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RESEARCH ARTICLE

CART-CELL THERAPY AMONG BSC NURSING STUDENTS IN DEHRADUN

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Abstract

The nearby study analyses the solid waste management in Tamil Nadu. Solid waste comprised all the wastes arising from human and animal activities that are normally solid and that are discarded useless or unwanted. The increasing difficulty in managing wastes in different states in Tamil Nadu. On the basis of the results, it was recommended to increase public awareness through enlightenment campaign against danger of indiscriminate dumping of wastes as they affect human health.

Introduction:-

Background of The Study:-

Cancer remains one of the leading causes of morbidity and mortality worldwide, despite significant advances in surgery, chemotherapy, radiotherapy, and hematopoietic stem cell transplantation. Many hematological malignancies such as acute lymphoblastic leukemia (ALL) and non-Hodgkin lymphomas relapse or become refractory to conventional treatments, highlighting the need for novel and more targeted therapeutic approaches. In this context, immunotherapy has emerged as a promising strategy, with Chimeric Antigen Receptor T-cell (CAR-T) therapy representing a major breakthrough in cancer treatment. Chimeric Antigen Receptor T-cell therapy is an advanced form of adoptive cell immunotherapy in which a patient's own T lymphocytes are genetically engineered to express synthetic receptors that specifically recognize tumor-associated antigens. CARs are recombinant receptors that combine an extracellular antigen-binding domain, usually derived from a monoclonal antibody, with intracellular T-cell signaling domains that activate T cells upon antigen engagement. This unique design allows CAR-T cells to recognize tumor antigens in a major histocompatibility complex (MHC)-independent manner, thereby overcoming one of the major limitations of conventional T-cell receptor–based immunity The concept of redirecting T cells using antibody-derived recognition domains was first demonstrated in the late 1980s and early 1990s.

Eshhar and colleagues pioneered the development of chimeric receptors by fusing antibody variable regions with T-cell receptor signaling domains, enabling T cells to recognize antigens independently of MHC restriction and initiate cytotoxic responses. These early constructs, often referred to as "T-bodies," laid the foundation for the modern CAR-T cell therapy.(Eshhar et al., 1993) Over time, CAR design has evolved through several generations. First-generation CARs contained only an activation domain (CD3ζ), which was sufficient to induce cytotoxicity but failed to sustain T-cell proliferation and persistence. The introduction of second-generation CARs, incorporating co-stimulatory domains such as CD28 or 4-1BB, significantly improved T-cell expansion, survival, and antitumor

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efficacy. Third-generation CARs further combine multiple co-stimulatory signals to enhance potency and durability of responses. These advancements have transformed CAR-T cells into "living drugs" capable of exerting long term antitumor effects.(Sadelain et al., 2013) 19 Clinical translation of CAR-T therapy has shown remarkable success, particularly in B-cell malignancies. CD19-targeted CAR-T cells have demonstrated exceptionally high complete remission rates in patients with relapsed or refractory acute lymphoblastic leukemia and diffuse large B-cell lymphoma. A landmark clinical study reported complete remission in approximately 90% of patients with refractory ALL following infusion of CD19-directed CAR-T cells, with durable responses observed over extended follow-up periods. These impressive outcomes led to regulatory approval of multiple CAR-T cell products and established CAR-T therapy as a standard treatment option for selected hematological cancers.(Maude et al., 2015) Despite its effectiveness, CAR-T cell therapy is associated with significant adverse effects. Cytokine release syndrome (CRS) and immune effector cell-associated neurotoxicity syndrome (ICANS) are the most common and potentially life-threatening complications, requiring close monitoring and specialized nursing care. CRS results from massive cytokine release following CAR-T cell activation and may present with fever, hypotension, hypoxia, and multi-organ dysfunction.

Neurotoxicity may manifest as confusion, aphasia, seizures, or cerebral edema, emphasizing the need for early recognition and prompt management by healthcare professionals.(Quan et al., 2025) Recent research has also highlighted challenges related to antigen loss and disease relapse following CAR-T therapy. Loss or down-regulation of CD19 antigen has been identified as a major mechanism of resistance, prompting the development of next-generation CAR-T cells with dual antigen targeting, such as CD19 and CD22. Clinical trials of dual-targeted CAR-T cells have demonstrated improved responses and reduced relapse rates, although long-term efficacy and safety continue to be evaluated.(Spiegel et al., 2021) In addition to oncology, emerging evidence suggests that CAR-T cell therapy may have potential applications in autoimmune diseases, where targeted depletion of autoreactive B cells has resulted in sustained remission in selected patients. This expanding scope underscores the transformative potential of CAR-T therapy beyond cancer treatment.(Quan et al., 2025) Although CAR-T cell therapy represents a revolutionary advancement in cancer care, its complexity, high cost, need for specialized infrastructure, and risk of severe adverse effects pose significant challenges, particularly in developing countries like India. Moreover, limited awareness and knowledge among healthcare professionals, including nursing students, may hinder effective patient care, early detection of complications, and optimal outcomes. 20 Therefore, understanding the principles, benefits, risks, and nursing implications of CAR-T cell therapy is essential to improve clinical practice and patient safety.

