent.[7, 8] With advances in healthcare in developed countries and the extension of human life expectancy, the number of COPD patients has been steadily increased, gradually evolving into one of the major diseases in developed nations.[9] According to the Global Burden of Disease Study Program, COPD ranked 11th in disease burden based on 1990 data, rising to 6^{th} by 2019. Its disability-adjusted life years (DALYs) across all age groups showed a significant increase from 1990 to 2019.[10]

In recent years, the prevalence of chronic respiratory diseases has been steadily rising due to factors such as increased air pollution and smoking. The treatment costs for these conditions are expensive, and they typically require lifelong care. If the treatment is delayed or of poor quality, the disease may worsen, imposing a significant burden on the global economy and healthcare systems.[11] In China, high smoking prevalence, inadequate control of risk factors such as exposure to biomass fuels and air pollution, and high incidence of COPD contribute to a prevalence rate of approximately 13.7% among individuals aged 40 and above, rising to 27% among those aged 60 and above.[12] The prevalence rate among those aged 50 and above has reached 15%, with the number of deaths ranking first globally, making it a significant public health issue worldwide.[13] The prevalence of COPD in China continues to rise steadily, with an increasing trend toward younger groups. An epidemiological survey conducted in seven regions across China in 2007 found that the prevalence of COPD among the population aged 40 and above was 8.2%.[14] Jin Yanxin[15] et al. employed a stratified sampling method combined with cluster sampling to recruit 712 elderly community residents from January to December 2020. They administered a symptom-based COPD screening questionnaire, identifying a suspected COPD detection rate of 16.7% and a high-risk COPD detection rate of 10.3%. The detection rates of the suspected and the high-risk COPD were higher among older individuals, those with lower body mass index, and heavier smokers ($p < .05$). Pulmonary function testing confirmed 69 cases of COPD, with a prevalence rate of 9.7%. The incidence of diagnosed COPD showed statistically significant differences across different age groups, body mass index categories, and smoking exposure levels among the elderly ($p < .05$). According to epidemiological survey data, the prevalence of COPD in China ranges from 5% to 13%. In recent years, with the acceleration of population aging, the number of COPD patients has been increasing, making it a significant disease affecting people's physical and mental health.[16–18]

2. The role of screening questionnaires in the early diagnosis of COPD

In 2020, the World Health Organization reported that COPD was the third leading cause of death globally, ranking as the third most prevalent chronic disease after hypertension and diabetes. While COPD has a high prevalence, its detection rate remains low. Literature reports indicate that approximately 8.3% to 50% of COPD patients are not diagnosed in a timely manner each year. The primary reason for delayed diagnosis is that a large number of early-stage COPD patients exhibit no typical symptoms, and pulmonary function testing is not sensitive to early-stage airway diseases.[19] Early diagnosis of COPD remains a significant challenge. Delayed diagnosis not only hinders timely treatment but may also lead to further deterioration of the condition. Promoting early screening and diagnosis is crucial for addressing this issue.[20]

Studies indicate that early screening of high-risk populations—such as those with smoking histories, occupational exposures, chronic respiratory symptoms, or family histories of chronic respiratory diseases—can significantly increase diagnostic rates within these groups.[21] Screening questionnaires aid in diagnosing early-stage COPD cases. These questionnaires primarily cover age, history of exposure to risk factors, and respiratory symptoms. Commonly used screening tools include the COPD Diagnostic Questionnaire (CDQ), the COPD Population Screening Tool (COPD-PS), Lung Function Questionnaire (LFQ), COPD in Primary Care (CAPTURE), and the COPD Self-Screening Questionnaire (COPD-SQ).

The CDQ demonstrates high accuracy in screening for COPD. Smoking is one of the risk factors for COPD, making the CDQ particularly useful for screening individuals with a history of smoking. The revised version of the CDQ used in China demonstrates a sensitivity of 82.45% and a specificity of 72.78% for diagnosing COPD, with a negative predictive value reaching 92.9%. It is particularly suitable for screening individuals with a history of smoking.[22] The COPD-PS diagnostic test demonstrates a sensitivity of 66% and a specificity of 89% for COPD, showing good efficacy in the early diagnosis of COPD.[23] The LFQ questionnaire demonstrates a sensitivity of 73.2% and specificity of 58.2% for screening COPD. The 2017 China National Health and Nutrition Examination Survey marked the first translation of the LFQ

