ijtos 2024; doi 10.22376/ijtos.2024.2.1.19-26

International Journal of Trends on OncoScience

ISSN-2583-8431

Review Article

Radiotheranostics in Oncology

Radiotheranostics in Oncology

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Abstract: This review discusses the urgent requirements in modern oncology to address the complexities associated with metastatic cancer, a condition that often lacks comprehensive understanding, particularly concerning receptor expression. The emerging concept of theranostics, which merges precise diagnostics and therapies within the precision medicine framework, underscores the need for further investigation. A central focus of this review is radiotheranostics, a versatile approach offering personalized diagnostic and therapeutic possibilities. It examines the intricate components of radiotheranostics, such as radionuclides, metal-complexing agents, and receptor-specific agents designed to target molecular markers linked to cancer selectively. The study explores potential applications of radiotheranostics, especially in scenarios where conventional treatments have limitations. Investigating patient acceptance and determining the optimal administration route are critical aspects that demand thorough examination to facilitate the integration of radiotheranostics into clinical practice. Furthermore, this review aims to reveal the potential of new ligands and isotopes to enhance the effectiveness of radiotheranostics. Molecular imaging, functioning at the molecular and cellular levels, constitutes a significant element of this study, delivering in-depth anatomical and functional insights. Recognizing the pivotal role of Cancer Stem Cells (CSCs) in precise cancer treatment, the review explores techniques for their identification and characterization within the framework of radiotheranostics. Despite its promise, radiotheranostics faces unique challenges from logistical constraints and regulatory intricacies, setting it apart from conventional chemotherapy. This review seeks to elucidate these challenges and provide potential solutions. In summary, this review responds to the crucial need for advancing our understanding and application of radiotheranostics, holding the potential to offer significant palliative measures, extend patient survival, and even provide cures, particularly for those with metastatic disease and suitable molecular targets.

Keywords: Metastatic cancer, radiological medicine, PET imaging, radioactive isotopes, theranostic radiotherapy, Molecular imaging, Theranostics

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Received On 24 November 2023
Revised On 12 December 2023
Accepted On 22 December 2023
Published On 5 January 2024

Funding This research did not receive any specific grant from any funding agencies in the public, commercial or not for profit sectors.

Citation Dr B Sreedevi, Dr N Kishore, Dr. Somenath Ghosh and Gurman Kaur , Radiotheranostics in Oncology.(2024).Int. J. Trends in OncoSci.2(1), 19-26 http://dx.doi.org/10.22376/ijtos.2024.2.1.19-26

1. INTRODUCTION

Modern oncology endeavors to confront the challenges of oncology diagnosis by aligning crucial molecular data with available targeted therapies. However, a fundamental question emerges regarding the practical application of precision oncology in the context of metastatic disease, particularly when our understanding of the ailment remains incomplete, especially concerning the expression of receptors. Recently, theranostics has emerged as a prospective focus in cancer research[1], representing a systematic merger of precise diagnostics and therapies in line with the precision medicine paradigm. The diagnostic facet of radiotheranostics primarily involves a quantitative PET-SPECT imaging methodology employing radiotheranostic compounds, facilitating the determination of specific molecular targets within each cancer lesion throughout the body. Advances in imaging technology that can discern specific proteins and tissue components preferentially expressed in cancer tissue compared to healthy tissue, coupled with a comprehensive grasp of the interactions between targeting agents and nanodevices, propel innovations within the rapidly evolving field of radiotheranostics[2]. An intrinsic feature in radiotheranostics, a crucial aspect, pertains to identifying patients suitable for radio-targeted therapies. Therapies derived from the likeness regarding the targeted regions in imaging, thereby forging a close linkage between therapeutic interventions and imaging outcomes[2]. Notable instances include the diagnosis and treatment of thyroid cancer[3,4] through various forms of radioactive iodine, such as ^{124}I and ^{131}I. The use of radioactive iodine has significantly enhanced the prognosis of metastatic thyroid cancer, transforming it from a condition with a break outlook to one with an approximate 85% overall survival rate. [5] The primary goals of radiotheranostic applications are to enhance the quality of life for patient groups and stabilize end-stage diseases impervious to conventional treatments, alongside ongoing research into radiation therapy for conditions extending beyond cancer, such as severe arthritis.[6] In this paradigm, therapeutic radioisotopes are strategically localized within or near the malignancy by targeting ligands, which also serve as anchors. These targeting ligands frequently encompass immunoglobulins (e.g., against immunological identifiers CD20, CD37, or CA 19-9) or small-molecule peptides (e.g., fibroblast-activated protein inhibitors [FAPI]). The radiopharmaceuticals incorporate various macrocyclic chelates, including DOTA Coordination. The chemical entity denoted as 1,4,7,10- tetraazacyclododecane-1,4,7,10 tetras acetic acid possess the ability to encapsulate both α emitters (e.g., ^{223}Ra or ^{225}Ac) and β emitters (e.g., ^{177}Lu, ^{90}Y, or ^{166}Ho)[7]. Radioiodine therapies have become a staple of nuclear medicine and are routinely administered worldwide. By deploying tailored Radionuclide probes designed for diagnostic or therapeutic purposes in the medical context, specifically directed detection of particular cells, often melanoma cells, customized to each patient's unique underlying condition, radiotheranostics upholds the highest point of personalized medicine ideals.