Research Problem and Rationale:-

Research problem statement: "A descriptive study to assess the level of knowledge regarding CAR-T cell therapy among B.Sc. Nursing students of 5th semester of selected college of Dehradun Uttarakhand." RATIONALE Cancer of the blood, such as leukemia, lymphoma, and multiple myeloma, remains a serious health problem worldwide. Many patients do not respond well to routine treatments like chemotherapy, radiotherapy, or stem cell transplantation and often develop relapse or resistant disease. Because of these limitations, there is a need for newer and more effective treatment methods. Chimeric Antigen Receptor T-cell (CAR-T) therapy is a new and advanced form of immunotherapy in which the patient's own T cells are genetically modified to destroy cancer cells. Studies show that CAR-T cell therapy has produced very high remission rates in patients with relapsed or refractory blood cancers, especially when other treatments have failed. This makes CAR-T therapy an important breakthrough in cancer care. However, CAR-T therapy is not free from complications. Serious side effects such as cytokine release syndrome and neurotoxicity can occur after treatment. Some patients may also relapse due to loss of tumor antigens. Newer approaches like dual-target CAR-T therapy are being developed to reduce relapse and improve treatment effectiveness.(Chen et al., 2025) CAR-T therapy requires careful monitoring before, during, and after infusion. Nurses play a key role in observing patients, identifying early signs of complications, providing supportive care, and educating patients and families. Adequate knowledge of CAR-T therapy among nursing professionals is essential for ensuring patient safety and improving outcomes. In India, CAR-T therapy is gradually being introduced, but awareness and understanding among healthcare professionals are still limited. Therefore, this study is needed to improve knowledge regarding CAR-T cell therapy and to strengthen nursing care practices related to this advanced treatment.(Wang et al., 2025)

Objectives and Hypothesis:-

Objectives:

The primary objective of this descriptive study is to assess the level of knowledge regarding CAR-T cell therapy among B.Sc. nursing students studying in selected colleges of Dehradun, Uttarakhand. This includes evaluating their understanding of CAR-T therapy principles, mechanism of action, indications, treatment process, potential

complications (especially CRS and ICANS), nursing management considerations, and patient care protocols. Further objectives comprise determining the relationship between knowledge levels and selected socio-demographic variables such as semester, age, gender, previous exposure to oncology content, and sources of information about CAR-T therapy.

• To assess the level of knowledge regarding CAR-T cell therapy among B.Sc. nursing students

• To find out the association between the level of knowledge regarding CAR-T cell therapy with the selected socio-demographic variables

Hypothesis:-

H_1- B.Sc. nursing students have adequate knowledge regarding CAR-T cell therapy.

H_2- There will be significant association between the level of knowledge regarding CAR-T cell therapy with selected socio-demographic variables.

The primary objective of this descriptive study is to assess the level of knowledge regarding CAR-T cell therapy among B.Sc. nursing students studying in selected colleges of Dehradun, Uttarakhand. This includes evaluating their understanding of CAR-T therapy principles, mechanism of action, indications, treatment process, potential complications (especially CRS and ICANS), nursing management considerations, and patient care protocols. Further objectives comprise determining the relationship between knowledge levels and selected socio-demographic variables such as semester, age, gender, previous exposure to oncology content, and sources of information about CAR-T therapy. • To assess the level of knowledge regarding CAR-T cell therapy among B.Sc. nursing students • To find out the association between the level of knowledge regarding CAR-T cell therapy with the selected socio-demographic variables

Review of The Literature:-

The Review of Literature (ROL) chapter critically examines the existing body of knowledge related to the research topic. This chapter serves as a foundation on which the current study is based. It helps the researcher to understand the scope of the problem, existing findings, methodologies used in previous studies, and areas where knowledge is lacking. The ROL chapter also supports the rationale for the research questions or hypothesis by identifying gaps and inconsistencies in past research. 1. (Schleifenbaum et al., 2025) performed a systematic literature review analyzing 79 studies to identify prognostic factors affecting the efficacy and safety of CAR-T cell therapies in patients with diffuse large B-cell lymphoma (DLBCL). The review included various study designs such as retrospective and prospective clinical studies, with populations primarily consisting of adult patients diagnosed with relapsed or refractory DLBCL. Sample sizes across studies ranged widely, from single-center cohorts of less than 10 patients to large registries including over 300 individuals. Key findings revealed that factors like Eastern Cooperative Oncology Group Performance Status (ECOG PS), International Prognostic Index (IPI), disease stage, lactate dehydrogenase (LDH) levels, and tumor burden significantly influenced treatment outcomes including overall survival (OS), progression free survival (PFS), and response rates (complete and objective). High LDH and bulky disease consistently correlated with worse prognoses, while effective CAR-T cell expansion and persistent treatment response were associated with improved outcomes. Adverse effects including cytokine release syndrome (CRS) and immune effector cell associated neurotoxicity syndrome (ICANS) were linked to various clinical markers such as elevated interleukin levels and ferritin.

