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REVIEW

Advances in Understanding Recurrent Pulmonary Infections Following Foreign Body Aspiration: A Narrative Review

Qian Tang[1,*], Xing Chen[2,3,*], Kunjie Ran[4], Xueqin Yang[1], Ting Yuan[1], Juanjuan Li[1], Juan Zheng[1], Chen Xu[1], Heping Li[1], Yang Zhao[1], Jingsong Wang[1]

[1]Department of Pharmacy, Guangyuan Central Hospital, Guangyuan, Sichuan, People's Republic of China; [2]School of Stomatology, North Sichuan Medical College, Nanchong, Sichuan, People's Republic of China; [3]Department of Stomatology, Guangyuan Central Hospital, Guangyuan, Sichuan, People's Republic of China; [4]Department of Pharmacy, The First People's Hospital of Guangyuan, Guangyuan, Sichuan, People's Republic of China

*These authors contributed equally to this work

Correspondence: Jingsong Wang; Yang Zhao, Department of Pharmacy, Guangyuan Central Hospital, Guangyuan, Sichuan, People's Republic of China, Email wjs5515@163.com; 591914757@qq.com

Abstract: Recurrent pulmonary infections (RPIs) represent a common yet clinically complex entity, primarily triggered by aspiration or the presence of foreign bodies. They are notoriously insidious and challenging to detect clinically. These infections typically involve the invasion of bacteria, viruses, or fungi, leading to inflammation and damage of lung tissue. The development of RPIs may also arise from the interplay of multiple factors. Due to their inherent complexity and association with poor prognosis, RPIs constitute a significant cause of mortality stemming from pulmonary infections. Understanding the risk factors associated with RPIs secondary to foreign body aspiration is crucial for effective clinical management. This narrative review synthesizes current knowledge on the pathogenesis, diagnosis, management, and prevention of RPIs caused by foreign body aspiration. We emphasize the heightened vulnerability of pediatric and elderly populations. The review delineates characteristic clinical presentations and outlines appropriate diagnostic modalities. Furthermore, it provides perspectives on antimicrobial therapy and the critical importance of foreign body removal. The synthesis aims to inform future research directions, preventive strategies, and therapeutic approaches, ultimately seeking to improve patient outcomes and mitigate the risk of recurrent infections.

Keywords: foreign body aspiration, pulmonary infection, recurrence, diagnosis and treatment, prevention

Introduction

Pneumonia has persisted as a leading global cause of mortality for decades.[1,2] According to the Global Burden of Disease Report 2021, pneumonia caused 2.1 million deaths between 1990–2021, predominantly affecting children under 5 years and adults over 70 years.[3] Foreign body aspiration represents a significant etiological contributor to pneumonia, particularly prevalent in these age groups.[4,5] The aspirated foreign body, due to its highly concealed nature and tendency to evade detection during examinations, leading to prolonged pulmonary retention,[6,7] predispose to infections such as bacterial, viral, or fungal pathogens,[8] and failure to promptly diagnose and remove the foreign body often precipitates recurrent pulmonary infections (RPIs), severe complications, and mortality,[9,10] imposing substantial societal and familial burdens.[11]

RPIs (typically defined as ≥2 episodes within 1 year or ≥3 episodes at any time) may arise from diverse etiologies, with foreign body aspiration representing a significant and modifiable cause, particularly prevalent in children.[5] Furthermore, migration of foreign bodies,[12] aspiration secondary to gastroesophageal reflux,[13,14] and unreported/unrecognized aspiration history (due to patient amnesia or communication barriers),[15] constitute key risk factors for recurrent infections. These and other aspiration-related risk factors collectively predispose to RPIs. Additionally, elderly patients

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with neurological disorders (Parkinson's disease, Alzheimer's disease, etc.) exhibit heightened susceptibility due to dysphagia-induced aspiration, wherein delayed recognition severely compromises quality of life.[16] Critically, prompt diagnosis and complete foreign body removal are pivotal for terminating infection recurrence and preventing complications.