questionnaire into Chinese. With a total score of 25 points, a score between 5 and 18 indicates potential risk for COPD.[24] CAPTURE is a new questionnaire that works best when used with a peak expiratory flow meter. The COPD-SQ questionnaire was developed specifically for the Chinese COPD population, demonstrating a sensitivity of 60.6%, a specificity of 85.2%, and the diagnostic concordance of 28.7%. In a study screening individuals aged 40 and above using the COPD-SQ questionnaire, the COPD detection rate was more than double that of the general population.[25] A comparative study demonstrated that the LFQ achieved the highest diagnostic accuracy, followed by the revised CDQ and COPD-PS. It is recommended that the LFQ and COPD-PS be used for the Chinese population.[26] The COPD screening questionnaire is simple and easy to administer, making it well-suited for broad population screening and for primary care facilities to conduct preliminary assessments of individuals potentially affected by COPD.

3. Non-pharmacological management for COPD patients

Regarding non-pharmacological treatments, health education and self-management should be integrated throughout the entire course of a patient's treatment. COPD is a chronic, persistent disease with an irreversible course. Identifying patient-related risk factors is crucial for reducing the overall risk. Early intervention can minimize the occurrence of disability.[27] Many patients with COPD in advanced pathological stages have experienced symptoms for years without diagnosis or treatment, only to be diagnosed at an advanced stage once symptoms become severe.[28]

The mixed smoke produced by burning cigarettes contains various chemical components such as tar, nicotine, and carbon monoxide, which are among the risk factors for COPD.[29] Quitting smoking is one of the key measures in COPD management, helping to slow disease progression and improve symptoms. Reducing exposure to indoor and outdoor pollutants and allergens is recommended, along with regular influenza and pneumococcal vaccinations to lower the risk of respiratory infections. Patients should maintain healthy eating habits and appropriate body weight, while psychological interventions are advised to reduce stress.[30] Martinez et al.[31] defined young smokers (aged < 50 years with $\geq$ 10 pack per year of smoking history) as those meeting one or more of the following criteria: FEV1/FVC < lower limit of normal (LLN) after bronchodilator use, consistent with chest) meeting one or more of the following criteria: FEV1/FVC < LLN after bronchodilator use, chest CT abnormalities (visual evidence of pulmonary emphysema, air trapping, or mild or more severe bronchial thickening), and accelerated FEV1 decline ($\geq$ 60 mL/year).

A cohort study involving over 6,000 middle-aged and elderly individuals suggests that the 10-year cumulative incidence of COPD is 13.5%. Cough and sputum production are significantly associated with the development of COPD in women, while dyspnea and wheezing are significantly associated with the development of COPD in men.[32] The cross-sectional study of the European Community Respiratory Health Survey (ECRS), involving 18,000 adults aged 20-44 years across 16 countries, found that participants with chronic cough and sputum production had a COPD incidence rate four times higher than those without these symptoms. This suggests that chronic cough and sputum production are independent risk factors for the occurrence of COPD.[33,34] Guerra et al.[35] conducted a study involving over 1,400 participants aged 21 to 80 in the southwestern United States. After more than 24 years of follow-up, the incidence of airflow obstruction among adults aged 50 and above was 42% in those with chronic bronchitis and 23% in those without chronic bronchitis. Early studies on e-cigarette exposure indicate that it similarly causes changes in lung function and structure.[36,37] Occupational exposure and air pollution are also associated with respiratory diseases.[38,39]

4. Pharmacological treatment of COPD

Treatment adherence is crucial for COPD. Managing chronic respiratory diseases typically requires long-term medication and non-pharmacological interventions, including proper use of inhaled medications, regular pulmonary rehabilitation training, and lifestyle modifications. Non-adherence to treatment due to adverse drug reactions, complex treatment regimens, or lack of adequate support directly impacts disease control outcomes and patients' quality of life.[40] Due to the high degree of heterogeneity in patients' clinical manifestations and disease progression, treatment strategies must be tailored to individual conditions, lifestyle factors, and responses to develop personalized treatment plans.