1.1 Components of Radiotheranostics

Radiopharmaceuticals comprise three essential elements: The radionuclides, which serve Diagnostic or therapeutic roles. The metal-complexing agent facilitates the linkage between the ligand or probe and its associated radionuclide, and the Receptor or investigative agent itself is designed to bind selectively to highly specific cancer-related molecular markers on tumor cells[8]. An example of a "theranostic pair" involves a probe exhibiting nearly identical chemical and structural attributes, with labeling achieved through the utilization of a radionuclide possessing therapeutic or diagnostic characteristics. This ensures the engagement of the same molecular marker in both molecularly targeted therapy and diagnostic imaging. In an ideal scenario, a "perfect" in the realm of theranostics, a pair is constituted by two isotopes originating from an identical chemical element. A noteworthy illustration is provided by Radioiodine, in which ^{131}I (a beta emitter) is employed for treating thyroid disorders, while ^{123}I (Single-photon emission computed tomography) SPECT and ^{124}I PET serve diagnostic purposes. These isotopes are advantageous due to their chemical similarities, differing mainly in emissions and physical half-lives. To acquire molecular diagnostic images, the diagnostic counterpart can be conducted using (Positron emission tomography) PET or SPECT/CT, and even PET/CT or PET/MRI. In SPECT or PET, the radiopharmaceutical of choice comprises either a positron or gamma emitter. Optimal imaging conditions aim to minimize radiation exposure to the patient, achieved through the tissue's absorption characteristics, low-energy interactions, and extended radiation ranges of radiopharmaceuticals emitting gamma and positron radiation. These attributes enable effective disease staging localization distinct from anatomical imaging methods, exemplified by CT or MRI, underscoring the importance of selecting the most suitable radionuclide. The extent of Cellular damage to the target cell and the effectiveness of treatment are directly proportional to the (High linear energy transfer) LET of the target cell. Radioisotopes such as Samarium^{-153} (^{153}Sm), Yttrium^{-90} (^{90}Y), Lutetium^{-177} (^{177}Lu), and ^{131}I, characterized by beta particle emissions, are commonly utilized in medical applications. These isotopes exhibit limited radiation emission range and prompt energy delivery to the tumor cell, minimizing harm to adjacent healthy tissues. Many radionuclides manifest multiple discrete emission types with distinct energy peaks, making several therapy-oriented radioisotopes suitable for non-diagnostic imaging. This attribute is invaluable for post-therapy molecular targeting confirmation using SPECT/CT imaging while mitigating the impact of pharmacological interventions and interference.