This review aims to synthesize the clinical features, diagnosis, management, and prevention strategies for aspiration-induced RPIs, with focused attention on pediatric and elderly populations with comorbidities. By elucidating population-specific risk factors, emphasizing optimized utilization of imaging and bronchoscopy for enhanced foreign body detection, and underscoring the imperative of foreign body extraction, alongside discussion of preventive measures, this work seeks to elevate clinical awareness. Ultimately, we aspire to improve diagnostic rates and cure efficacy, thereby reducing infection recurrence, ameliorating patient prognosis, and lowering associated mortality and disease burden. Concurrently, this review endeavors to provide insights for refining early identification, precision interventions, and long-term management in high-risk individuals.

Recurrent Pulmonary Infections

Clinical Characteristics

RPIs from foreign body aspiration manifest clinically with recurrent cough, dyspnea, wheezing, and fever.[8] Auscultation reveals tracheal slapping sounds, wheezes, and unilateral diminished or absent breath sounds.[17] Imaging demonstrates recurrent consolidation in identical lung segments, mediastinal shift, atelectasis, hyperinflation, or obstructive pneumonia with air-trapping.[18,19] Pediatric patients may additionally exhibit failure to thrive, thoracic deformities, and digital clubbing.[17,20]

Reasons

Failure to promptly detect aspirated foreign bodies leads to their prolonged retention in the lungs, ultimately causing RPIs.[6,15] RPIs from occult aspiration often lack documented aspiration history and are most prevalent in children.[21–24]Their underdeveloped chewing function and cough reflex typically prevent spontaneous expulsion of aspirated objects.[25,26] In elderly patients, neurological disorders (including epilepsy, Parkinson's disease and stroke),[27–31] impair swallowing and cough efficacy, allowing retained foreign bodies and pathogens to persistently irritate lung tissue.[10,32–34] Repeated aspirations particularly predispose to recurrent infections.[35–42]

Aspiration during altered states of consciousness (such as shock, general anesthesia and intoxication) also lacks witnessed history, foreign bodies are only discovered upon recurrent infection episodes.[43] Certain medications and anatomical abnormalities further increase aspiration risk. Pharmacological contributors include sedative-hypnotics, anticholinergics, antipsychotics, and anxiolytics.[44] Structural or physiological esophageal alterations—such as systemic sclerosis and tracheoesophageal fistulae—constitute additional risk factors.[45] Moreover, patients with nasogastric/nasointestinal tubes or tracheal intubation/tracheostomy may experience pulmonary inoculation via spillage of gastro-esophageal contents,[46] or aspiration of oropharyngeal colonizing pathogens.[47,48]

During bronchoscopy, migrated foreign bodies may evade detection, while pathogen-laden objects can disseminate to other lung regions, triggering recurrent infections.[49–51] Additionally, non-metallic inorganic or small foreign bodies often elude radiographic identification, permitting prolonged airway retention with persistent pulmonary irritation and inflammation.[52] Meanwhile, objects obscured by granulation tissue, mucus, or purulent exudate also complicate detection.[53] Although antimicrobial therapy may temporarily alleviate symptoms during exacerbations, discontinuation permits pathogen resurgence and infection recurrence unless the foreign body is removed.[21,54,55]

Pathogenesis

The pathogenesis of RPIs secondary to foreign body aspiration involves multiple interconnected mechanisms. Microbial colonization and infection constitute a primary pathway: aspirated foreign bodies provide niches for bacterial, viral, or fungal adherence and proliferation, directly inciting pulmonary infection.[8,16] Repeated aspiration episodes further introduce oropharyngeal colonizing flora into the lower respiratory tract, exacerbating established infections.[46] Host