The Global COPD Initiative guidelines employ a symptom- and exacerbation-based grading system to emphasize symptom scoring and exacerbation risk in guiding long-term pharmacotherapy. Treatment for dyspnea prioritizes the use of long-acting bronchodilators, moving away from excessive reliance on inhaled corticosteroids. For patients experiencing frequent acute exacerbations with blood eosinophil counts at or above 300/μL, inhaled corticosteroids are recommended.[41]

A multicenter, randomized, double-blind, placebo-controlled study, 841 patients with GOLD 1 (mild) and 2 (moderate)

COPD received either 18 μg tiotropium bromide inhaled once daily (419 patients) or a matching placebo inhalation (422 patients) for a total follow-up period of 24 months. The results showed that tiotropium bromide treatment resulted in higher FEV1 values than placebo treatment. Following bronchodilator use, the annual decline in FEV1 was significantly less pronounced in the tiotropium bromide group compared to the placebo group.[42] Patients experiencing acute exacerbations of COPD (AECOPD) require hospitalization for pharmacological treatment, including bronchodilators and expectorants. Critically ill patients may receive respiratory support, corticosteroids, and antibiotics.[43]

5. Telemedicine for COPD

In a study, 120 pulmonologists from 16 European hospitals evaluated 50 cases comprising pulmonary function tests and clinical information, while artificial intelligence analyzed the same data. The pulmonologists diagnosed 44.6% of cases correctly, with high variability (kappa = 0.35). In contrast, the AI correctly interpreted all pulmonary function test results (100%) and made the correct diagnosis in 82% of cases.[44] Zanaboni et al.[45] proposed telemedicine-based personalized exercise training using home treadmills for COPD patients. The study addressed the challenge of managing COPD patients' health outside of hospitals and demonstrated significant benefits in reducing readmission rates. Vianello et al.[46] conducted a 12-month randomized controlled trial that remotely monitored heart rate and blood oxygen saturation in COPD patients. Based on individual patient conditions, home visits and treatments were arramged to achieve remote, continuous health management for COPD patients.

Li Chunyan et al.[47] employed remote monitoring to manage 50 patients with COPD complicated by type II respiratory failure. By adjusting parameters on home-based noninvasive ventilators, they facilitated patient recovery and improved quality of life. Digital health technologies and artificial intelligence will also play an increasingly vital role in managing chronic respiratory diseases. Smart inhalers, remote monitoring devices, and mobile health applications can help patients better manage medication use, monitor their condition in real time, and maintain communication with their doctors. The application of these technologies not only improves treatment adherence but also enhances the personalization and precision of disease management.[48] AI-based predictive models can analyze patient symptom data to forecast the risk of acute exacerbations, enabling proactive intervention measures.[49] Virtual care and remote monitoring technologies will enable patients to receive high-quality medical services at home, reducing the need for hospital visits.[50]

6. Community-based primary care management system for COPD

Implement a community-based primary care management system for COPD, where family physicians sign contracts with residents and develop personalized health management plans. Regular health education sessions and home visits are conducted, adhering to the principle of early diagnosis and treatment to improve prognosis and enhance quality of life. Literature reports indicate that the United Kingdom has established a relatively well-developed community healthcare management model, creating a community COPD prevention and treatment network. Standardized COPD prevention and treatment guidelines have been formulated, covering stable-phase and mild acute treatment, as well as referrals during acute exacerbations. The Netherlands is progressively implementing a tiered COPD care model. Australia has adopted the Chronic Disease Self-Management Plan (CDSMP) model. Leveraging modern network technology, a telemedicine management model has been developed. This model integrates multiple components including remote physical activity monitoring, decision support, consultation, education, coaching, and rehabilitation. It enables timely resolution of complex issues encountered by COPD patients during disease progression, enhances patient knowledge, alleviates adverse psychological states, and effectively improves prognosis while elevating quality of life.[51–53]

In 2018, China formulated and implemented the "Guidelines for Primary Care Diagnosis and Treatment of COPD." Its core provisions assign primary care institutions responsibility for COPD health education, prevention, screening, identification of high-risk or suspected patients, treatment, post-treatment rehabilitation, and long-term follow-up, while establishing a two-way referral system.[54] Health China Action (2019-2030) states that for chronic respiratory diseases, efforts should focus on assisting key populations in early detection and diagnosis, controlling risk factors, and preventing disease onset. Lung function tests should be added to physical examinations for individuals aged 40 and above. Health management for COPD patients should be strengthened, and primary healthcare facilities should enhance their capacity for conducting pulmonary function tests.[55] According to the "Guidelines for the Diagnosis and Treatment of COPD (2021 Revised Edition)," early screening and intervention for COPD should be implemented to enhance the rate of early diagnosis, reduce missed diagnoses, and improve the current state of COPD diagnosis and treatment in China.[56]