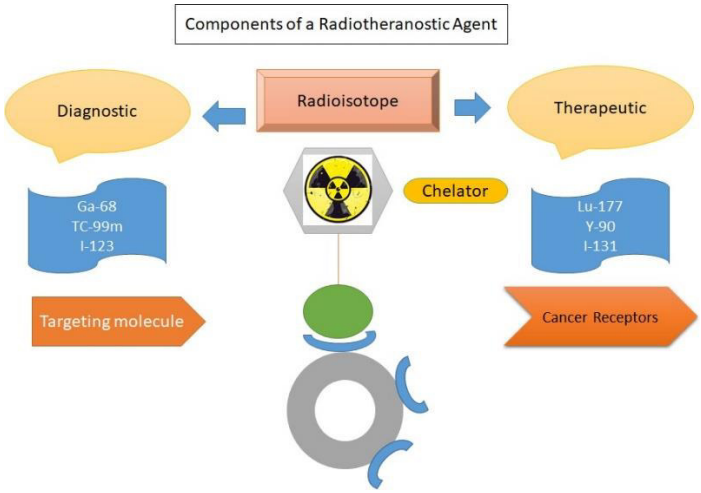

Fig 1. Components of A Radiotheranostic

1.2 Radionucleids for Radiotheranostics

In the context of thyroid physiology, iodide is a fundamental component utilized in the synthesis of thyroid hormones, particularly in the context of radioiodine therapy. The sodium-iodide symporter, known as NIS and situated on the lateral basal membrane, facilitates iodide uptake by follicular thyroid cells from the bloodstream. Subsequently, iodide is processed through oxidation and attached to thyroglobulin by thyroid peroxidase. Through endocytosis, thyroglobulin iodine is returned to the follicle cell, where it undergoes hydrolysis and is subsequently released into the bloodstream as thyroid hormones T3 and T4 [9]. It is essential to note that the thyroid cell cannot distinguish between radioactive and non-radioactive substances molecules due to their shared structural characteristics. Various radioiodine isotopes find practical utility in diagnosis and therapeutic intervention for conditions including differentiated thyroid disease and hyperthyroidism. For nuclear medicine investigations, radiopharmaceuticals containing 99mTc are employed in over 85% of cases, primarily for SPECT. [10] The emission and half-life of 99mTc make it an optimal choice for synthesizing radiopharmaceuticals and their application in imaging [11]. When [99m-Tc] TcO4 is introduced into cells, it demonstrates the ability to damage DNA and reduce cell survival rates, particularly in breast cancer epithelial cells. The distinction in redox state and kinetic properties between rhenium and technetium is critical. Cell labeling is predominantly achieved through the use of ^{111}In, offering the advantage of compatibility with SPECT imaging rather than PET. Two substances have shown efficacy in labeling various cell types. In diagnostics, ^{111}In produces gamma radiation and low-energy auger electrons, which have a limited range of dispersion. While electrons outside the cell are negligible, those within or near the nucleus can significantly impact the cell's DNA. Notable examples of nitrogen donor sites include hard metal Ga^{3+} and chelators such as DOTA, NOTA, and HBED [12]. The development of gallium-based ^{67}Ga radiopharmaceuticals has involved using radionuclides ^{68}Ga and ^{67}Ga. Specifically, ^{68}Ga is employed in tumor imaging, capitalizing on its single EC decay and low energy emissions. The production of ^{64}Cu, derived from [13] ^{64}Ni, has shown cytotoxicity when coupled with carriers and chelators. In cancer cell models, it has demonstrated a greater accumulation than in normal cell models, suggesting its potential efficacy in cancer cell applications. Zr-89's relatively extended half-life makes it suitable for radiopharmaceuticals based on antibodies, offering greater stability and in vivo security. Its low-energy positron emission provides optimal high-resolution PET imaging. In PET imaging, radioactive ^{18}F retains a distinct significance, albeit ^{68}Ga PET imaging exhibits somewhat lower sensitivity and spatial resolution than ^{18}F PET. Furthermore, ^{186}Re produces an extended half-life and emits particles, while ^{188}Re possesses a shorter decay rate and releases particles with greater tissue penetration. Uranium and actinium often occur together. The equilibrium between ^{90}Y and its parent isotope ^{90}Sr is critical. Production of ^{225}AC arises from the decay ^{233}U and subsequent transformation via neutron capture decay processes into ^{227}Ac through ^{228}Th. In the case of ^{90}Y, beta particle radiation not only impacts the target cell more swiftly but also extends its influence to the surrounding cellular environment. Beta particles released by ^{90}Y can inflict direct and indirect cellular damage. Direct damage pertains to the irreparable alteration of DNA structure, while indirect damage involves the increase of harmful free radicals in the cytosol [14]. Gradually, ^{177}Lu is emerging as the industry standard for radionuclide-based therapies. Its future as a theranostic agent is quite promising, as it holds potential applications not only in post-treatment scans but also in patient dosimetry[15,16].

1.3 Radiotheranostics For Some Diseases[17]

The following list provides a comprehensive overview of radiotheranostic agents within nuclear medicine, delineating their dual diagnostic and therapeutic roles across a diverse spectrum of medical conditions. It is imperative to acknowledge that the availability and progression of these radiotheranostic agents can significantly vary across different nations and regions. Among the prominently featured radiotheranostics are:

Iodine-131 and Iodine-124 (^{131}I and ^{124}I): These isotopes are useful in managing thyroid cancer, especially when employed alongside the sodium-iodine symporter.