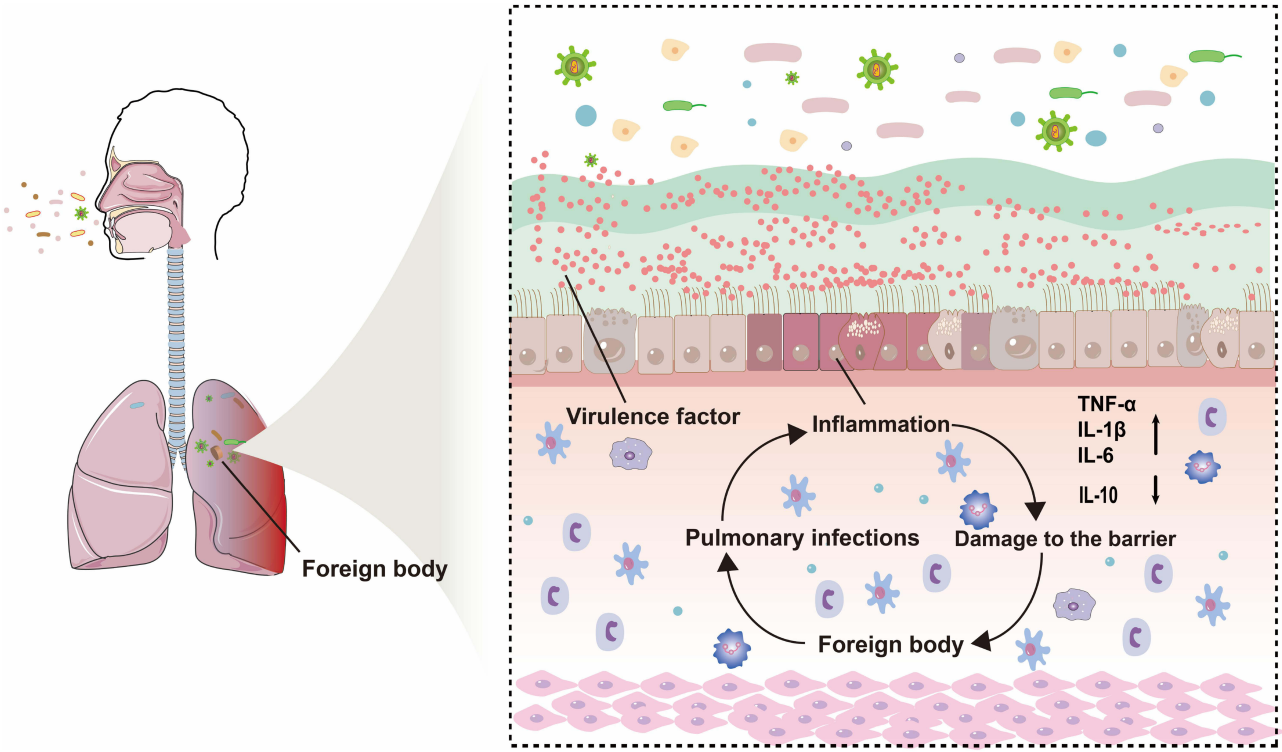

Figure 1 Recurrent pulmonary infections caused by foreign body aspiration.

inflammatory responses represent a second critical axis: prolonged foreign body retention triggers sustained inflammation with elevated proinflammatory cytokines (including IL-6, IL-1β, TNF-α).[56] Chronic inflammation subsequently promotes granulomatous tissue formation, progressively obstructing airways.[57] Airway barrier disruption completes a self-perpetuating cycle: mechanical obstruction by foreign bodies or granulomas causes regional hypoventilation and mucosal injury. This impairs mucociliary clearance and increases susceptibility to further aspiration, establishing a vicious cycle of "Foreign body-Pulmonary infection-Inflammation-Barrier compromise". Cumulatively, these processes drive progressive lung dysfunction and endobronchial complications (Figure 1).[6,8,18,25,58]

Diagnosis

Clinical Assessment

Preliminary diagnosis of RPIs triggered by foreign body aspiration relies heavily on thorough clinical assessment, encompassing history taking, symptom analysis, and critical physical examination. Meticulous inquiry into aspiration history, even suspected or remote episodes, is essential.[15] Concurrent evaluation for underlying conditions—such as gastroesophageal reflux, neurological disorders (cerebral palsy and post-stroke sequelae), swallowing dysfunction, and structural or functional esophageal abnormalities (achalasia and hiatal hernia, etc).—is imperative, as these factors significantly elevate the risk of foreign body aspiration and recurrent infections.[10,59]

