ALL ABOUT ACUTE LYMPHOBLASTIC LEUKAEMIA

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ABSTRACT

Acute lymphoblastic leukemia (ALL) is a malignant cancer of the blood and bone marrow characterized by the uncontrolled proliferation of immature lymphoid cells known as lymphoblasts. These abnormal cells accumulate in the bone marrow and disrupt the production of normal blood cells. Current treatments for ALL include chemotherapy, radiation therapy, and stem cell transplantation. These treatments have significantly improved survival rates but are associated with toxicity and relapse due to their non-selective action on rapidly dividing cells. Recent developments in biotechnology have introduced gene-based therapies such as chimeric antigen receptor T-cell (CAR-T) therapy, which modifies a patient's own T-cells so they can specifically recognize and destroy leukemia cells. This paper reviews scientific literature comparing chemotherapy and CAR-T therapy in the treatment of ALL. The analysis focuses on remission rates, relapse rates, treatment toxicity, and treatment cost. Clinical trials demonstrate that chemotherapy achieves remission in most newly diagnosed patients, while CAR-T therapy produces remission rates above 80% in patients with relapsed or treatment-resistant ALL. However, CAR-T therapy is associated with immune-related side effects and significantly higher treatment costs. Current research suggests that CAR-T therapy functions as a complementary treatment option for relapsed ALL rather than a complete replacement for conventional chemotherapy.

Introduction

Acute lymphoblastic leukaemia (ALL) is a haematological cancer that develops in the bone marrow and leads to the rapid production of immature lymphoid cells called lymphoblasts. These abnormal cells accumulate in the bone marrow and bloodstream and interfere with the production of normal blood cells such as erythrocytes, platelets, and mature leukocytes. As leukaemia cells increase in number, the body becomes unable to produce enough healthy blood cells, leading to symptoms such as anaemia, fatigue, frequent infections, bruising, and bone pain (Pui, Robison & Look, 2011).

ALL is considered one of the most common childhood cancers. It accounts for approximately 25% of all cancers diagnosed in children worldwide. The incidence of ALL is estimated to be between 1 and 4 cases per 100,000 people annually, with the highest occurrence in children between the ages of two and five years. Although ALL can also occur in adults, survival outcomes are generally poorer in adult patients compared with children (Hunger & Mullighan, 2015).

Before the development of modern chemotherapy treatments in the mid-20th century, ALL was almost always fatal within a few months of diagnosis. Advances in chemotherapy protocols, supportive care, and medical monitoring have dramatically improved survival outcomes. Current treatment strategies have increased the five-year survival rate in children with ALL to approximately 85–90%, while adult survival rates range between 40–50% depending on the genetic subtype of the disease and patient health factors (Hunger & Mullighan, 2015).

Despite these improvements, relapse remains one of the most significant challenges in the treatment of ALL. Relapse occurs when leukemia cells survive initial therapy and begin to multiply again. Approximately 15–20% of pediatric patients and up to 50% of adult patients experience relapse following initial chemotherapy treatment (Pui, Robison & Look, 2011). Relapsed ALL is more difficult to treat because leukemia cells may develop genetic mutations that allow them to resist chemotherapy drugs.

Traditional treatments such as chemotherapy work by targeting rapidly dividing cells and disrupting cellular processes such as DNA replication and mitosis. However, these treatments are not selective for cancer cells. Healthy cells that divide rapidly, including bone marrow cells, gastrointestinal epithelial cells, and hair follicle cells, are also affected. As a result, patients frequently experience side effects such as nausea, fatigue, hair loss, immune suppression, and increased risk of infection.

Recent advances in molecular biology and biotechnology have led to the development of targeted treatments designed to attack leukemia cells more precisely. One of the most promising developments is chimeric antigen receptor T-cell (CAR-T) therapy. CAR-T therapy involves genetically modifying a patient's own T-cells so they can recognize and destroy leukemia cells more effectively. This approach represents an example of precision medicine, where treatments are designed according to the biological characteristics of an individual patient rather than applying a single treatment to all patients (June & Sadelain, 2018).