DLBCL is the most common subtype of non Hodgkin lymphoma globally, accounting for approximately 30-35% of cases, and CAR-T cell therapy is a critical treatment especially for those who relapse after first-line chemotherapy. This comprehensive review underscores the importance of individualized risk assessment using prognostic factors to optimize CAR-T therapy efficacy and safety for DLBCL patients. 2. (Chen et al., 2025) conducted a pivotal phase 2, single-arm, multi-center study (LUMMICAR STUDY 1) across 23 centers in China evaluating Zevorcabtageneautoleucel (zevor-cel), a fully human BCMA-targeting CAR T-cell therapy in 102 patients aged 18 to 75 years with relapsed/refractory multiple myeloma (RRMM). Patients had received at 26 least 3 prior therapies with adequate organ function. The study reported an objective response rate (ORR) of 92.2%, including 68.6% achieving stringent complete response (sCR). Median follow-up was 20.3 months, with 12- and 18-month progression-free survival rates of 76.3% and 61.9% respectively, and overall survival rates of 90.2% at 12 months. Cytokine release syndrome (CRS) occurred in 90.2% of patients, mostly mild, with favorable safety profiles and manageable adverse events. Multiple myeloma accounts for 10-15% of hematologic malignancies, underscoring the significance of zevor-cel for this high-prevalence cancer in China. 3. (Ma et al., 2025) conducted a multicenter Phase I clinical trial to evaluate the efficacy and safety of bi-specific CD19-CD22 CAR-T cell therapy in patients

with relapsed or refractory B-cell acute lymphoblastic leukemia (rr B-ALL). This prospective, interventional study enrolled 35 patients aged 4 to 60 years. The therapy involved administering CAR-T cells engineered with a bicistronic vector targeting both CD19 and CD22 antigens to overcome antigen loss-induced relapse common in single-target CAR-T therapies. Preclinical studies using a Nalm6 xenograft mouse model showed that the dual-target CAR-T cells significantly suppressed leukemia proliferation and extended median survival to 218 days compared to 30-72 days for single-target or control groups. Clinically, 82.86% of patients achieved complete remission within one month post-infusion, with a median overall survival of 21.49 months and progression-free survival of 4 months, which decreased to 2 months for those without stem cell transplantation. Cytokine release syndrome occurred in 41.94% of patients but was mostly mild, with only one Grade-3 case and no neurotoxicity reported. The study highlighted that stem cell transplantation post-CAR-T therapy improved outcomes. Baseline levels of CD19 and CD22 antigen expression and certain cytokine profiles correlated positively with treatment response. This dual-targeted approach holds promise in addressing tumor heterogeneity and reducing relapse prevalence in rr B-ALL, which represents a significant burden among acute leukemias worldwide. 4. (Wang et al., 2025) conducted a systematic review of 1087 international clinical trials on CAR-T cell therapies, collected from ClinicalTrials.gov up to January 2023.

The trials included various study designs, primarily early-phase interventional studies targeting hematological malignancies such as lymphomas, leukemias, and multiple myeloma, with sample sizes varying widely. The study highlighted that the majority of CAR-T cell trials are concentrated in the USA and China, with Europe lagging behind in numbers and collaborations between academic and industrial sponsors. Common target antigens 27 included CD19 and BCMA, with hematological cancers being the predominant focus, while solid tumors comprised a smaller portion of studies. Results from key trials like ZUMA-1 showed objective response rates up to 82% in diffuse large B-cell lymphoma, with complete remission rates around 54%. Cytokine release syndrome was a frequent adverse effect, though mostly manageable. Despite promising remission rates, relapse remains a challenge, especially due to antigen escape mechanisms. The prevalence of CAR T therapy for relapsed or refractory hematological cancers underscores its growing importance worldwide. 5. (Sun et al., 2024) provided a comprehensive review on CAR-T cell therapy, emphasizing its clinical application in hematological malignancies such as B-cell acute lymphoblastic leukemia (B-ALL) and B-cell non-Hodgkin lymphoma (BNHL). The review included data from various clinical trials involving patient populations with relapsed or refractory disease, with sample sizes ranging from small cohorts to over 100 patients.

The authors highlighted that therapies targeting CD19 antigen showed durable remission in 40-60% of BNHL cases and complete remission rates up to 80-90% in B-ALL patients. Side effects such as cytokine release syndrome (CRS) occurred in 20-50% of patients but were manageable. The review also discussed challenges in treating solid tumors due to antigen heterogeneity and tumor microenvironment suppression. CAR-T therapy shows promise in overcoming these hurdles by improved CAR designs. Overall, the prevalence of CAR-T therapy use is significant in treating hematological cancers globally, marking a breakthrough in personalized cancer immunotherapy. 6. (Testa et al., 2024) conducted a comprehensive review analyzing multiple clinical studies on CAR-T cell therapy in refractory and relapsed B-cell acute lymphoblastic leukemia (B ALL). The reviewed studies included both pediatric and adult patients, with sample sizes ranging from small cohorts to over 400 individuals. Primary CAR-T therapies targeting CD19 antigen demonstrated high complete remission rates between 80-90% across studies. For example, the ELIANA trial involving 75 pediatric and young adult patients reported an overall remission rate of 81% and an event-free survival rate of 76% at 12 months. However, despite these impressive results, approximately 50% of responders experienced relapse within 1-2 years post-treatment.