Recurrent respiratory symptoms constitute core indicators, including persistent or recurrent cough (particularly irritative choking cough), sputum production, dyspnea manifestations (such as tachypnea and wheezing), and systemic symptoms like fever.[15,60,61] Additionally, recurrent or persistent symptoms, along with symptom correlation with feeding/posture, provide crucial diagnostic clues.[62]

Physical examination, equally vital as history, is pivotal for clinical diagnosis.[17,63] Auscultation may reveal focal, persistent, or recurrent abnormal breath sounds—such as wheezes, crackles (dry or moist rales), or diminished breath sounds—especially in specific lobes/segments.[17] Percussion may demonstrate dullness or hyperresonance.[64] Children

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may exhibit signs of respiratory distress, including inspiratory retractions and perioral cyanosis.[65,66] These signs facilitate rapid lesion localization and severity assessment by clinicians.

Comprehensive analysis of clinical assessment (history, symptoms, and physical examination) not only suggests possible RPIs due to foreign body aspiration but also aids in identifying high-risk patients and guiding subsequent investigative selection.

Core Diagnostic Investigations

When clinical assessment strongly suggests RPIs secondary to foreign body aspiration, radiographic imaging and bronchoscopy serve as primary diagnostic tools (Table 1).

Chest radiography is typically the initial imaging modality, potentially revealing parenchymal infiltrates, atelectasis, hyperinflation, mediastinal shift, or directly visualizing radiopaque foreign bodies.[15,60] However, its sensitivity and specificity are suboptimal, especially for radiolucent foreign bodies or small lesions.[67] Crucially, negative results cannot exclude the diagnosis. Chest computed tomography (CT) constitutes the most reliable imaging method for diagnosing foreign body aspiration and evaluating complications, including recurrent pneumonia, lung abscess, and bronchiectasis.[68,71–74] Furthermore, high-resolution CT precisely localizes infectious foci, quantifies lung damage (including inflammation, consolidation, emphysema, bronchiectasis), and detects most foreign bodies (including some radiopaque types), proving particularly valuable in chronic or recurrent cases. Limitations include higher radiation exposure than radiography, elevated cost, and potential missed diagnoses of certain foreign bodies (minute or vegetable matter) or locations.[74,77–79]

Bronchoscopy remains the gold standard for diagnosing and treating endobronchial foreign bodies.[15,54] It enables direct airway visualization, confirming the presence, location, and nature of foreign bodies under direct vision—a capability unmatched by other modalities. Bronchoscopy is strongly recommended for patients with high clinical suspicion but negative CT findings.[15,54] Simultaneously, it permits therapeutic foreign body extraction, constituting definitive etiological management.[80] Direct visualization also facilitates collection of deep airway secretions or bronchoalveolar lavage fluid (BALF) for microbiological culture and cytological analysis, enhancing pathogen detection rates.[10,75]

Ancillary Diagnostic Investigations

Certain laboratory tests provide supportive information for infection status assessment but cannot independently confirm foreign body presence. Complete blood count may reveal elevated white blood cell count, neutrophil percentage, C-reactive protein (CRP), and procalcitonin (PCT), indicating bacterial infection and inflammatory response, thereby aiding in evaluating infection severity and activity.[60] However, these hematological parameters lack specificity, as

