Novel treatment insights for pneumoconiosis: A Narrative Review

Nuevos enfoques terapéuticos para la neumoconiosis: una revisión narrativa

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Abstract / *Resumen*

Pneumoconiosis is a group of diseases provoked by mineral dust inhalation. Inhaled particles are phagocyted by alveolar macrophages, leading to an intracellular toxicity cycle caused by reactive oxygen species, inflammation, severe pulmonary fibrosis. Due to the limited reach of current interventions that are incapable of ceasing the disease or destroying lesions, this pathology keeps representing a critic challenge for the global public health. The objective of this investigation is to describe the variants of pneumoconiosis, current and potential approaches, as well as to contrast the efficacy of these approaches (both current and emerging). To achieve this, an exhaustive review in several databases, analysing literature from the last five years focused on pathophysiology and novel therapeutic proposals. Findings indicate that currently accepted therapies, like the Whole Lung Lavage and antifibrotic drugs, are limited to stopping the progression of the disease and their symptoms; whilst the lung transplant is the only method to cure pneumoconiosis completely, but portrays very high risks. In contrast, testing on animal models puts in evidence that directed drugs, like

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Nerandomilast and Galunisertib, efficiently stop fibroblastic proliferation and migration. Herbal compounds such as Sodium Tanshinone IIA Sulfonate and Kaempferol exhibit antioxidant effects capable of removing silicotic nodules. Additionally, an approach that really stands out is nanonechnology by the use of engineered conjugated nanoparticles to penetrate through several barriers of the respiratory tract and deliver genetic or pharmacological therapies in a precise and less invasive way. In conclusion, approaches in the present ate insufficient to revert damage caused by pneumoconiosis, hence these alternatives represent genuine faith to cease the disease from its roots, making the development of randomized controlled clinical trials an imperative to evaluate their viability and security to be used for humans.

Keywords: Pneumoconiosis, future approaches, review paper.

Resumen La neumoconiosis es un grupo de enfermedades provocadas por la inhalación de polvo mineral. Las partículas inhaladas son fagocitadas por los macrófagos alveolares, lo que desencadena un ciclo de toxicidad intracelular causado por especies reactivas de oxígeno, inflamación y fibrosis pulmonar grave. Debido al alcance limitado de las intervenciones actuales, incapaces de detener la enfermedad o destruir las lesiones, esta patología sigue representando un desafío crítico para la salud pública mundial. El objetivo de esta investigación es describir las variantes de la neumoconiosis, los enfoques actuales y potenciales, así como comparar la eficacia de estos enfoques (tanto actuales como emergentes). Para ello, se realizó una revisión exhaustiva en diversas bases de datos, analizando la literatura de los últimos cinco años centrada en la fisiopatología y las nuevas propuestas terapéuticas. Los hallazgos indican que las terapias actualmente aceptadas, como el lavado pulmonar total y los fármacos antifibróticos, se limitan a detener la progresión de la enfermedad y sus síntomas; mientras que el trasplante de pulmón es el único método para curar la neumoconiosis por completo, pero conlleva riesgos muy elevados. En contraste, las pruebas en modelos animales demuestran que fármacos dirigidos, como Nerandomilast y Galunisertib, detienen eficazmente la proliferación y migración de fibroblastos. Compuestos herbales como el sulfonato de tanshinona IIA sódica y el kaempferol exhiben efectos antioxidantes capaces de eliminar los nódulos silicóticos.

Además, un enfoque que destaca es la nanotecnología, mediante el uso de nanopartículas conjugadas diseñadas para penetrar diversas barreras del tracto respiratorio y administrar terapias genéticas o farmacológicas de forma precisa y menos invasiva. En conclusión, los enfoques actuales son insuficientes para revertir el daño causado por la neumoconiosis; por lo tanto, estas alternativas representan una esperanza real para erradicar la enfermedad de raíz, lo que hace imperativo el desarrollo de ensayos clínicos controlados aleatorizados para evaluar su viabilidad y seguridad en humanos.

