Exploring the Potential, Challenges, and Future Directions of Stem cell Therapy in Lung Cancer Therapeutics

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Received October 14, 2024
Accepted August 06, 2025
Electronic access August 30, 2025

Lung cancer is one of the deadliest cancers globally, and currently, no cure exists. Stem cell therapy is emerging as a promising treatment of lung cancer, and is a major focus for researchers. The focus of this paper is to examine the potential and challenges of stem cell therapy in the treatment of lung cancer, and how these limitations could be addressed. Finding therapies to overcome lung cancer is vital to humankind. Therefore, while traditional treatments like radiotherapy and chemotherapy have been used widely, they have substantial limitations that impede their effectiveness in many patients. Stem therapy, therefore, has arisen as a possible therapeutic treatment. Stem cell therapy can offer regenerative targeted approaches to treatment. This paper discusses the potential of various stem cells, including Embryonic stem cells (ESCs), Induced pluripotent stem cells (iPSCs), Mesenchymal stem cells (MSCs), in treating lung cancer. These cells can actually repair and locate the damaged tissue precisely to reduce the side effects brought by the traditional treatment. However, challenges such as tumorigenicity, immune rejection, and delivery efficiency need to be addressed by further research done by the scientists. Moreover, the discussion will focus on some advanced delivery methods and regulatory considerations. This paper introduces stem cell therapies, highlighting the promising way of stem cell therapy to increase its effectiveness and help the patients improve their situation. This emphasises the need for ongoing research and clinical trials.

Keywords: Lung cancer; Stem cell therapy; Mesenchymal stem cells (MSCs); Embryonic stem cells (ESCs); Induced pluripotent stem cells (iPSCs); Tumorigenicity; Regenerative medicine.

Introduction

Lung cancer is one of the most prevalent and deadliest cancers worldwide. In 2020, it accounted for 12.4% of the 19.3 million total new cancer cases with lung cancer alone, and 18.7% of nearly 10.0 million cancer deaths—with 1.8 million deaths annually (WHO n.d.; Sung et al. 2021)[1,2]. Although smoking tobacco is the primary cause, non-smokers are also at risk due to air pollution, second-hand smoke, and genetic factors (Kanwal, Ding, and Cao 2017; WHO n.d.)[3,4]. There are two main types of lung cancer: small cell lung cancer (SCLC), which is closely associated with cigarette smoking, and non-small cell lung cancer (NSCLC), accounting for 80 percent of cases(American Lung Association, 2023)[5]. NSCLC generally grows and spreads more slowly than SCLC. NSCLC is categorised into three main subtypes: adenocarcinoma, typically found in the outer lung and originating in epithelial tissues; squamous cell carcinoma, usually located in the central lung near the bronchus; and large cell carcinoma, which can appear anywhere in the lung and often grows and spreads more rapidly. There is also a less common type called carcinoid lung cancer. Currently, the standard treatments for lung cancer are chemotherapy and radiotherapy. Chemotherapy involves sending in strong medicine to fight the cancer cells. Oftentimes chemotherapy can kill cancer cells and inhibit their growth. However, it can also adversely affect healthy, non-cancerous cells. The medicine is usually injected into the patients' veins, but they can also come in the other form like pills. For example, Erlotinib, a type of targeted cancer drug, is used to treat non-small cell lung cancer (NSCLC) (Cancer Research UK n.d.)[6]. In addition, radiotherapy is also used to treat cancer and involves using a machine to shoot radiation at the patients' bodies at the site of the cancer. In many situations, however, lung cancer has already spread into other parts of the body, in a process called metastasization. Both chemotherapy and radiotherapy can damage healthy cells in the process of killing cancerous cells. This can lead to severe side effects like fatigue, nausea, and immune suppression (Dr. McCall, n.d.)[7]. These limitations highlight the urgent need for more effective and less harmful treatment approaches.