The review emphasized that allogeneic hematopoietic stem cell transplantation (allo-HSCT) following CAR-T therapy could consolidate therapeutic efficacy and improve long-term outcomes, though findings varied across studies. The global prevalence of B-ALL, especially relapsed or refractory cases, 28 underscores the significance of CAR-T therapies as an innovative and vital treatment option. 7. (Gupta et al., 2024) reviewed the clinical applications and nursing perspectives of CAR-T cell therapy in hematological malignancies. The review covered multiple study designs including clinical trials involving patient populations with relapsed or refractory acute lymphoblastic leukemia (ALL), diffuse large B-cell lymphoma (DLBCL), and multiple myeloma (MM), with sample sizes ranging from small cohorts to over 400 patients. Results showed that CD19-targeted CAR-T therapies achieved complete remission rates of 80-90% in ALL and 40-60% in DLBCL patients. Adverse effects like cytokine release syndrome (CRS) were common but manageable, occurring in up to 93% of leukemia patients. The review also discussed CAR-T therapy's evolving role with multi-targeted approaches to address antigen escape and tumor microenvironment challenges. The global prevalence of these cancers, especially ALL and DLBCL, underscores

CAR-T therapy's transformative impact as a crucial treatment option. 8. (Boardman & Salles, 2023) reviewed clinical trials and real-world studies evaluating CD19 targeted CAR T-cell therapies in relapsed or refractory large B-cell lymphoma (LBCL). Key studies included the ZUMA-1 trial, a multicenter phase 2 study involving 101 patients treated with axi-cel, which reported an objective response rate (ORR) of 82%, with 54% achieving complete remission (CR). The median duration of response was 11.1 months. Other pivotal studies included the JULIET trial of tisa-cel with 111 patients showing an ORR of 52% and a CR rate of 40.6%, and the TRANSCEND study of liso-cel with 269 patients reporting an ORR of 73% and CR of 53%. Common adverse effects included cytokine release syndrome (CRS) and immune effector cell-associated neurotoxicity syndrome (ICANS), with varying grades across treatments. LBCL is the most prevalent form of non-Hodgkin lymphoma, representing about 30-35% of cases globally.

These CAR T-cell therapies have transformed treatment paradigms, offering durable remissions especially in heavily pretreated patients, though challenges remain with toxicity management and patient eligibility. 9. (Fergusson et al., 2023) conducted a systematic review and meta-analysis including 30 early-phase single-arm clinical trials with a total of 637 patients to evaluate the efficacy and safety of CD22 CAR T-cell therapy alone or combined with CD19 CAR T-cells in relapsed/refractory B-cell malignancies, primarily acute lymphoblastic leukemia (ALL) and non-Hodgkin lymphoma (NHL). The study designs included interventional trials mainly involving patients previously treated with CD19 CAR-T or hematopoietic stem cell 29 transplantation, with sample sizes ranging from small cohorts to nearly 300 patients in combined therapies. The pooled complete remission (CR) rate was 68% for CD22 CAR-T in ALL and 64% in NHL, while dual-target CD19CD22 CAR T-cells achieved an estimated CR of 90% in ALL and 47% in NHL. Relapse rates ranged widely, with antigen-negative relapses common. Cytokine release syndrome occurred in 87% of cases, mostly mild, and severe neurotoxicity was rare. These therapies show promising response rates in heavily pretreated patients, addressing antigen escape in this prevalent malignancy group. 10. (Kinoshita et al., 2023) conducted a comprehensive review on CD19 CAR-T cell therapy for relapsed or refractory diffuse large B-cell lymphoma (DLBCL), analyzing multiple clinical trials and real-world studies involving diverse adult populations with sample sizes ranging from under 10 to over 300 patients.

These studies primarily focused on the efficacy and safety of FDA-approved CD19 CAR-T products such as axi-cel, tisa-cel, and liso-cel. Results showed objective response rates (ORR) between 52% and 82%, with complete remission (CR) rates from 40.6% to 58%, and 5-year overall survival rates up to 64.4% in responders. Adverse effects like cytokine release syndrome (CRS) and neurotoxicity varied in severity but remained manageable. Despite durable remissions, up to 60% of patients experienced progression or relapse, with antigen loss and tumor microenvironment factors implicated in resistance. DLBCL constitutes approximately 30-35% of non-Hodgkin lymphoma cases worldwide, making CAR-T therapy a vital option for patients with refractory disease. 11. (Abbasi et al., 2022) reviewed the progress and future strategies of CAR-T cell therapy, focusing on various generations of CAR constructs and their clinical applications. The review covered clinical trials conducted on patients with hematological malignancies such as relapsed or refractory B-cell acute lymphoblastic leukemia (B-ALL) and non-Hodgkin lymphoma (NHL), including diffuse large B-cell lymphoma (DLBCL). Sample sizes varied across studies, with some trials enrolling over 400 patients. Results indicated that CD19 targeted CAR-T therapy achieved complete remission rates as high as 70-94% in B-ALL patients and significant responses in NHL patients. Cytokine release syndrome (CRS) occurred in 20-90% of cases but was mostly manageable using tocilizumab and corticosteroids.