Palabras claves: *Neumoconiosis, enfoques futuros, artículo de revisión.*

INTRODUCTION

Pneumoconiosis is a group of Occupational Interstitial Lung Diseases where an individual inhales very fine particles from determined substances. Afterwards, these particles are dragged towards the inferior respiratory tract and reach the pulmonary alveoli where they initiate a cycle consisting of cell toxicity after being phagocyted by alveolar macrophages, to then end up producing fibrosis and lesions within the pulmonary parenchyma.

The disease represents a delicate challenge; as huge incidences have been presenting every year. These incidences can be prevented by implementing protection and prevention measures for the worker, like Japan had used them; it demonstrated a significant decrement of prevalence from 17.4% to only 1% in a period from 1982 to 2013 (Shi et al., 2023), however, this inquest is focused exclusively on treatments in the medical field.

Today, new approaches to cease the disease, as currently accepted treatments are incapable of completely stopping the procesivity of this disease or destroying produced lesions. It is relevant to address this type of respiratory diseases hence several variants of pneumoconiosis as well as some novel approaches for pneumoconiosis and their mechanisms will be briefly described and compared with current treatments to treat said condition.

The approached that will be approached go from drugs such as Nerandomilast, Ramatroban, and Gefitinib, herbal compounds like Sodium Tanshinone IIA Sulfonate and Kaempferol; to engineered nanoparticles conjugated with modified genes and factors (genes like miRNA-146a) that could potentially treat pneumoconiosis in a less invasive fashion.

In addition, there will also be a demonstration about why the novel approaches mentioned, in contrast with treatment in the present, can go beyond the palliative focus and combat the problem from its roots: fibrotic pathways.

SEARCH METHODOLOGY

The present narrative review was performed through the implementation of a design to select the most relevant and novel scientific sources regarding pathophysiology and treatment proposals for pneumoconiosis. With the goal to achieve an adequate selection and gathering of available bibliographic resources, research was conducted under a structured approach on databases such as Pubmed, SciELO, and Google Academic, having the last five years of publication taken in consideration. Integrated literature was focused on evidence associated with pneumoconiosis and its respective clinical variants. Original studies and research focused on emerging treatment approaches was prioritized. The selection mechanisms were grounded in an initial analysis of studies, followed by a throughout evaluation of the manuscripts to guarantee the inclusion of pertinent evidence. In addition, research analysing biochemical mechanisms of the condition were contemplated, particularly, with an emphasis on fibrotic processes and reduction of oxidative stress.

DEFINITION

The term “Pneumoconiosis” derives from Greek “pneuma”, meaning air; and “konis”, meaning dust. This term was coined in the IXX century with the goal of describing diseases caused by mineral dust inhalation. (Akira *et al.*, 2023).

The sickness consists of a group of OILD in which there is an entrance of inorganic dust to the lungs, leading to pulmonary disfunction. (Qi *et al.*, 2021).

There are many variants of pneumoconiosis, each present representative lesions in the lungs (Akira *et al*., 2023).

- **Silicosis.** Caused by the inhalation of crystalline silica particles smaller than 5µm. There are two manifestations: silicoproteinosis (acute), derived from very high exposition for short periods (the most common cause is sandblasting), it forms centrilobulillar nodules, calcification of consolidation areas and hiliar and mediastinic lymphatic nodes; and Progressive Massive Fibrosis (chronic), that forms hiliar collagen nodules with opacities of 1.5cm in diameter. (Akira et al., 2023; Sherekar et al.,2025).
- **Asbestosis.** Caused by exposition to asbestos dust, provoking diffuse interstitial fibrosis. It is one of the main causes of parenchymal chronic diseases in the work field. This sickness forms nodules and opacities with a "Honeycomb" pattern, and pleural plaques. (Akira *et al.,* 2023; An *et al.,*2021).
- **Coal Workers Pneumoconiosis (CWP).** Its characteristic lesion is the manifestation of carbon macules, in other words, macrophages with little fibrosis in agglutination containing carbon dust and collagen fibres. Additionally, Mixed Dust Pneumoconiosis is common in coal workers due to the combination of carbon, kaolin, silica, and mica. If its nodules surpass 1.5cm in diameter, it would be pathologically defined as Progressive Massive Fibrosis (PMF). (Akira *et al.,* 2023).
- **Mixed Dust Pneumoconiosis (MDP)**. The pulmonary response to this variant is triggered by dust containing low silica concentration (<18% of inhaled dust). If the silica concentration is more significant, then the variant would be considered as silicosis with fibrosis derived from mixed dust. For this pneumoconiosis, irregular round opacities are formed, forming starred lesion patterns with less collagen in contrast with silicotic nodes. (Akira *et al.,* 2023).
- **Welder's Pneumoconiosis**. Produced by welding fumaroles. Lesions formed (siderosis) contain iron oxide hence centrilobulillar macules with combined dust are a common occurrence. These nodules are found along perivascular and perilobulillar lymphatic vessels, and normally disappear after ceasing exposition. (Akira *et al.,* 2023).