This paper presents a narrative literature review based on selected recent studies from PubMes, Scopus, and Science Direct, mostly between 2018 and 2024, with emphasis on peer-reviewed preclinical and clinical research related to lung cancer and stem therapy. Stem cell therapy has emerged as a potential cancer treatment by replacing damaged or cancerous tissues. Note that cancer stem cells (CSCs)—a subpopulation within tumors re-

sponsible for chemo-resistance—are different from therapeutic stem cells (ESCs, iPSCs, and MSCs) investigated for their potential to regenerate damaged lung tissue. In 2006, scientists Yamanaka and Takahashi reprogrammed multipotent adult stem cells, cells that found in adults that can turn into a limited range of cell types, to the pluripotent state, which can differentiate into many cell types, to create induced pluripotent stem cells (iPSCs) (Zakrzewski et al. 2019)[8]. This breakthrough has significant implications, as iPSCs can potentially reduce the risk of cancer and improve how patient cells function. Unlike chemotherapy and radiotherapy, which can cause significant damage to both healthy and cancerous cells, stem cell therapy could be used after these treatments to replace damaged tissue and restore normal functioning. Indeed, stem cell therapy is being used as a therapeutic for blood cancers, such as leukemia and lymphoma (NIH 2015)[4]. Given the success of stem cell therapy in other cancers, its potential application to lung cancer is of great promise.

Using stem cell therapy, researchers have explored strategies to harness normal stem cells to treat cancer. Stem cells, particularly those derived from mesenchymal sources, which can develop into connective tissue, blood vessels, and lymphatic tissue, have the ability to differentiate into various cell types in the human body. This is important because these cells can be engineered to mimic or replace damaged tissues and target cancer cells more precisely (Kwon et al. 2018)[9]. For instance, by directing stem cells to transform into cells that are more sensitive to conventional treatments like chemotherapy or radiation, we can enhance the effectiveness of these therapies and reduce side effects. Stem cells also have the ability to home in on tumor sites due to their natural migration capabilities and can be engineered to carry therapeutic agents directly to the cancerous cells. For example, one mechanism by which stem cells can fight cancer is through inducing apoptosis, the natural process of programmed cell death, helping the immune system recognise and destroy malignant (cancerous) cells more effectively (Lv et al. 2023)[10]. Given the rising interest in using stem cells as a therapeutic for treating lung cancer, this research paper will investigate the therapeutic potential of stem cells for treating lung cancer by exploring the new approaches being developed, as well as existing challenges that must be overcome to make this therapy an option feasible for patients.

Section 1: Therapeutic potential of stem cell therapy in lung cancer

Stem cells can continuously divide by mitosis, which is the process of nuclear division by which two genetically identical daughter cells are produced. When stem cells divide, they can differentiate into many different types of cells or just produce self-renewal stem cells, these are cells that divide in such a way that at least one of the resulting daughter cells remains undifferentiated and retains the ability to develop into another stem cell with the same proliferative capacity as the original cell. (Clarke 2005)[11]. There are multiple types of stem cells: pluripotent stem cells, induced pluripotent stem cells (iPSCs), as well as what are commonly known as adult stem cells, which are also called non-embryonic or somatic stem cells (NIH 2021)[6]. Pluripotent stem cells can differentiate into any cell type in the adult body, such as embryonic stem cells (ESCs). Adult stem cells, on the other hand, are found within specific tissues or organs and can differentiate into specialised cell types unique to that tissue or organ. For example, mesenchymal stem cells (MSCs), found in menses blood and bone marrow, can make and repair skeletal tissues, such as cartilage, bone and the fat found in bone marrow (Ding, Shyu, and Lin 2011; Mayo Clinic, n.d.)[12,13]. Each of these cells holds unique potential for overcoming lung cancer through different mechanisms, which will be explored in this section.