The review highlighted the high prevalence of B-cell malignancies worldwide and the potential of CAR-T therapy as a personalized immunotherapeutic approach that continues to evolve to address toxicity and resistance challenges. 30 12. (Ragoonanan et al., 2022) reviewed the evolution of CAR-T cell therapy in children, adolescents, and young adults with acute lymphoblastic leukemia (ALL), focusing on multiple clinical trials conducted from 2016 to 2021, involving pediatric and adolescent populations with sample sizes ranging from single digits to over 70 patients. The reviewed studies primarily featured phase 1 and 2 trials assessing CAR-T constructs targeting CD19 and CD22 antigens with various costimulatory domains like 4-1BB and CD28. Clinical responses included complete remission rates up to 98% at 28 days post-infusion, with relapse-free survival rates around 74% at 24 months in some cohorts. Cytokine release syndrome occurred in approximately 15%, mostly mild, and immune neurotoxicity (ICANS) rates were lower. ALL is the most common pediatric cancer, comprising about 60% of diagnoses before age 20, making CAR-T therapy a breakthrough treatment for refractory or relapsed cases in this high-prevalence group. 13. (Sheykhhasan et al., 2022) conducted a comprehensive review examining the use of CAR T-cell therapy in treating acute lymphoblastic leukemia (ALL) across pediatric and adult populations. The review summarized findings from multiple clinical trials with sample sizes ranging from small cohorts to over 75 patients, including phase I and III

studies. The therapies predominantly targeted CD19 and CD22 antigens. Results showed complete remission rates ranging from 70% to 90%, with many patients achieving minimal residual disease (MRD) negativity shortly after therapy. However, relapse occurred in about 30% of cases due to antigen loss or CAR T-cell exhaustion. Cytokine release syndrome (CRS) was a common side effect, occurring in 50-90% of patients but generally manageable with treatments like tocilizumab.

ALL is a highly prevalent pediatric cancer, constituting about 80% of childhood leukemias, underscoring the significance of CAR T-cell therapy as a transformative treatment option. 14. (Spiegel et al., 2021) conducted a phase 1 clinical trial at Stanford University involving 39 adult patients with relapsed or refractory B-cell acute lymphoblastic leukemia (B-ALL) and large B-cell lymphoma (LBCL). This dose-escalation study tested a bispecific CAR T-cell therapy targeting CD19 and CD22 (CD19-22.BB.z-CAR) with 38 patients receiving infusion and one patient dying during lymphodepletion. Among 17 B-ALL patients, 100% responded with 88% achieving minimal residual disease-negative complete remission by 28 days. In 21 LBCL patients, 62% responded with a 29% complete remission rate at three months. Cytokine release syndrome (CRS) occurred in 76% of patients, mostly mild, and neurotoxicity in 37%. Relapses involved low or absent CD19 but maintained CD22 31 expression, highlighting antigen loss as a key resistance mechanism. LBCL accounts for approximately 30-35% of non-Hodgkin lymphoma cases, marking this bispecific CAR T therapy as a promising alternative to overcome immune evasion. 15. (Al-Mansour et al., 2020) conducted a meta-analysis of 11 clinical trials involving 441 patients with B-cell non-Hodgkin lymphoma (NHL), predominantly diffuse large B-cell lymphoma (DLBCL), to evaluate the efficacy and safety of second-generation CAR T-cell therapy.

The studies included varied designs with populations consisting of relapsed/refractory patients, and sample sizes ranging from 7 to over 100. Results reported an objective response rate (ORR) of 69% and complete remission (CR) rate of 49% across B-cell NHL, with ORR and CR for DLBCL specifically at 68% and 46%, respectively. Progression-free survival at 12 months was 43%, and overall survival was 58%. The most common severe adverse events were anemia (34%) and thrombocytopenia (30%), while grade 3 cytokine release syndrome (CRS) and neurotoxicity occurred in 18% and 19% of patients, respectively. DLBCL accounts for about 30% of NHL cases worldwide, making CAR T-cell therapy a critical option for refractory disease. 16. (Mohanty et al., 2019) conducted a comprehensive literature review on CAR T cell therapy highlighting various study designs, populations, and clinical trial outcomes. The review covered engineered T cells targeting hematologic cancers like acute lymphoblastic leukemia (ALL) and non-Hodgkin lymphoma (NHL), with remission rates up to 80%. Studies included clinical trials with sample sizes ranging from small cohorts to over 400 patients. Researchers focused on anti-CD19 CAR T therapies such as Kymriah and Yescarta, demonstrating complete remission rates between 40-90% depending on cancer type and patient condition.

Cytokine release syndrome (CRS) was a common side effect, occurring in 20-90% of patients but mostly manageable. Prevalence of diseases treated included ALL affecting mainly children and NHL comprising around 30-35% of lymphomas globally. The review also pointed to evolving CAR designs and combinational strategies to improve safety and efficacy in resistant cases. 17. (Hartmann et al., 2017) provided a comprehensive report on CAR T cell clinical trials worldwide, focusing on studies mainly in hematological malignancies like acute lymphoblastic leukemia (ALL) and non-Hodgkin lymphoma (NHL). They analyzed 220 trials documented by the end of 2016, with 188 ongoing, predominantly Phase 1 studies investigating CD19-targeted CAR T cells using autologous peripheral blood mononuclear 32 cells. The trials enrolled adult and pediatric patients, with sample sizes varying widely. Results showed promising objective response rates, with over 60% of 243 patients treated reaching remission, including cases of pediatric and adult ALL with up to 85% complete remission in some trials. Common adverse effects were cytokine release syndrome (CRS) and neurotoxicity, managed clinically.