Because CAR-T therapy has demonstrated promising results in patients with relapsed or treatment-resistant ALL, it is important to evaluate how this therapy compares with traditional treatments such as chemotherapy. This literature review therefore examines existing scientific research comparing chemotherapy and CAR-T therapy in the treatment of ALL and analyzes remission rates, relapse rates, treatment toxicity, and treatment cost.

Literature Review

Traditional Treatments for ALL

Chemotherapy remains the primary treatment used for patients diagnosed with ALL. Chemotherapy drugs work by interfering with cell division and preventing cancer cells from multiplying. Treatment usually occurs in several phases. The first phase is induction therapy, which aims to eliminate most leukemia cells and achieve remission. This is followed by consolidation therapy, which targets remaining leukemia cells, and maintenance therapy, which continues for an extended period to prevent relapse (Hunger & Mullighan, 2015).

Common chemotherapy drugs used in ALL treatment include vincristine, corticosteroids, methotrexate, and anthracyclines. These drugs disrupt different stages of cell division and DNA replication in leukemia cells. When used in combination, they significantly increase the likelihood of achieving remission.

Chemotherapy has been highly effective in newly diagnosed patients. Research shows that remission occurs in approximately 85–90% of children and 60–80% of adults after initial chemotherapy treatment (Pui, Robison & Look, 2011). However, remission does not always result in a permanent cure because some leukemia cells may survive treatment.

Relapse remains a major limitation of chemotherapy treatment. In pediatric patients relapse occurs in approximately 15–20% of cases, while adult relapse rates may reach up to 50%. Patients with relapsed ALL often require more aggressive treatments such as stem cell transplantation or targeted therapies.

Chemotherapy is also associated with significant toxicity. Because chemotherapy drugs target rapidly dividing cells, healthy tissues are also damaged. This can lead to severe side effects including immune suppression, fatigue, nausea, and increased susceptibility to infections. Long-term complications such as organ damage and secondary cancers may also occur.

Stem cell transplantation may be used in patients with high-risk disease or relapsed ALL. In this procedure, diseased bone marrow is replaced with healthy donor stem cells. While stem cell transplantation can potentially cure some patients, it carries risks including infection, immune system complications, and graft-versus-host disease.

Gene Therapy and CAR-T Cell Therapy

Gene therapy represents a different approach to cancer treatment because it targets the biological mechanisms responsible for disease progression. One of the most promising gene-based treatments for ALL is CAR-T cell therapy.
CAR-T therapy involves genetically modifying a patient's own T-cells, which are immune cells responsible for identifying and destroying abnormal cells. During the treatment process, T-cells are first collected from the patient's blood using a procedure called leukapheresis.

Scientists then insert a gene into these T-cells that allows them to produce chimeric antigen receptors (CARs) on their surface. These receptors allow the modified T-cells to recognize specific proteins present on leukemia cells. In most cases of B-cell ALL, the CAR-T cells are designed to target the CD19 antigen found on leukemia cells (June & Sadelain, 2018).

After the T-cells are genetically engineered, they are multiplied in the laboratory and infused back into the patient's bloodstream. Once inside the body, the modified T-cells circulate through the bloodstream and identify leukemia cells expressing the CD19 antigen. The CAR-T cells then attack and destroy those leukemia cells.

Clinical trials have demonstrated promising outcomes for CAR-T therapy in patients with relapsed or treatment-resistant ALL. The ELIANA clinical trial reported that approximately 81% of patients achieved complete remission within three months after receiving CAR-T therapy (Maude et al., 2018). This is particularly significant because many of these patients had previously failed multiple chemotherapy treatments.

However, CAR-T therapy can also cause serious complications. One of the most common side effects is cytokine release syndrome, which occurs when the immune system becomes highly activated and releases large amounts of inflammatory molecules. Cytokine release syndrome occurs in approximately 70–90% of patients and can cause fever, low blood pressure, and breathing difficulties (June & Sadelain, 2018). Neurological complications such as confusion and seizures have also been observed in some patients.