Table 1 Comparison of Different Examination Methods

Examination Methods	Advantages	Disadvantages	References
X-Ray	Cost-effective, quick, and low radiation exposure.	Low sensitivity, specificity, and accuracy, and cannot provide direct information about the size, nature, or location of the foreign body.	[67–69]
Digital Radiography	Economical and rapid with the capability for dynamic observation and relatively low radiation exposure.	Its sensitivity to metallic foreign bodies is lower than that for non-metallic ones, and results are significantly affected by the operator.	[69,70]
Computed Tomography (CT)	High sensitivity and specificity, capable of localizing infection foci and assessing the severity of infections.	More expensive, involves higher radiation exposure, and accuracy is influenced by the size and nature of the foreign body.	[68,69,71–74]
Bronchoscopy	Allows simultaneous examination, treatment, and sampling, with a high safety and success rate.	Using of narcotics and may lead to complications such as bleeding and pulmonary damage.	[75,76]

abnormalities occur across infectious diseases. Conversely, culturing, smearing, and molecular testing of sputum or BALF aim to identify causative pathogens and their antibiotic susceptibility, guiding antimicrobial therapy.[81] Positive results require clinical correlation to distinguish colonization from true pathogens.

Cost-Effectiveness Considerations

Selecting the optimal diagnostic pathway necessitates balancing diagnostic efficacy, invasiveness, risk, and cost. Initial judgment based on clinical symptoms, signs, and risk factors helps avoid excessive testing. Due to its high sensitivity, chest CT has become the preferred imaging modality for suspected RPIs from foreign body aspiration, effectively evaluating pulmonary lesions and detecting most foreign bodies.[74,77–79] Conventional chest radiography offers limited value owing to low sensitivity but retains utility in specific scenarios (emergency screening) because of its accessibility and low cost.[15,60,67] Fluoroscopy provides limited information with operator-dependent variability and non-negligible radiation exposure.[82]

For patients with RPIs and clinical/CT findings suggestive of foreign bodies, diagnostic bronchoscopy is the definitive step for confirmation and cure. Even with negative CT, bronchoscopy should be actively considered if clinical suspicion remains high (classic history + signs).[15,83] Although costly, it addresses the fundamental need for foreign body removal, preventing subsequent recurrent infections and associated expenses. A "low-dose chest CT followed by bronchoscopy when indicated" strategy demonstrates favorable cost-effectiveness.[84]

Treatments

General Treatments

Maintaining airway patency is essential, and the decision to administer oxygen therapy should be based on the severity of dyspnea.[85] It is also essential to monitor the patient's vital signs, including continuous assessment of oxygen saturation, heart rate, blood pressure, electrolyte balance, internal environment status, and the function of other vital organs, while providing timely symptomatic management.[1]

Anti-Infection Treatments

The pathogenic bacteria associated with RPIs caused by foreign body aspiration are related to the site of infection. Therefore, the selection of empirical antimicrobial therapy should be based on the common pathogens in community-acquired pneumonia (CAP) and hospital-acquired pneumonia (HAP), as well as the local microbial epidemiology and resistance patterns.[86]

Common pathogenic bacteria in CAP include Streptococcus pneumoniae, Staphylococcus aureus, Haemophilus influenzae, and Pseudomonas aeruginosa.[17,46,87–90] Some patients may present with viral infections or a combination of viral and bacterial infections, with the most frequently identified viruses being rhinoviruses, adenoviruses, respiratory syncytial virus, influenza A viruses, and coronaviruses. Symptomatic supportive treatment is primarily employed for viral infections, without the standalone use of antimicrobial agents.[2,91] For bacterial infections, antimicrobial treatment can be guided by the common pathogenic bacteria, selecting β-lactams such as amoxicillin-clavulanate, fluoroquinolones like levofloxacin, and macrolides such as azithromycin.[43,92]

For complicated infections, empirical combination therapy with two agents may be chosen, including β-lactams plus fluoroquinolones or aminoglycosides.[93] In cases where bacterial cultures yield multidrug-resistant organisms, treatment options based on susceptibility results may include piperacillin-tazobactam, cefepime, carbapenems, linezolid, or vancomycin.[94]

Routine treatment with anti-anaerobic agents is not recommended for either CAP or HAP. However, when patients present with oral diseases, empyema, or pulmonary abscesses, clindamycin or metronidazole may be administered to cover anaerobic bacteria.[1,46,93,94]

In conclusion, for pulmonary infections resulting from foreign body aspiration, empirical antimicrobial therapy should aim to cover both Gram-negative and Gram-positive bacteria, with targeted therapy adjusted following the results of cultures and susceptibility tests.