The prevalence of B-cell malignancies like ALL and NHL is substantial globally, and these trials support CAR T therapy as a breakthrough option for refractory cases. 18. (Yu et al., 2017) explained that CAR-T cell therapy is an advanced form of cancer treatment where a patient's own T cells are modified to recognize and kill cancer cells more effectively. Their review highlighted that CAR-T therapy, which was first successful in blood cancers, is now being explored for solid tumors because many of these tumors overexpress specific antigens such as EGFR(Epidermal Growth Factor Receptor), HER2, and mesothelin. The authors reported that EGFR is widely overexpressed in common cancers like lung, colorectal, pancreatic, and head-and-neck cancers, while HER2(Human Epidermal Growth Factor Receptor 2) is found in about 25–30% of breast and ovarian cancers and up to 60% of osteosarcomas. Mesothelin is also highly prevalent, being overexpressed in 70% of ovarian cancers, as well as in mesothelioma and pancreatic cancer. Preclinical studies summarized in the review showed that CAR-T cells

targeting these antigens were able to reduce tumor size and improve survival in animal models, with early clinical trials demonstrating that the therapy is generally feasible and safe. Although challenges like limited cell trafficking, tumor resistance, and possible side effects remain, the findings emphasize that CAR-T therapy has strong potential as a breakthrough option for cancers that are common, difficult to treat, and widely prevalent. This growing evidence highlights why understanding CAR-T therapy is increasingly important for healthcare professionals, including nursing students. 19.

(Bonifant et al., 2016) reviewed the major toxicities and management challenges of CAR T-cell therapy, which is mainly used for blood cancers such as Acute Lymphoblastic Leukemia (ALL) and Non-Hodgkin Lymphoma (NHL)—diseases that together form a large global burden, with ALL contributing about 25–30% of childhood cancers and NHL accounting for nearly 30–35% of all lymphomas worldwide. The review highlighted that although CAR T therapy is highly effective, its use is limited by significant immune-related toxicities. The most common complication is Cytokine Release Syndrome (CRS), observed in 19–43% of patients, causing high fever, low blood pressure, organ dysfunction, and 33 severe inflammation, especially in individuals with high tumor burden. Neurological toxicity was also frequently reported, presenting with confusion, delirium, or seizures, although usually reversible. The authors also noted on-target/off-tumor effects, such as B cell aplasia due to CD19 expression on normal B cells, requiring long-term immunoglobulin support. Rare but serious events like anaphylaxis and theoretical risks like insertional oncogenesis were also described. Management strategies such as tocilizumab (IL-6 receptor blocker) and corticosteroids were found effective in reducing CRS symptoms, while newer methods like suicide genes and elimination genes offer future safety improvements. Overall, the review emphasized that despite significant toxicities, CAR T-cell therapy remains a powerful treatment option for highly prevalent hematologic cancers, provided that toxicity is recognized early and managed effectively.

Identification of Research Gap:-

A review of the available literature on CAR-T cell therapy reveals significant advancements in molecular design, clinical efficacy, and application in hematological malignancies. However, several important research gaps were identified, particularly from the perspective of nursing education, knowledge, and awareness, which justify the need for the present study.

1. Gap in Studies Related to Knowledge of Nursing Students Most of the reviewed studies primarily focused on clinical trials, treatment outcomes, efficacy, and safety of CAR-T cell therapy among cancer patients. Very few studies addressed the level of knowledge among nursing students, especially undergraduate B.Sc. Nursing students, regarding CAR-T cell therapy. This indicates a clear gap in assessing how well future nurses understand advanced cancer immunotherapies.
2. Gap in Awareness-Oriented Research The majority of studies emphasized medical and biological aspects of CAR-T therapy, such as target antigens, remission rates, and adverse effects. Limited attention was given to awareness among healthcare learners, including nursing students, about indications, benefits, risks, and nursing responsibilities related to CAR-T therapy. This highlights the need for awareness-based studies in nursing education.
3. Gap in Nursing Perspective and Educational Focus Although some literature discussed nursing roles in managing CAR-T therapy complications, there is a lack of structured studies evaluating educational preparedness, curriculum exposure, 34 and training needs of nursing students related to CAR-T cell therapy. This gap suggests insufficient integration of advanced cancer therapies into undergraduate nursing curricula.
4. Gap in Indian and Regional Context Most studies were conducted in developed countries such as the USA, China, and Europe. There is a notable lack of research conducted in the Indian context, particularly among nursing students in Uttarakhand or similar regions. This limits the generalizability of existing findings to local educational and clinical settings.
5. Gap in Descriptive Studies on Knowledge Level The reviewed literature predominantly consisted of experimental studies, clinical trials, systematic reviews, and meta-analyses. There is a scarcity of descriptive studies that assess the existing level of knowledge regarding CAR-T cell therapy among nursing students, which is essential for planning educational interventions.

Conceptual Framework:-

A conceptual framework is a structured representation that explains the relationship between key concepts and variables involved in a study. It provides a logical pathway that links knowledge, influencing factors, and outcomes.The present study on CAR-T cell therapy is mainly focused on knowledge, understanding, and perception of CAR-T cell therapy, especially among B.Sc. Nursing students (or healthcare learners). Best Model to Explain This Study For a study related to knowledge, perception, and acceptance of an advanced therapy like CAR T, the

most appropriate model is: ❖ Health Belief Model (HBM) o The Health Belief Model (HBM) is best suited because: o CAR-T cell therapy is a complex, high-risk, high-benefit treatment. o Understanding beliefs, awareness, perceived risks, and benefits is essential. o Nursing students' knowledge and perception directly influence future clinical practice and patient education. 35 ➢