Lutathera (Dotatate): This innovative radiotheranostic utilizes Peptide-based ^{177}Lu and ^{68}Ga for the treatment of neuroendocrine tumors, achieving regulatory approval in 2018.

Satoreotide Tetraxetan: Another Peptide-based radiotheranostic, it uses ^{177}Lu and ^{68}Ga and shows promise in the domains of breast cancer, small-cell lung cancer, and

neuroendocrine tumors, advancing through the phases of clinical trials.

Small Molecule PSMA-617: This radiotheranostic, incorporating ^{177}Lu, ^{68}Ga, and ^{18}F, is engineered to target prostate cancer unresponsive to castration, currently undergoing Phase 3 clinical trials.

Various Radiotheranostics for Bone-related Conditions: This category includes Quadramet (Lexidronam) for stimulating new bone formation, Radium-223 (Xofigo) for prostate cancer and bone metastases, and Strontium-89 (Metastron) for alleviating bone pain, each employing distinct radioactive isotopes.

Antibody-based Radiotheranostics: Zevalin (Ibritumomab tiuxetan) and Azedra (Iobenguane) are instrumental in treating specific lymphomas and neuroendocrine tumors.

Experimental Radiotheranostics: Critical radiotheranostics in clinical investigation include Apamistamab (Iomab-B), Lilotomab Satetraxetan (Betalutin), Omburtamab, 3BP-227, and FAPI, with varied applications spanning multiple cancer types.

Pentixather: This Peptide-based radiotheranostic is successively deployed for the management of multiple myeloma and lymphoma.

Microspheres: Glass and Resin microspheres are instrumental in the treatment of hepatocellular carcinoma and liver metastases by precisely targeting tumor vessels through radiation therapy. The applications of these agents collectively represent a dynamic and evolving landscape within nuclear medicine.

1.4 Patient Acceptance and Best Route of Administration

Most patients typically exhibit a high degree of tolerance towards the uncomplicated procedures inherent to systemic radiotheranostics delivery. In comparison to chemotherapy and other targeted therapeutic approaches, the incidence of documented side effects remains notably lower, with fatigue and nausea constituting the primary complaints. While nephrotoxicity (accounting for approximately 10% of cases with ^{177}Lu-dotatate) and myelosuppression (affecting roughly 25%) represent potential adverse outcomes, both in the short and long term, related to the radiopharmaceutical and its corresponding ligand, these manifestations can necessitate dose reductions when they occur [18]. For the sake of minimizing invasiveness, the administration of radiotheranostics, largely intravenous, is the preferred method for addressing prevalent or prospective disseminated ailments. Nevertheless, in specific scenarios, the challenge arises of delivering intravenous radiotheranostics at dosages adequate for targeting cancer cells while concurrently mitigating off-target damage. This predicament finds resolution in certain individuals with localized illnesses through catheter-delivered intraarterial radiotheranostics[19]. Strategies incorporating the tumor's affinity for lipodol and the pronounced hypervascularity of the tumor have been harnessed to enhance the selectivity of radioisotope delivery via catheter. A recent avenue of interest involves amalgamating physiologically tailored theranostic agents, such as dotatate, with the heightened selectivity afforded by catheter-directed treatments. Notably, both intra-arterial and intravenous routes have been employed for the administration of ^{177}Lu-dotatate in meningioma patients. Intriguingly, intra-arterial delivery offers higher dosages, greater cytotoxicity, and a reduced incidence of systemic adverse effects. In conclusion, the fusion of interventional techniques, including tumor ablation, with tailored imaging agents characterized by biologic selectivity can yield a theranostic effect of noteworthy significance.