Embryonic stem cells (ESCs)

ESCs are pluripotent cells derived from early-stage embryos that have the ability to grow into any cell type within the three germ layers: endoderm, mesoderm, and ectoderm (Madeline 2019; Karen C. 2012)[14,15]. This regenerative potential has prompted researchers to explore how ESC-derived cells might be harnessed (for example, transplant) to repair lung tissue damaged by conventional lung cancer treatments. ESC-derived alveolar epithelial type II cells (AT2-like cells) have been shown to improve alveolar repair in lung injury models, suggesting therapeutic potential in NSCLC cases with structural damage (Beers and Moodley 2017)[16]. While clinical trials and studies are still in preliminary stages, there have been some promising results demonstrating that ESC-derived cells can enhance lung function and reduce damage in animal models. For instance, ESCs have shown potential in tissue regeneration and improving lung function in conditions like pulmonary fibrosis (a disease where the lung tissue becomes scarred, making it difficult to breathe) and emphysema (a condition where the air sacs in the lungs are damaged, leading to shortness of breath). However, these findings should be critically assessed, as concerns about tumorigenicity, immune rejection, and the long-term durability of these benefits remain significant challenges (Hassan et al. 2009)[17]. Additionally, ESCs can be engineered to express tumor-suppressing genes, providing a targeted strategy to inhibit the growth and spread of lung cancer cells. One example includes the over expression of the cMYC gene in ESC-derived pulmonary neuroendocrine cells, which helped model malignant SCLC, offering insights into both treatment development and early intervention approaches (Chen et al. 2024)[18]. Therefore, ESCs offer an alternative approach to treating lung cancer. They can help repair damaged lung tissue and also be engineered to

fight cancer directly.

Induced pluripotent stem cells (iPSCs)

iPSCs are adult cells reprogrammed back to a pluripotent state, enabling them to differentiate into various cell types, similar to ESCs (Chehelgerdi et al. 2023)[19]. iPSCs are created by introducing specific genes that restore the cell's pluripotency. iPSCs offer the potential for patient-specific therapies, where they can be differentiated into lung cells or immune cells specifically engineered to target lung cancer (Zhou et al. 2022)[20]. They can also be used to create personalised lung cancer models by establishing patient-specific cell lines that carry the same genetic mutations as the lung tumor, which could be used for additional research, and the development of new therapies (Chehelgerdi et al. 2023)[19]. In particular, patient-derived iPSCs have been used to model lung adenocarcinoma, the most common type of NSCLC, by reprogramming tumor cells into iPSCs, then redifferentiating them to study oncogenic signaling, tumor resistance, and immune responses (Shukla et al. 2018)[21]. These models allow precise targeting of cancer-driving mutations and help screen drug candidates. Moreover, iPSC-derived immune cells such as cytotoxic T lymphocytes (CTLs), are now being developed to recognise lung cancer-specific antigens. Early-stage trials have demonstrated that these engineered CTLs can suppress tumor growth in lung tumor xenografts (a transplant of tissue from one species to a different species) (Nishizaka et al. 2000)[22]. These advancements in iPSC technology directly support the central research question by providing innovative approaches to overcoming lung cancer's complexity and improving treatment outcomes through personalised medicine.

Mesenchymal stem cells (MSCs)

MSCs are a type of adult stem cell found in various tissues, like bone marrow and fat, that can develop into different cell types, such as bone, cartilage, and fat cells (Zakrzewski et al. 2019)[8]. They are particularly promising for lung cancer treatment due to their natural tumor-homing abilities and capacity to modulate the tumor microenvironment (Shams et al. 2023)[23]. MSCs can be engineered to deliver therapeutic agents, such as nanoparticles or cytokines, directly to tumor sites, thereby enhancing the efficacy of treatment and minimizing the systemic side effects (Joshi et al. 2023)[24]. In pre-clinical models of lung cancer, MSCs are modified to express TNF-related apoptosis-inducing ligand (TRAIL), a special protein that can kill cancer cells by sending a signal to activate their self-destruction without harming healthy cells. In this model, MSCs have successfully induced selective apoptosis in lung tumor cells, significantly enhancing the effectiveness of conventional chemotherapy treatments (Sage, Thakrar, and Janes 2016)[25]. Another study demonstrated that MSCs loaded with doxorubicin nanoparticles could reduce tumor size and improve survival rates of mouse models with lung cancer (Romeo and Barreiro Arcos 2023)[26]. While no MSC-based therapy has yet received FDA approval specifically for lung cancer, Prochymal®, a MSC product approved by Health Canada for graft-versus-host disease (Kurtzberg et al. 2014)[27]. This success represents a clinically valid example of MSC-based therapy, supporting the feasibility of such approaches in human use. Early clinical trials targeting lung cancer have shown promising outcomes; for instance, administration between 100-150 million MSCs per patient resulted in tumor shrinkage and improved clinical outcomes (Kabat et al. 2019)[28]. To fully realise the potential of MSCs in oncology, standardisation of cell expansion, delivery strategies and methods of cell engineering are still required. Nonetheless, their multifunctional properties, including targeted delivery, immune modulation, and tumour microenvironment remodelling, underscore MSCs as a compelling therapeutic platform for solid tumours such as lung cancer.