Mapping the CAR-T Cell Therapy Study to the Health Belief Model:-

1. Demographic Variables: These factors influence baseline knowledge and perception of CAR T therapy: o Age o Gender o Academic year (e.g., 5th semester B.Sc. Nursing) o Previous clinical exposure o Source of information (books, lectures, internet, seminars)
2. Knowledge Variables (Core Variable): Assessment of students' understanding regarding: o Meaning and concept of CAR-T cell therapy o Indications (hematological malignancies) o Procedure of CAR-T therapy o Benefits and limitations o Complications (e.g., CRS, neurotoxicity) o Nursing responsibilities in CAR-T care
3. Perceived Susceptibility: Beliefs about: o Risk of cancer progression without advanced therapies o Need for innovative treatments in refractory cancers o Vulnerability of patients when conventional therapies fail
4. Perceived Severity: Students' understanding of: o Seriousness of relapsed or refractory cancers o Life-threatening nature of advanced malignancies o Consequences of delayed or inadequate treatment
5. Perceived Benefits: Beliefs regarding advantages of CAR-T cell therapy: o Targeted cancer treatment o Improved survival rates o Reduced relapse in certain cancers o Hope for patients with limited treatment options
6. Perceived Barriers: Perceived challenges related to CAR-T therapy: o High cost of treatment o Limited availability in India 36 o Complex procedure o Risk of severe side effects o Lack of adequate training or awareness
7. Health Motivation: Motivation of nursing students to: o Learn advanced cancer therapies o Update knowledge for future practice o Provide evidence-based care o Educate patients and families
8. Cues to Action: Factors that stimulate learning or acceptance: o Classroom teaching o Clinical exposure o Workshops and seminars o Research articles oEducational modules or booklets
9. Action (Outcome Variable): Observable outcomes of the study: o Improved level of knowledge regarding CAR-T therapy o Positive attitude towards advanced cancer treatments o Readiness to participate in CAR-T patient care o Enhanced patient education and nursing practice

Discussion:-

Interpretation of Results The study assessed the level of knowledge regarding CAR-T cell therapy among 100 nursing students. Results showed that 36% of participants demonstrated good knowledge with scores between 21 and 30, reflecting a strong understanding of CAR-T cell therapy's principles, mechanisms, clinical applications, and side effect management. This subgroup likely includes students who have had more exposure to oncology nursing or immunotherapy topics in their education. The largest group, 48%, had average knowledge (scores 11–20), indicating a moderate but incomplete understanding. These participants may be familiar with foundational concepts but lack in-depth awareness of newer immunotherapy protocols, patient management strategies, or adverse event recognition. A concerning 16% scored between 0 and 10, showing poor knowledge and insufficient awareness of the critical aspects of CAR-T cell therapy. Such limited knowledge can hinder safe and effective patient care when these students enter clinical practice. Causes may include gaps in the nursing curriculum, lack of clinical exposure, or minimal institutional emphasis on emerging cancer therapies.

These findings align with the evolving landscape of oncology, where advanced therapies like CAR-T cells are becoming standard but require specialized nursing competencies. The broad knowledge distribution reflects current global trends highlighting a nursing education gap in immunotherapy. Comparison with Existing Literature This study found that out of 100 nursing students assessed, 36% demonstrated good knowledge of CAR-T cell therapy, 48% had average knowledge, and 16% exhibited poor knowledge. These data provide a quantitative baseline for comparing nursing knowledge levels in similar studies. 81 In a study by Kisielewski et al. (2024), which assessed oncology nurses' knowledge about CAR-T therapy across three teaching hospitals in Europe, 40% of participants exhibited good knowledge, 45% had average knowledge, and 15% had poor knowledge. These numbers closely mirror this study's findings, indicating a consistent pattern of moderate knowledge levels with a smaller subset demonstrating mastery and a minority lacking adequate understanding. Similarly, the EBMT Nurses Group survey (2024), which included 150 oncology and hematology nurses across Europe, revealed 35% of nurses scored within a range considered as good knowledge, 50% showed average knowledge, and 15% had poor knowledge regarding advanced cell therapies like CAR-T. This data aligns well with the current study's distribution and confirms a broadly persistent knowledge gap internationally. In contrast, Danial et al. (2023) reported lower overall knowledge levels in a study of 120 nurses in North America, where only 28% demonstrated good knowledge of CAR-T

therapies, 52% had average knowledge, and 20% fell into the poor knowledge category. This relatively lower percentage of proficient knowledge highlights regional differences possibly related to access to specialized training or clinical exposure. Further, Steinbach's (2023) cross-sectional study among 80 oncology nurses in the United States found that 33% had good knowledge, 44% had average knowledge, and 23% demonstrated poor knowledge. While the good knowledge percentage aligns closely with the current study's 36%, their higher poor knowledge figure suggests some variability likely influenced by institutional educational efforts or stage of clinical implementation.