Remove Foreign Body

Timely Imaging examinations can detect and localize pulmonary foreign bodies, while bronchoscopy is the primary method for managing foreign bodies, facilitating their timely identification and removal, thus reducing the recurrence infections of pulmonary.[68] Bronchoscopes are classified into rigid and flexible types, and there is ongoing debate regarding which is preferable.[95] Rigid bronchoscopy may be chosen for patients with unstable respiration, significant bleeding, or foreign bodies located in the central airways.[96,97] Flexible bronchoscopy is suitable for children, patients requiring repeated procedures, or those with foreign bodies in peripheral airways.[98–101] The choice of bronchoscope should consider the location, size of the foreign body, and tracheal diameter preoperatively.[102,103] Additionally, if a flexible bronchoscope fails to retrieve a foreign body, it may be used in conjunction with a rigid bronchoscope.[104] During bronchoscopy, to prevent fail to pinpoint in diagnosis due to granulation tissue or purulent secretions enveloping the foreign body, saline can be used for repeated irrigation, or local adrenaline may be applied. If necessary, preemptive anti-infective treatment or corticosteroids can be administered to mitigate inflammation before re-evaluating with bronchoscopy.[54,100,105] Following the removal of pulmonary foreign bodies, early bronchoalveolar lavage can promote the absorption and resolution of pulmonary inflammation.[106] Surgical foreign body removal may be indicated when objects are excessively large, or when bronchoscopy is contraindicated (due to bronchiectasis/abscess) or has failed.[107]

Treatment of Underlying Conditions

Timely treatment for RPIs induced by different types of foreign body aspiration is crucial. Active management of underlying conditions is recommended, such as using medications to suppress gastroesophageal reflux in affected patients.[13,108] For patients with neurological disorders leading to swallowing difficulties, such as stroke, epilepsy, and Parkinson's disease, proactive rehabilitation exercises should be encouraged.[109,110] Patients with oral diseases should receive appropriate treatment and maintain regular oral hygiene.[111–113]

Other Treatments

The use of corticosteroids for treating pulmonary infections caused by foreign body aspiration remains controversial and is not routinely recommended. They should only be used when deemed necessary, such as nebulized budesonide for alleviating airway inflammatory response. And requiring comprehensive consideration of clinical manifestations, number of affected lobes, extent/density of consolidation, CRP and LDH levels, alongside daily efficacy assessment.[93,114,115]

Prevention

For infants and young children, this age group represents the highest-risk population for foreign body aspiration, necessitating targeted preventive measures. Firstly, primary interventions focus on optimizing feeding techniques: maintain infants/toddlers in a semi-upright position (approximately 30–45 degrees) during feeding, avoiding supine positioning for milk or meals. Secondly, adapt feeding methods by using nipples with appropriate flow rates and introducing complementary foods following the principle of progressing from thin to thick textures and fine to coarse consistencies, ensuring food properties match developmental stages. Concurrently, strict restriction of high-risk choking foods—such as whole nuts, whole grapes—is crucial.[116–121] Finally, caregivers must learn the Heimlich maneuver for emergencies.[122]

Children should remain seated while eating under parental supervision, with restrictions on inappropriate behaviors (running/jumping, talking during meals); heightened vigilance is required when children consume high-risk foods. During play, minimize exposure to small objects like button batteries, toy parts, and coins to reduce RPIs at the source.[123]