In section one, we explore the diverse potential of stem cell therapies, including ESCs, iPSCs, and MSCs, in revolutionizing lung cancer treatment by offering regenerative, personalised, and targeted approaches. This discussion aligns with our central research question by investigating how emerging therapies can lead to significant improvements in survival and quality of life for lung cancer patients.

Section 2: challenges and limitations of stem cell therapy for the treatment of lung cancer

Stem cell therapy is fundamentally different from conventional treatments as it is a living therapy. Once introduced into the body, stem cells remain biologically active and may behave in unpredictable and uncontrolled ways. They can differentiate, migrate, and interact with surrounding tissues and bring immune signals (Hwang, Varghese, and Elisseeff 2008)[29].

These behaviors are especially notable in complex environments like lung tissue, where inflammation or damage may alter cell responses. As a result, several critical challenges must be addressed before applying stem cell therapy widely to lung cancer. These include the risk of tumour formation (tumorigenicity), the potential for immune rejection, difficulties in delivering cells to targeted tumour sites, and ethical and regulatory concerns. The following sections will discuss each of these limitations in detail and explore current evidence regarding how they may affect the safety and clinical success of stem cell-based therapies for lung cancer.

Tumorigenicity

Tumorigenicity is the potential of stem cells to differentiate into cancerous cells (Ben-David and Benvenisty 2011)[30]. It includes malignant transformation of differentiated PSCs and

benign teratoma formation from residual undifferentiated PSCs (Lee et al. 2013)[31]. Both types of tumors may consist of cells from one germ layer (such as skin, nerves, or muscles), or from all three germ layers (a wide range of tissues in the body) (Gao et al. 2020)[32]. Tumorigenicity is specifically concerned in lung cancer treatment, where the introduction of stem cells could accidentally contribute to tumor growth (Wang 2023)[33]. Studies in mice and soft agar cultures have demonstrated such risks, especially when differentiation is incomplete. In some cases, stem cells have failed to suppress tumour progression, or even supported angiogenesis in tumour models (uiffo and Karnoub 2012)[34]. To address this, regulatory bodies like the US FDA require preclinical tumourigenicity testing, lineage validation, and safety switches such as suicide genes to eliminate abnormal cells if necessary (ISSCR 2021a)[35]. While clinical evidence remains limited, these measures are crucial before stem cell therapies can safely proceed into broader human trials.

Immune rejection

Immune rejection occurs when transplanted tissue is recognised as foreign by the recipient's immune system, which will cause the immune response to destroy the transplanted tissue (Meissner, Schulze, and Dale 2022)[36].This issue becomes more significant when the stem cells are not autologous. Studies have shown that autologous stem cell transplants in lung cancer models can trigger immune responses that compromise the therapy's effectiveness (Petrus-Reurer et al. 2021)[37]. Furthermore, immune rejection can be aggravated by the presence of pre-existing lung inflammation or damage, which is common in lung cancer patients (Otsuka et al. 2020)[32]. Although preclinical models provide insight into these risks, there is still limited clinical evidence from human studies. Moreover, there are differences in global regulatory requirements. For instance, Japan has implemented a fast-track system for regenerative medicine, while the US FDA requires extensive testing to ensure safety and efficacy (Beetler et al. 2023)[38]. These discrepancies emphasise the need for harmonised standards. Although promising, most immune response data still come from animal models. More clinical evidence is needed to assess rejection risks in real patients. Overall, immune rejection remains a critical challenge for the reliable and safe use of stem cells in lung cancer therapy.