1.5 New Ligands and Isotopes

In the context of enabling both imaging and treatment, the accumulation of radiolabel within cells occurs through internalization processes, often coinciding with heightened expression in target tissues, particularly in the case of tumor-associated stromal cells. The choice of radioisotopes for PET includes fluorine-18 (^{18}F) and gallium-68 (^{68}Ga), with the increasing adoption of zirconium-89 (^{89}Zr), especially in conjunction with antibodies. Iodine-131 (^{131}I) has traditionally been prominent in therapeutic theranostics, particularly when combined with antibodies. However, more recently, lutetium-177 (^{177}Lu) has emerged as the standard radioisotope for therapeutic applications. The ongoing research and development efforts are bringing forth numerous novel targets, radioisotopes, targeting ligands, and therapeutic combinations, along with expanded indications for already approved radiotheranostic medications. Ideal therapeutic targets possess an extracellular component and exhibit selective overexpression, albeit at low levels, in cancerous or tumor-associated cells as opposed to normal tissues. Notably, fibroblast activation protein (FAP) [20], a prolyl endopeptidase, stands out as one of the emerging biological targets [21], primarily regulated by fibroblasts connected to cancer. Additionally, the integrin and the GRP-R, including aVß3 and aVß5 molecular docking sites, are currently under investigation as potential targets, particularly for the treatment of meningioma, paraganglioma, and pheochromocytoma [22,23] Research initiatives are exploring the use of ^{177}Lu-dotatate for conditions such as hepatocellular carcinoma and ^{177}Lu-OPS201 (NCT03773133) for breast and small-cell lung cancer, showing promising initial findings. Furthermore, there is growing interest in employing ^{177}Lu-dotatate-like treatments neoadjuvantly, as well as [24] ^{177}Lu-PSMA-617 before pelvic lymph node dissections and radical prostatectomy[25]. Common therapeutic radioisotopes that leverage ß emission for their therapeutic mechanisms include ^{177}Lu, ^{90}Y, and ^{131}I. Despite encouraging results seen with ^{225}Ac-PSMA-617 in prostate cancer, the clinical translation of ß-emitting theranostics may face temporal constraints due to logistical challenges, encompassing radionuclide manufacturing, half-life considerations, waste management, and the potential for heightened adverse effects[26]. The future outlook presents opportunities for diversification beyond peptide-based ligands, with the potential development of small compounds, nanobodies, and modified proteins for radiolabeling. Moreover, pretargeted radioimmunotherapy is emerging to enhance treatment efficacy compared to non-pretargeted approaches, offering novel prospects in ligand-based targeting in theranostics.

1.6 Radiotheranostics in Molecular Imaging

Utilizing a variety of imaging probes, including molecular probes, tracers, and contrast agents, molecular imaging operates at the molecular and cellular levels, delivering comprehensive anatomical and functional information. The

objectives of molecular imaging in Cancer Stem Cells (CSC) research encompass identifying CSC resistance mechanisms to therapy, prognosis assessment, treatment outcome evaluation, and predicting therapy outcomes. By utilizing cell surface indicators, molecular imaging permits the observation and exploration of cancer stem cells (CSCs) based on their unique biological attributes. Recent advancements within molecular imaging technologies have introduced in vivo capabilities that support the discovery of CSCs, providing an invaluable in vivo platform for gaining insights into the metabolic landscape, cancer progression, adaptability, and the behavior of CSCs in their natural milieu. The approach of radioisotope-based therapeutics, known as radiotheranostics, incorporates recent developments within nuclear quantification medicine and molecular imaging utilizing SPECT and PET[27]. Additionally, it involves the methodical fusion of a diagnostic and therapeutic agent on a common molecular framework originally developed within the discipline of nuclear medicine. Diagnostic imaging plays a pivotal role in confirming target expression and facilitating dosimetric calculations, radiotracer pharmacokinetics analysis, determination of therapeutic radiotracer dosages, and developing personalized treatment plans. From a diagnostic perspective, conditions such as toxic uninodular or multinodular adenomas, Graves' disease, and Differentiated Thyroid Carcinoma (DTC) can all be accurately diagnosed with subsequent planning for radioiodine therapy employing SPECT imaging.[28, 29,,] Although ^{124}I is less widely available than ^{123}I, PET imaging with ^{124}I remains an exceptional diagnostic tool. These advancements have led to the development of numerous small molecule Fibroblast Activation Protein (FAP) inhibitors (FAPI) for both imaging and therapeutic purposes. Notably, the highest uptake of these FAPI compounds has been observed in cholangiocellular carcinoma, Sarcoma, esophageal carcinoma, breast malignancy, and lung neoplasms., particularly in the context of ^{68}Ga-FAPI-02 and ^{68}Ga-FAPI-04 [30] [120].