Graphite Pneumoconiosis. Small opaque nodules with graphite dust and PMC are the most commonly found manifestations on this variant. These nodules can be centrilobulillar

or can manifest along interlobulillar septa and subpleural areas. There are two types of nodules derived from graphite pneumoconiosis: small ill-defined, which are highly abundant, and correspond to macular lesions along the walls of bronchioles; and well-defined nodules corresponding to major macular damage (Akira *et al.,* 2023).

EPIDEMIOLOGY

Pneumoconiosis is considered a threat to public health. Its prevalence in 2017 was, approximately, of 527500 cases, including 60000 new reported cases. This disease has high mortality levels, provoking more than 21000 deaths globally since 2015. (Qi *et al.*, 2021).

Back in 2019, around 200000 new cases were registered around the world, and there were statistics showing that 920000 would live having lifestyles adapted to the incapacity arisen from pneumoconiosis. All this according to the Global Burden of Disease Study 2019. (Hou *et al.,* 2025).

Furthermore, possibilities exist indicating that in less developed countries there are undiagnosed and unreported cases due to their inadequate health systems. Making the counting of cases exceptionally challenging; taking into account that pneumoconiosis has also resurged in more developed countries with more efficient health systems like USA and Australia. (Qi *et al*., 2021).

Therefore, it can be inferred that pneumoconiosis is a global public health issue that points out the need to adopt preventive measures, especially within the working field, to avoid this sickness.

SIGNS AND SYMPTOMS

Patients suffering from pneumoconiosis often present tachipnea, respiratory crackles, friction sounds whilst pulmonary auscultation, superficial breathing, chest tightening, low tolerance to exercising, coughing, and sneezing. Additionally, lesions and nodules can appear in pulmonary parenchyma depending on the determined variant of pneumoconiosis. (Delight *et al.*, 2023).

PATHOPHYSIOLOGY

To have a better understanding on the mechanisms of each treatment approach work, it is necessary to have the mechanisms in which pneumoconiosis takes place. Its pathophysiology follows the following process (Figure 1):

- Inhaled particles are trapped in the respiratory tract (larynx, pharynx, trachea, bronchi, bronchioles), by the mucociliary barriers for its subsequent expulsion.
- Very fine particles finer than 5µm surpass this defence line and end up in within the alveolar space of the inferior respiratory tract.
- These particles then bind to collagen structure receptors (MARCO) located on the membranes of alveolar macrophages (this is the way how alveolar macrophages recognize external particles), and are phagocyted afterwards.
- Phagocyted particles induce the formation of Reactive Oxygen Species (ROS), producing intracellular toxicity in alveolar macrophages.
- This generated toxicity causes activation or apoptosis of alveolar macrophages, attracts antibodies IgA and IgC and activates the NALP3/NLRP3 complex; which recruits inflammation factors (IL-1β, IL-6, IL-10, TNF-α, TGF-β, and FGF).
- The expression of TGF-β and FGF increments fibroblastic activity in that designated zone, leading to cicatrisation (fibrosis).