Delivery and homing of the stem cells

Delivery and homing of stem cells remain other challenges in lung cancer therapy. Effective delivery is essential for ensuring that stem cells reach affected lung areas and remain there long enough to exert therapeutic benefits. However, the lung's complex structure, including its vast surface area, vascular network, and dynamic airflow, poses challenges to stem cell delivery (Labusca, Herea, and Mashayekhi 2018)[39]. Various delivery methods have been explored, including intravenous injection (delivery of medicine through a needle or tube inserted into a vein), intratracheal instillation (introduction of a medicine directly into the trachea), and direct intrapulmonary administration (injection of medicine into lungs through inhalation) (Ikrama et al. 2023)[40].

Each has advantages and limitations. For instance, intravenous injection is minimally invasive but often results in a significant portion of the stem cells getting trapped in the pulmonary capillary bed, limiting access to deeper lung tissue (Karp and Leng Teo 2009)[41]. Intratracheal instillation may improve localisation but face issues such as uneven distribution and rapid clearance (Liesveld, Sharma, and Aljitawi 2020)[42]. In some studies, stem cells failed to reach or persist at tumour sites, and therapeutic outcomes were not significantly improved (Fan et al. 2020)[43]. Overall, targeted delivery and stable homing remain critical barriers to the success of stem cell therapy in lung cancer.

Ethical and regulatory issues

Ethical and regulatory issues always surround stem cell therapy, particularly regarding embryonic stem cells (ESCs), which raise significant moral concerns due to their derivation from embryos. Critics argue that using embryos for research undermines the sanctity of life. For this reason, they advocate for alternatives, such as induced pluripotent stem cells (iPSCs) or adult stem cells, which avoid these ethical dilemmas. However, iPSCs come with challenges, including lower efficiency and technical complexities compared to ESCs (HSCI n.d.a; Cona 2024)[1,44].

Some researchers, however, argue that using embryos–when donated with informed consent and not for reproductive purposes–can be ethically justified given potential to treat severe diseases. What's more, the laws and regulations for stem cell therapies vary across countries. For instance, Japan has implemented a fast-track system for regenerative medicine, while the US FDA requires extensive testing to ensure safety and efficacy (Beetler et al. 2023)[38]. Such inconsistency can impede global development and complicate cross-border clinical trials, with increasing costs for researchers and companies navigating carrying standards (American Lung Association, 2024)[13]. Furthermore, some studies have shown contradictory findings, with stem cell therapies failing to produce significant clinical benefit in certain models (Albini et al. 2015)[45]. Addressing ethical concerns and regulations are important for advancing stem cell therapies.

A global regulatory committee could standardise practices and accelerate development. This is essential for overcoming the approach currently impeding progress in treatments like those for lung cancer.