1.7 Radiotheranostics Within the Context of Cancer Stem Cells (Csc)

Researchers have devised a plethora of techniques aimed at identifying and characterizing Cancer Stem Cells (CSCs), recognizing the pivotal role this plays in the targeted and efficient treatment of cancer. Integrating monoclonal antibodies (mAbs) into radiotheranostic approaches for CSC targeting bears immense potential in enhancing CSC detection and tailoring bespoke anti-CSC therapies[31]. Theranostic formulation encompassing ^{68}Ga-ventilator/^{177}Lu-pentixather has been proposed for CXCR4-directed therapy in a diverse range of cancer patients. Nano protein chemokines, constituting a subfamily of cytokines, are secreted by numerous stromal and epithelial cells. Al-Ejeh and colleagues studied the efficacy of a combined approach involving chemotherapy, peptide receptor radionuclide therapy, and ^{177}Lu-labeled anti-EGFR mAbs in the context of focusing on the selective inhibition of Cancer Stem Cells in instances of triple-negative breast carcinoma. Impressively, radio immunotherapy displays potential not only in the eradication of CSCs but also in significantly impeding tumor growth, as evidenced by the deployment of ^{131}I-AC133, which effectively targeted Colonic CSCs bearing CD133 and hindered neoplastic growth in a substantial fraction of cancer cells [32]. Exploring potential novel molecular targets for utilization in theranostic methodologies represents a promising stride in early-stage oncology, with a pronounced emphasis on immunological aspects. This recent advancement in receptor-targeting approaches and the formulation of innovative radiopharmaceuticals promises to provide an intriguing perspective on the theranostics of CSCs.

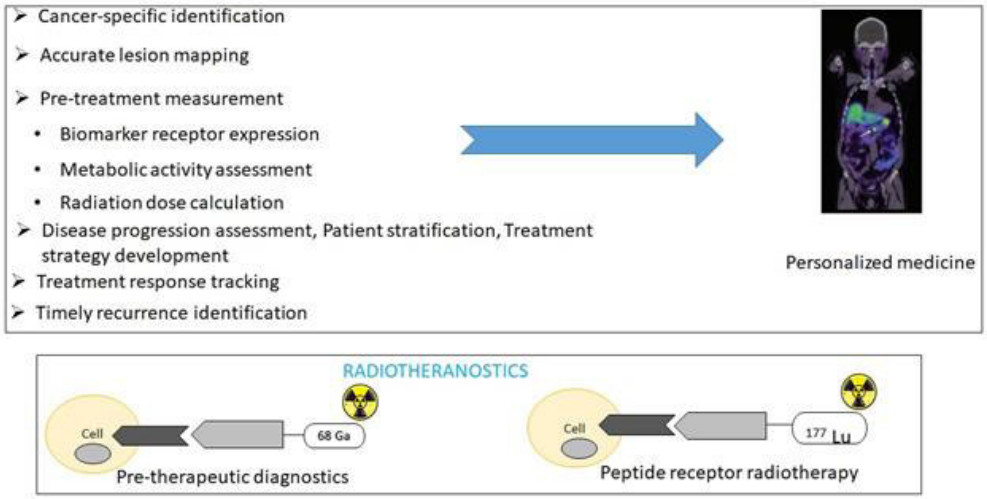

Fig 2. Radiotheranostics for Personalized medicines

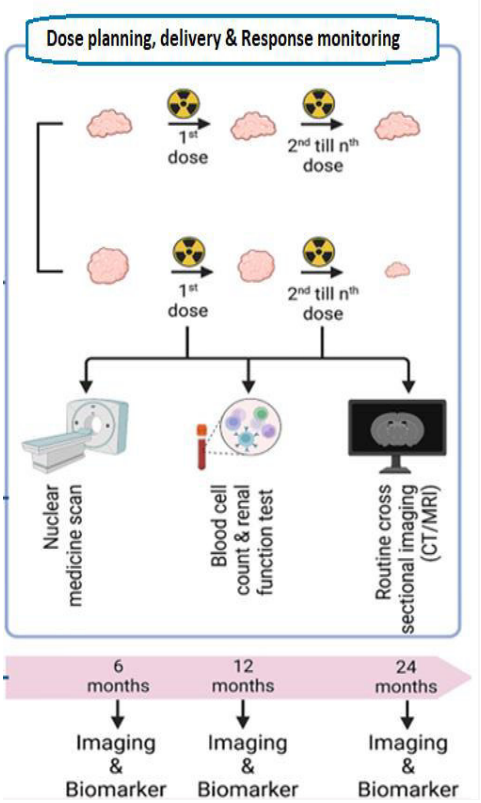

Fig 3: Radiotheranostics in oncology[33]