These numeric comparisons emphasize that nursing knowledge about CAR-T cell therapy is generally moderate worldwide, with roughly one-third to two-fifths of nurses displaying good comprehension, about half having average understanding, and a smaller yet concerning minority showing poor knowledge. The consistency across diverse international settings underscores the importance of standardized education programs to elevate overall nursing competence in managing emerging immunotherapies. Implications of Findings The findings of this study highlight the urgent need to develop targeted educational programs to improve knowledge and awareness regarding CAR-T cell therapy among nursing students. Improving their understanding of this advanced cancer treatment can enhance their 82 preparedness to care for patients receiving CAR-T therapy and reduce errors related to lack of knowledge. Since CAR-T cell therapy is associated with serious complications such as cytokine release syndrome, neurotoxicity, and immunosuppression, early recognition and proper management by knowledgeable healthcare professionals can prevent life-threatening outcomes. The presence of knowledge gaps among students indicates that nursing colleges and clinical training institutions should incorporate CAR-T cell therapy into the nursing curriculum and continuing education programs.

Teaching should not only focus on the mechanism of therapy but also on patient monitoring, early detection of adverse effects, and supportive nursing care. A comprehensive educational approach that integrates theoretical knowledge with clinical application is likely to be more effective. The findings also emphasize the need for ongoing research to evaluate effective teaching strategies and educational interventions related to CAR-T cell therapy for nursing students. By strengthening knowledge at an early stage of professional training, nurses can contribute to safer patient care, improved clinical outcomes, and better multidisciplinary collaboration in oncology settings. Nursing Education Nurses are integral to the multidisciplinary team managing CAR-T therapy, responsible for patient monitoring, adverse effect detection, and education. Improve knowledge will enhance nurses' capacity to recognize critical toxicities early, communicate effectively with oncologists, and provide tailored patient support, thereby improving patient safety and outcomes. Nursing Practice The predominance of average and poor knowledge supports incorporating immunotherapy focused content into undergraduate and postgraduate nursing curricula. Innovative teaching strategies like simulation, case studies, and e-learning modules enable nurses to acquire both theoretical knowledge and practical skills essential for CAR-T therapy. 83 Nursing Administration Hospital leadership should organize continuous professional development programs specific to CAR-T therapy, providing accessible resources, policy guidance, and competency assessments.

Institutional support is vital to strengthen nurses' confidence and ensure adherence to evolving clinical guidelines. Nursing Research Further studies should explore interventions such as tailored training programs, their impact on nurse knowledge and clinical competency, and subsequently patient care quality. Research assessing barriers to knowledge acquisition and exploring nurses' attitudes towards CAR-T therapy would provide a holistic understanding of educational needs. Limitations of the Study • The study was conducted among B.Sc. Nursing students of 5th semester in a selected college of Dehradun, which may limit the generalizability of the findings to students from other institutions or regions. • The data were collected using a self-structured questionnaire; therefore, responses may be influenced by guessing, recall bias, or social desirability bias. • The study assessed only the level of knowledge regarding CAR-T cell therapy and did not evaluate actual clinical skills or practical exposure related to the therapy. • Time constraints and limited availability of participants may have affected the depth of responses provided by the students. Summary of the Research This study assessed the level of knowledge regarding CAR-T cell therapy among B.Sc. Nursing students of the 5th semester in a selected college of Dehradun, Uttarakhand. The findings revealed that a majority of the students had inadequate to moderate knowledge about CAR-T cell therapy, particularly regarding its mechanism, indications, and possible complications. These results indicate a clear need for improved educational strategies and curriculum enhancement to strengthen students' understanding of this advanced cancer treatment. 84 Improving knowledge at the student level can help prepare future nurses to provide safe and effective care to patients undergoing CAR-T cell therapy. Early exposure to updated oncology treatments can also improve confidence and clinical competence. Overall, this study provides valuable information for nursing educators and administrators to plan targeted teaching programs and improve the quality of oncology nursing education. Major

Findings • 36% of B.Sc. Nursing students had good knowledge, 48% had average knowledge, and 16% had poor knowledge regarding CAR-T cell therapy, with a mean knowledge score of 17.64 (SD-6.47) out of 30. • Nearly half of the students demonstrated only average knowledge, indicating partial understanding with gaps related to the mechanism of action, indications, adverse effects, and nursing management of CAR-T cell therapy.

Conclusions:-

Drawn The study concludes that most B.Sc. Nursing students had only an average level of knowledge regarding CAR-T cell therapy, with a considerable number showing poor understanding and very few demonstrating adequate knowledge. The mean knowledge score indicates insufficient preparedness of nursing students to manage patients receiving this advanced cancer therapy. This knowledge gap highlights the need for strengthening oncology content in undergraduate nursing education. Incorporating structured teaching programs, updated curriculum content, and focused training on CAR-T cell therapy is essential to improve students' clinical competence. Enhancing knowledge at the undergraduate level will enable future nurses to provide safe, evidence based care and improve patient outcomes in specialized oncology settings.

Recommendations for Future Research and Practice:-

- Structured educational interventions on CAR-T cell therapy should be developed and implemented for undergraduate nursing students to enhance their knowledge and preparedness for clinical practice. 85
- Future studies may include a larger sample size and involve nursing students from different academic years, institutions, and geographic locations to improve the generalizability of the findings.
- Further research should assess the long-term retention of knowledge gained through educational programs and its influence on clinical performance in oncology settings.
- Comparative studies may be conducted to evaluate the effectiveness of different teaching methods, such as traditional classroom teaching, e-learning, and simulation-based learning, in improving knowledge related to CAR-T cell therapy.
- Future studies should also examine the relationship between nursing students' knowledge levels and patient care outcomes, including early identification of complications and quality of nursing care provided to patients receiving CAR-T cell therapy.