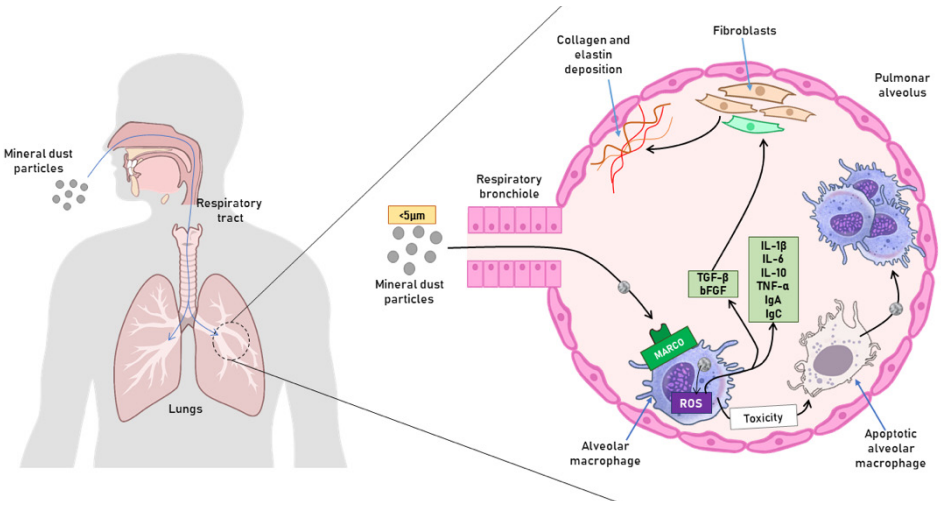


Figure 1. Mechanism of pneumoconiosis.

It is important to note that particles inside apoptotic macrophages exit said cells intact to induce ROS toxicity to more macrophages. Furthermore, in some variants of pneumoconiosis, particles permanently stay in the pulmonary parenchyma, hence the disease can manifest or progress even after around 20 years (silicosis is the most common variant that features this characteristic). (Sherekar *et al.,* 2025; Delight *et al.*, 2023)

DIAGNOSIS

Pneumoconiosis is a challenging condition to diagnose, as when said condition is diagnosed it has already progressed to its advanced stages; hence the need of a pre-clinical diagnose and well-trained personnel (Qi *et al.*, 2021).

In addition, diagnosis requires a background from the worker and a preliminary medical examination (lab, ECG, or thorax x-rays) to confirm exposition to dust (both short and long periods of exposition time), determine the existence of abnormalities or lesions after imaging analysis, and the elimination of other conditions that could potentially lead to confusion and alter the diagnosis. Then, the patient is given a diagnosis certificate with the pneumoconiosis variant and its respective condition stage; or, if there is suspicion due to the manifestation of several symptoms, the patient is to be maintained under observation (Qi *et al.,* 2021).

CURRENT APPROACHES

- Lung transplant: It is currently the only treatment capable of eliminating pneumoconiosis completely. Lung transplant is put in practice for advanced stages of any variant of the disease, helping patients expand their lifetime 6 to 7 years, approximately. This procedure portrays very high risks, requiring the use of immunosuppressants to avoid the rejection of the graft. (Li *et al,* 2022)
- Whole Lung Lavage (WLL): Mainly used to treat silicosis in its early stages. On recent studies is shown that it improves long-term results in terms of symptomatology, lung function, and reduces mortality especially on patients with artificial dust related pneumoconiosis and silicoproteinosis. (Li *et al.*, 2022).

- Tetrandine: A potent calcium channel inhibitor that stops inflammation and fibrotic processes to enhance lung activity. Tetrandine is relatively new for this approach as it was recently approved in China. (Li et al., 2022; Tang *et al.*, 2023).
- Antifibrotics (Pirfenidone and Nintedanib): Used to reduce progressivity of idiopathic pulmonary fibrosis and silicosis. Recently, they have been approved by the Food and Drug Administration (FDA) in the USA. However, in the case of pirfenidone, according to a study performed by Miedema et al., 2022, it can bring adverse effects like fatigue, gastrointestinal discomfort, rashes, to mention a few. (Li *et al.*, 2022; Miedema *et al.*, 2022)

POTENTIAL APPROACHES

In the present, a variety of drugs and methods have been put under experimentation with the goal of, potentially, implement them as an approach to not only lessen lesions, but to also eradicate pneumoconiosis.