Methodology

This research paper uses a qualitative literature review methodology to compare traditional therapies and CAR-T therapy in the treatment of ALL. Instead of conducting laboratory experiments or clinical trials, the study analyzes previously published scientific research.

Academic sources were collected from peer-reviewed medical journals and scientific databases including PubMed, Google Scholar, and the National Cancer Institute database. Search terms included "acute lymphoblastic leukemia", "CAR-T therapy", "chemotherapy outcomes", "ALL relapse rates", and "CAR-T clinical trials".
Studies were selected based on several criteria. First, the research had to focus specifically on ALL. Second, the studies needed to provide measurable data related to treatment outcomes such as remission rates, relapse rates, treatment toxicity, or survival outcomes. Third, preference was given to large clinical trials and review articles published in major medical journals.

Four key variables were used to compare chemotherapy and CAR-T therapy in patients with ALL. These variables included remission rates following treatment, relapse rates after treatment, treatment toxicity and patient tolerance, and economic cost of treatment.

Data from the selected studies were analyzed to identify patterns in treatment effectiveness and patient outcomes. This allowed comparisons to be made between traditional chemotherapy treatments and newer gene-based therapies.

One limitation of this methodology is that CAR-T therapy is a relatively recent treatment. Because of this, long-term survival data remains limited. Differences in patient populations and treatment protocols between studies may also affect direct comparisons between therapies.

Findings and Discussion

The analysis of current scientific literature reveals important differences between chemotherapy and CAR-T therapy in the treatment of ALL.

Chemotherapy remains highly effective for newly diagnosed patients. Remission occurs in approximately 85–90% of children and 60–80% of adults after initial chemotherapy treatment (Pui, Robison & Look, 2011). However, relapse remains a major challenge, particularly in adult patients.

CAR-T therapy has demonstrated particularly strong results in patients with relapsed or treatment-resistant ALL. Clinical trials show remission rates between 80% and 90% in these patients (Maude et al., 2018). In some studies, approximately 50–60% of patients remained relapse-free one year after CAR-T therapy.

The mechanisms of treatment are also very different. Chemotherapy destroys rapidly dividing cells throughout the body while CAR-T therapy uses genetically engineered immune cells to specifically recognize and destroy leukemia cells.

Treatment toxicity also differs between the two approaches. Chemotherapy produces widespread side effects because healthy rapidly dividing cells are also damaged. CAR-T therapy produces immune-related side effects such as cytokine release syndrome and neurological complications. Although these side effects can be severe, they are often temporary and manageable with medical treatment.

Cost represents another major difference between the two treatments. Chemotherapy treatment for ALL typically costs between $30,000 and $100,000 depending on treatment duration and hospital care. In contrast, CAR-T therapy can cost more than $475,000 per patient, not including hospitalization and monitoring (Neelapu et al., 2018). This high cost limits access to CAR-T therapy in many healthcare systems.

Conclusion

Advances in medical research have significantly improved treatment outcomes for patients with ALL. Chemotherapy remains the primary treatment and has increased survival rates to approximately 85–90% in children with ALL.

CAR-T cell therapy represents an important development in cancer treatment because it uses genetically engineered T-cells to specifically target leukemia cells. Clinical trials have demonstrated remission rates above 80% in patients with relapsed or treatment-resistant ALL.

Despite these promising results, CAR-T therapy also presents several challenges including severe immune-related side effects and extremely high treatment costs. In addition, long-term survival outcomes remain uncertain because the therapy is relatively new.

Overall, current research suggests that CAR-T therapy should be viewed as a complementary treatment rather than a replacement for traditional therapies. Chemotherapy remains the standard treatment for newly diagnosed patients, while CAR-T therapy provides an important treatment option for patients with relapsed or treatment-resistant ALL.

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