7. Home oxygen therapy issues

Recent clinical studies at home and abroad have confirmed that long-term home oxygen therapy can significantly im-

prove patients' exercise tolerance, enhance lung function, reduce hospital admissions, and elevate quality of life.[57] Indications for long-term home oxygen therapy include: Arterial partial pressure of oxygen (PaO_2) $\leq$ 55 mmHg or arterial oxygen saturation (SaO_2) $\leq$ 88%, with or without two episodes of hypercapnia occurring within 3 weeks; PaO_2 55-60 mmHg with pulmonary hypertension, peripheral edema (indicating congestive heart failure), or polycythemia (hematocrit > 55%); The goal of long-term oxygen therapy is to achieve $PaO_2 \geq 60$ mmHg and/or $SaO_2 \geq 90\%$ at sea level while at rest.[58] Long-term oxygen therapy is a recognized intervention for COPD with resting hypoxemia, administered for at least 15-18 hours daily.[59] The arterial blood oxygen partial pressure of 60 mmHg and/or the arterial blood oxygen saturation of > 90% can thereby achieved.[60] Studies indicate that the most effective oxygen therapy is achieved through home nasal cannula administration at 1-2 L/min, with daily oxygen use exceeding 15 hours.[61]

For COPD patients, long-term oxygen therapy can improve oxygenation parameters and reduce cardiac workload. Noninvasive ventilation provides effective respiratory support during acute exacerbations, reducing the risk of intubation, hospital stay, and mortality. Lung volume reduction surgery is indicated for patients with severe emphysema as a less invasive alternative. By excising damaged lung tissue, it improves airflow dynamics and lung function, thereby enhancing exercise capacity and alleviating symptoms.[62] For patients with advanced COPD accompanied by respiratory failure, long-term home oxygen therapy not only alleviates hypoxic symptoms and improves quality of life but also slows disease progression and the decline rate of lung function, increases survival rates, and promotes pulmonary rehabilitation.[63]

The 2020 Clinical Practice Guideline on Home Oxygen Therapy for Adult Chronic Lung Diseases by the American Thoracic Society strongly recommends long-term oxygen therapy for COPD patients with severe resting hypoxemia; opposes long-term oxygen therapy for COPD patients with moderate resting hypoxemia; and recommends intermittent oxygen therapy for COPD patients with severe exertional hypoxemia, i.e., providing portable oxygen during physical exertion or activities of daily living when walking freely.[64] In 2022, the Danish Respiratory Society Guidelines on Long-Term Nasal High-Flow Oxygen Therapy (with or without supplemental oxygen) recommended the use of long-term high-flow nasal cannula therapy (LT-HFNC) for COPD patients experiencing frequent acute exacerbations ($\geq$ 2 severe COPD exacerbations per year) and persistent hypoxic respiratory failure. Additionally, LT-HFNC is recommended for COPD patients who struggle to wean off high-flow nasal cannula therapy following an acute exacerbation.[65]

8. PULMONARY REHABILITATION

Physical rehabilitation (PR) has become an indispensable component of COPD treatment, widely applied across all stages of the disease. When integrated with medication, a rational, progressive, and patient-tailored PR program facilitates standardized treatment and long-term management for COPD patients. It improves symptoms, relevant laboratory test results, and pulmonary function assessments, ultimately enhancing patients' quality of life and survival outcomes.[66,67] The core components of PR include respiratory muscle training, airway clearance techniques, exercise training, non-invasive mechanical ventilation, and nutritional support and so on.[68] Breathing exercises include diaphragmatic breathing, pursed-lip breathing, head-down and forward-tilted positions, controlled slow and deep breathing, diaphragmatic pacing/electrical stimulation breathing, and respiratory muscle strength training (exercise training). Physical training encompasses various forms such as aerobic exercise, strength training, and flexibility training.[69]

Early PR during AECOPD has been demonstrated in numerous studies to facilitate recovery of pulmonary function, shorten hospital stays, and reduce the incidence of adverse reactions.[70] PR administered immediately upon admission is generally safe for AECOPD patients, but must be conducted under close medical supervision to facilitate the management of potential adverse reactions and to establish a comprehensive early PR plan. Guide patients to perform PR in stages according to their individual circumstances, aiming to improve patient compliance, enable more individuals to successfully complete their PR plans and promote recovery.[71]

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