- **Nerandomilast (BI 1015550)**: Nerandomilast is a phosphodiesterase 4B (FDE4B) inhibitor. It was administered intratracheally on sedated mice with a 1% concentration of sodium pentobarbital. There was a conclusion from studying BI 1015550 indicating that it can potentially lessen hidroxiproline concentrations in lung tissue. Additionally, inhibition of inflammatory cytokines and reduction of collagen deposition was shown. This way, further treatment (palliative treatment and prognosis) can be lighten. (Liu *et al,* 2025).
- **Galunisertib**: Tested on mice, it suppresses TGF-β signalling, which is necessary to regulate fibrosis and epithelial-mesenchymal transition. This effectively stops silica induced fibroblastic migration and proliferation. This drug is also mentioned to mitigate silicosis (and other variants of pneumoconiosis) in further stages. (Li *et al*., 2025).
- **Ramatroban:** A TXA2 and DP2 antagonist that blocks these receptors, directly inhibiting the progressivity of pneumoconiosis. (Hou *et al.,* 2025).
- **Fosfamatinib**: Generally used to treat thrombocytopenia because it attacks SYK;

a kinase enzyme that transmits signals of immune receptors in hematopoietic cells. (Hou *et al.*, 2025; Wang *et al.*, 2022).

- **Gefitinib:** Used to inhibit the EGFR gene, an important gene for cell growth and survival regulation. Therefore, it is put in utilization as an approach for lung cancer. This drug can potentially enhance the state of the lungs and reduce fibrosis and inflammation on a high scale. (Hou *et al.*, 2025; Wang *et al.*,2022)
- **Metformin:** This drug activates autophagy and is involved in various signalling pathways of fibrosis. (Hou et al., 2025).
- **Treatment with herbal components**: Some plant-based components can influence pathologic mechanisms of pneumoconiosis and may be useful to eradicate it. (Arancakova et al., 2021). Some of them are:
- **Sodium Tanshinone IIA Sulfonate**: A Salvia Miltiorrhiza extract used in chinese traditional medicine to treat coronary disease. It showed powerful antioxidant and anti-inflammatory features. In rats, it demonstrated less collagen deposition in the lung and ROS and malondialdehyde reduction. In rabbits, it showed reduction of lesions and nodules in the lung (Arancakova et al., 2021).
- **Kaempferol**: Antioxidant, anti-inflammatory and antifibrotic. In mice, it showed inflammation inhibition and proinflammatory cytokine expression decrease. Around the day 28, small silicotic nodule suppression was noticed. (Arancakova et al., 2021).
- **Dioscin**: Steroid anti-inflammatory and immunoregulatory saponin. In mice, it reduced fibrocyte recruitment and fibroblast activation; leading to fibrosis delay and collagen deposition reduction. (Arancakova *et al*., 2021).
- **Astragaloside IV**: Reduces collagen and fibronectin deposition, attenuating pulmonary fibrosis. (Hou *et al*., 2025).
- **Atractylenolide III**: Responsible of avoiding autophagy, relieving macrophage ROS induced apoptosis. (Hou *et al.*, 2025).
- **Glycyrrhizic Acid**: Inhibits the interaction of several inflammation factors, improving the condition of the patient from the beginning. (Hou *et al.*, 2025).
- **Nanotechnology**: There exist many barriers to use nanoparticles as a transport method: mucociliary secretions, epithelia, the pulmonary tract, and blood vessel

barriers; these are all related to pulmonary fibrosis. (Sherekar *et al.*, 2025).