Section 3: addressing limitations to using stem cells to treat lung cancer

Improving Safety and Efficacy

The clinical application of stem cell therapies faces challenges related to safety and efficacy, particularly in cancer treatment, where risks like immune rejection and tumorigenicity are significant. To address immune rejection, research has focused on developing techniques to reduce these risks. In order to reduce immune rejection, scientists are turning to induced pluripotent stem cells (iPSCs) and mesenchymal stem cells (MSCs), which are less likely to be rejected by the immune system. Additionally, iPSCs have the advantage of being derived from the patient's own cells, substantially lowering the risk (Takahashi and Yamanaka 2006)[46]. However, iPSCs still pose a risk of forming teratomas. Recent studies highlight that incomplete differentiation and genomic instability in iPSCs can increase tumour formation, requiring careful checks and preparation before transplantation (Sato et al. 2019)[47]. Therefore, new safety approaches aim to ensure that iPSCs are fully differentiated into the desired cell types before transplantation. Additionally, implementing rigorous screening methods can help to minimise the presence of undifferentiated cells (Chehelgerdi et al. 2023)[19]. To reduce the risk of tumorigenicity, recent research has focused on using genetic engineering, introducing suicide genes into stem cells (Gysel et al. 2023)[48]. These suicide genes can be activated by a specific drug to triggers the death of any unwanted cells that may become tumorigenic after transplantation, thus preventing tumor formation. Another advancement in improving safety is the use of encapsulation technologies, where stem cells are enclosed in a biocompatible membrane (Zhang and Huang 2022)[49]. This membrane allows the cells to secrete therapeutic factors without direct interaction with the host tissue, thereby reducing the risks of immune rejection and tumorigenicity (Freimark et al. 2010)[50]. Current research is also exploring the use of extracellular vesicles (EVs), which are tiny particles released by cells that can carry proteins, RNA, and other molecules. EVs derived from stem cells offer a safer alternative to whole-cell transplantation, as these vesicles retain the therapeutic properties of stem cells without the associated risks (Erkan et al. 2017)[51]. By addressing the safety and efficacy concerns of tumorigenicity and immune rejection head on, the future of stem cell therapeutics for the treatment of lung cancer is advancing rapidly. Indeed, overcoming these challenges helps to ensure that patients receive effective and safe interventions.

Current advances in delivery methods of stem cells to the lungs

Early methods of delivering stem cells to the lungs, such as intravenous (IV) injection, which relied on the idea that stem cells would naturally migrate to the lungs via the bloodstream (MedlinePlus 2023)[52], were widely used due to their simplicity. However, this method often resulted in poor homing: most cells were trapped in the liver and cells reaching the lung survive less than 24 hours, limiting their therapeutic effect on the lungs (Ferrini et al. 2021)[53]. Indeed, several preclinical studies using IV MSCs failed to show improved tumour outcomes, stressing the importance for better targeting methods (Ankrum and Karp 2010)[54]. To improve this, researchers have developed intranasal (through the nose) delivery and inhalation-based systems that introduce stem cells directly into the lungs (Frijlink and de Boer 2005)[55]. These localised approaches bypass systemic circulation, increase cell retention at the disease site, and enhance therapeutic efficacy (Monteillier et al. 2018; Ibrahim, Verma, and Garcia-Contreras 2015)[56,57]. Compared to intravenous methods, inhalation-based approaches have shown a 2-3 fold improvement in lung tissue retention in preclinical models. Similar to stem cell delivery systems, inhaled chemotherapy agents such as topotecan have demonstrated a 30-fold increase in lung tissue concentration and improved survival in preclinical tumor models, supporting the rationale for localized pulmonary delivery (Kuehl et al. 2018)[58]. However, even these newer approaches face limitations in sustaining cell viability or tumour retention over time, as observed in some large-animal models and early clinical testing. To improve specificity, researchers have explored nanoparticle and microsphere systems capable of co-delivering stem cells with targeting ligands that bind selectively to lung tumor cells (Deng et al. 2021; Duan et al. 2021)[59,60]. While these carriers reduce off-target effects and improve delivery precision, clinical translation remains limited due to concerns over reproducibility and long term safety.Additionally, extracorporeal circulation systems–wherein blood is infused with stem cells outside the body and then reintroduced into the lungs–have shown potential to enhance stem cell concentration at target sites (Aguirre et al., n.d.; Wagner et al. 2020)[61,62]. Although promising, these approaches remain experimental, and robust clinical outcomes are still lacking. Overall, while these delivery methods have advanced significantly, most remain in preclinical or pilot-testing stages. Continued optimization is critical to achieving more effective stem cell therapies for lung cancer.