For elderly patients with underlying conditions (such as gastroesophageal reflux, stroke, dysphagia, immunodeficiency), relevant vaccinations can prevent RPIs induced by aspiration.[41,90,124] Dysphagic patients should receive swallowing rehabilitation and appropriate food texture selection.[109,110] Bedridden or dependent individuals require rigorous oral hygiene and regular professional dental cleaning; active treatment of oral diseases reduces oropharyngeal colonizing bacteria.[111–113] Additionally, elevate the bed head by 35–40° (if no contraindications) and adopt suitable feeding postures.[125] Psychiatric patients require guided use of antipsychotics, antihistamines, and anticholinergics, with supervised per-dose administration

when necessary.[44,126] Patients undergoing general anesthesia must fast ≥8 hours and abstain from fluids ≥2 hours preoperatively.[43] Unconscious individuals (due to intoxication, shock) should be placed prone or semi-recumbent.[127] Patients with esophageal disorders warrant comprehensive nursing support, with surgery if indicated.[45]

Conclusion and Prospect

RPIs caused by foreign body aspiration are more commonly observed in pediatric and geriatric populations. Additionally, patients with swallowing dysfunction, compromised immune function, and those who are unable to care for themselves are also at higher risk for RPIs induced by foreign bodies, which can impose significant lifestyle stress and economic burdens on families. To reduce the incidence of RPIs caused by foreign bodies, the most effective strategies to reduce their incidence involve improving diagnostic rates, the selection of appropriate antimicrobial interventions, and the implementation of effective preventive strategies.

On one hand, rational selection of diagnostic tools for aspiration-induced RPIs enables timely confirmation of foreign body size/location while reducing unnecessary bronchoscopies. Compared to bronchoscopy, imaging investigations offer higher patient acceptance but require balancing radiation exposure against diagnostic value. Advancements in artificial intelligence (AI) now enable reduced radiation exposure without compromising image quality. Enhancing physicians' image interpretation skills and diagnostic proficiency—cultivated through extensive clinical experience—remains vital. Future research should explore AI-assisted imaging analysis to boost diagnostic efficiency and cost-effectiveness. For patients undiagnosed by chest CT but with high suspicion of aspiration-induced recurrent pulmonary infection, timely bronchoscopy facilitates both foreign body removal and definitive diagnosis. However, even when performed by experienced clinicians using optimal bronchoscopes, complications remain non-negligible. Bronchoscopy may also exacerbate inflammation by irritating infected bronchial mucosa. Thus, we recommend prioritizing bronchoscopy *only* with clear aspiration history and clinical manifestations. Patients without documented aspiration history should first undergo CT to evaluate for foreign bodies and assess pulmonary infection severity; bronchoscopy should then be considered based on CT findings and clinical status. Future studies should optimize bronchoscopic techniques to minimize complications and develop more efficient diagnostic tools.

On the other hand, early and precise antimicrobial therapy post-diagnosis is essential. Empirical broad-spectrum antibiotics (third-generation cephalosporins) may be initiated pending pathogen identification. Obtain paired blood cultures before first antibiotic dose. Ensure sputum sample adequacy for culture (>25 leukocytes and <10 squamous epithelial cells per low-power field); bronchoalveolar lavage fluid (BALF) should yield isolated pathogens. Confirmed pathogens warrant targeted antimicrobials to reduce resistance development. Pathogen profiles are dynamic; therefore, antibiotic selection must consider local epidemiology, resistance patterns, and nosocomial infection data—not solely guidelines.

Finally and most critically, the current absence of dedicated guidelines for managing aspiration-induced RPIs underscores the paramount importance of prevention—especially in high-risk children and elderly populations. Recurrent pediatric pulmonary infections warrant prompt screening for aspiration etiology. For elderly individuals with dysphagia, immunosuppression, or dependence, maintaining oral hygiene reduces aspiration-related infections. Future research should explore multidisciplinary prevention models integrating medical, nursing, and rehabilitative resources—including regular home visits by community physicians/nurses/therapists. Additionally, detailed treatment guidelines addressing special populations and complex cases are urgently needed to standardize clinical management.

In summary, pulmonary infections resulting from foreign body aspiration possess a strong tendency to be covert, and the affected populations exhibit specific characteristics. When physicians encounter repeated pulmonary infections in special populations and suspect foreign body aspiration, timely bronchoscopic examination is crucial to rule out or confirm pulmonary infections caused by foreign body aspiration.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

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