- At the moment, these barriers have been surpassed by engineered nanoparticles that transport genes, drugs, and active ingredients.
- Timuline-based genes conjugated nanoparticles: In mice with asthma, features effective mucociliary penetration. Chronic inflammation, fibrosis, and mechanical deregulation in asthmatic lungs have been already normalized.
- Cerium oxide nanoparticles conjugated with miRNA-146a: Increments miR146a, altering leukocyte recruitment, decreasing inflammation, oxidative stress, collagen deposition, and preventing acute lesions derived from bleomycin.
- Curcumin and SCD-19 (tautomerase activity inhibitor) conjugated nsnoparticles: They demonstrated adequate mucociliary penetration and bacterial infection removal of cystic fibrosis (Sherekar *et al.*, 2025).

- Potential therapeutic approaches: There is a notion on those factors than can improve or aggravate the disease via altering the pathophysiologic mechanisms of pneumoconiosis. This includes both the expression and decrease of miRNA and other genes. Including, for example, miR-449a, miR-205-5p, miR-29b, miR-770-5p, and miR-411-3p expression to promote autophagy and signalling suppression of important genes for the disease to progress. (Hou *et al.*, 2025).

DISCUSION

Detection of pneumoconiosis strongly depends on imaging, which makes the disease more difficult to diagnose early hence it reduces the options for its approach. This represents a present problem as it shortens the treatment range to treat it, bringing in consideration that there are very few current methods to treat it too (some of them being very dangerous).

Lung transplant is the only practised method that can eradicate the disease in its advanced stages, but mortality and the risk of affecting the quality of life of the patient is high, considering that even if the condition post-surgery favourably evolves, the graft has a maximum life average of 7 years; provoking the appearance of future long-term difficulties on the function of the lung.

The Whole Lung Lavage is not very efficient to treat pneumoconiosis and exclusively reaches its maximum efficiency against silicoproteinosis (a silicosis variant), although it does reduce the progression of the sickness and enhances lung function, it does not erradicate the disease nor eliminates severe lesions like the existent cicatrisation.

Although currently accepted drugs, like tentrandine, nintedanib, and pirfenidone, all have promising mechanisms to treat the disease, they are still under early stages of use for this fashion of treatment as well as there are yet no enough effective methods as treatments hence the imperative of research to find more novel approaches to pneumoconiosis.

With the new approaches that are being studied, there are possibilities to mitigate pneumoconiosis. Experimental drugs for pneumoconiosis feature promising mechanisms, as they manage to stop fibrotic, coagulation, and inflammation processes (there are occasions in which the inflammation severely affects the existing condition). And herbal compounds, some of them used in chinese traditional medicine for the treatment of other diseases can also have the potential to lessen and even approach the disease effectively if they could be tested on humans.

The most promising section of potential approaches is the implementation of Nanotechnology. Although, Nanotechnology is still under studies, it does demonstrate a very big potential to efficiently treat the variants of pneumoconiosis in less aggressive and invasive ways in contrast with lung transplants. The use of engineered gene-conjugated nanoparticles could target factors and genes involved in inflammasomes. As mention earlier, there is a lot of knowledge about relevant factors for inflammation to take place; this is why Nanotechnology could take this knowledge to combine them along with the iniciative of conjugated nanoparticles and carry on with their respective testing. In the case where this experimentation was effective and safe for human beings, pneumoconiosis could stop being a public health problem in the future.

CONCLUSION

Methods accepted in the present are insufficient to appropriately treat pneumoconiosis as they only delay damage and the appearance of lesions; and lung transplants, which is

indeed effective, it portrays very high risks, adding that the patient could have the need to stay under palliative post-surgery treatment.

Some of the novel approaches are very promising, highlighting the potential of Nanotechnology; Nerandomilast, selective inhibitor of phosphodiesterase 4B (PDE4B), an enzyme relevant for inflammation and fibrosis; and Sodium Tanshinone IIA Sulfonate used in chinese traditional medicine that demonstrated effective reduction of existing lesions derived from pneumoconiosis in rabbits. However, it is important to note that, although all these treatments do have a huge potential and exceptional results, they are still limited to animal experimentation models.

According to what has been reviewed and with the problem that this work disease represents, carrying out studies is imperative, such as randomized controlled trials (RCT) putting these new approaches to the test in order to determine whether they could be a viable treatment for pneumoconiosis and its variants or not and their consequent consideration as a safe option for humans.

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