Movement in ethical considerations and public policy

The ethical landscape surrounding stem cell therapy has evolved considerably, with a growing recognition of the need for clear and consistent regulatory frameworks to ensure the safe and ethical use of stem cells. One of the most significant ethical issues in stem cell research, particularly with embryonic stem cells (ESCs), has been the destruction of human embryos, which has sparked widespread debate. However, new technology like induced pluripotent stem cells (iPSCs), offers alternatives to help bypass these concerns (Volarevic et al. 2018)[63]. Furthermore, iPSCs can be generated from the patient's cells, reducing the risk of immune rejection while avoiding the ethical implications

associated with human ESCs (Takahashi and Yamanaka 2006)[46]. In response to these advances, organizations such as the International Society for Stem Cell Research (ISSCR) have updated their ethical guidelines to ensure that research and therapies are conducted responsibly (Juguilon and Wu 2024)[64]. ISSCR is a leading global organization which aims to advance stem cell research and its applications by providing ethical guidelines. It represents scientists, clinicians, and educators involved in stem cell research and regenerative medicine. These guidelines emphasize the importance of informed consent and transparency in clinical trials and stress the need for robust regulatory oversight to prevent unproven or unsafe treatments from reaching the market (ISSCR 2021)[65]. If researchers do not adhere to ISSCR guidelines, they may face the risk of loss of funding, reputation damage or even legal issues (ISSCR 2024)[65]. Countries like Japan have pioneered policies that allow for the fast-track approval of promising regenerative therapies, while mandating long-term safety monitoring to ensure safety. Similar regulatory frameworks have been adopted in Australia, which has imposed strict guidelines on stem cell clinics to protect patients from unsubstantiated medical claims (HSCI n.d.b)[66]. Overall, navigating these ethical considerations is vital for fostering public trust and ensuring the responsible advancement of stem cell therapies in lung cancer treatment. Advancements in stem cell delivery methods and ethical considerations are crucial for optimizing lung cancer treatment. By improving safety and efficacy, researchers can address key challenges like immune rejection and tumorigenicity. Ethical guidelines and regulatory frameworks ensure responsible development and improve public trust in these promising therapies.

Conclusion

In summary, stem cell therapy shows significant promise in the treatment of lung cancer due to its ability to regenerate damaged tissue, target cancer cells, and improve the efficacy of existing therapies. This paper has explored the diverse therapeutic potential of stem cells, including embryonic stem cells (ESCs), induced pluripotent stem cells (iPSCs), and mesenchymal stem cells (MSCs). Each type of stem cell offers unique mechanisms for targeting tumor cells, enhancing traditional treatments like chemotherapy and radiotherapy, and reducing the side effects associated with these treatments. However, there are significant challenges such as tumorigenicity, immune rejection, and effective delivery and homing that remain obstacles that must be addressed to better realise the therapeutic potential of stem cells for treating lung cancer.

Combining stem cell therapy with existing treatments like chemotherapy and radiotherapy could lead to more effective and comprehensive treatment strategies for lung cancer. Stem cells can be engineered to target tumors more precisely, reduce damage to healthy cells, and enhance the patient's immune response. For instance, MSCs can be modified to deliver therapeutic agents directly to the tumor site or to make tumors more sensitive to radiation or chemotherapy. Additionally, using stem cells to repair tissue damaged by conventional treatments could improve patient outcomes and reduce the side effects of these therapies. The cooperation between stem cells and current therapeutic approaches represents a promising avenue for improving survival rates and the quality of life for lung cancer patients.

Future research will need to focus on overcoming the challenges of immune rejection, tumorigenicity, and efficient stem cell delivery. More studies are needed to optimise the use of stem cells, ensure their safety, and refine their integration with existing treatments. Additionally, the ethical and regulatory landscape must continue to evolve to support the responsible development of stem cell therapies. Some early-stage clinical trials have failed to meet endpoints, highlighting the variability in stem cell behavior and the need for more rigorous patient selection and dosing protocols. Despite these challenges, the future of stem cell therapy in treating lung cancer is positive. With continued research and collaboration, stem cells have the potential to evolve lung cancer treatment, offering hope for more effective and less harmful therapies. It is of great importance that research efforts continue to explore and refine these therapies to fully unlock their potential to treat not only lung cancer, but a variety of other cancers as well.

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