1.8
Training

The clinical application of radiotheranostics in medicine presents unique challenges due to logistical constraints and regulatory complexities, setting it apart from the more established landscape of conventional chemotherapy. Overcoming these hurdles is feasible, especially considering the half-life of radiotheranostic therapies, typically lasting hours to days in contrast to the months required as part of chemotherapy. The requirement for post-radiotheranostic imaging and the careful management of radiation waste disposal[34] further contribute to the complexity of its implementation. The successful and safe integration of radiotheranostics into medical practice hinges upon a proficient, adequately skilled, and properly educated healthcare team, including Medical professionals, doctors, radio pharmacologists, healthcare physicists, and nursing staff[35]. Among these professionals, medical physicists play a pivotal role by leveraging their expertise in dosimetry and radiation safety. Certified medical physicists, particularly those well-versed in endo-radiotherapy dose-planning and patient dosimetry, are indispensable for realizing the vision of personalized medicine within the realm of radiotheranostics. Furthermore, the handling of substantial volumes of therapeutic radioisotopes, including nuclides emitting beta and alpha particles, necessitates this specialized knowledge, owing to the inherent potential risks involved. Radio pharmacists, in turn, must exhibit proficiency in scrutinizing patient profiles and addressing inquiries regarding the use and effects of radiotheranostic medications. To extend the reach of radiotheranostics to a global scale, future endeavors should contemplate strategies such as e-learning programs, exchange initiatives, and comprehensive education for medical students. The successful adoption of radiotheranostics into clinical practice requires highly skilled practitioners in professionals in the fields of nuclear medicine and radiology to possess the capacity to forge connections between interdisciplinary gaps spanning across the domains of radiochemistry, pharmaceutical sciences, nuclear imaging, and clinical research and the multifaceted dimensions in the field of oncological clinical practice. This collaborative effort is paramount to effectively assimilating radiotheranostics into the healthcare landscape.

1.9 Limitations

The clinical interpretation and expanded utilization of radio thermometry encounter several notable challenges. In the domain of nuclear medicine and radiology, where the utilization of radioactive materials is rigorously regulated and largely confined to diagnostic applications, obstacles emerge. In a parallel manner to current tumor diagnostics, practitioners venturing into the field of theranostics are compelled to surmount interdisciplinary boundaries and assemble disease-specific teams. Compounded by the presence of reactors and a need for more investment in modern facilities adhering to stringent manufacturing standards, the production of medicinal radioisotopes often needs to meet demand, leading to occasional supply constraints. The advancement of theranostics research stands to gain immensely from adequate financial support, particularly in the context of well-designed prospective clinical investigations. Furthermore, the progress of this discipline hinges substantially on the formation of extensive multidisciplinary teams. These challenges encompass not only the scarcity of comprehensive, wide-ranging studies but also the limited availability of radiotheranostics in the marketplace. The evolution of this field is contingent on robust investment in fundamental, preclinical, and translational research, necessitating proactive involvement from pharmaceutical corporations and regulatory authorities.

2 CONCLUSION

The application of radiotheranostics, however, brings forth the potential for significant palliative measures, extended survival, or even potential cures, particularly among patients whose metastatic disease exhibits the appropriate molecular targets. While a definitive cure for cancer may remain exclusive, it is conceivable to manage it as a chronic condition, thereby affording patients a considerably extended lifespan with minimal adverse effects and an overall improved quality of life. The emerging field of nuclear oncology, exemplified by radiationtheranostics, represents a formidable paradigm shift in cancer therapy. It combines molecular targeting with personalized radiation dosimetry to obliterate malignant cells selectively. The realization of this transformative potential necessitates concerted multidisciplinary efforts to surmount institutional, financial, and educational barriers, forging therapeutic teams that possess the requisite methodological and medical expertise. The expansion of specialized theranostic centers and the education of professionals in this discipline will inevitably hinge on the initial clinical successes. Given the distinct molecular profiles exhibited by each tumor, more than a one-size-fits-all treatment approach is needed. Theranostics empower us to visualize specific tumor markers and undertake patient stratification and selection, thereby facilitating the tailored selection of the most optimal treatment strategies. The ongoing exploration of theranostics promises to yield novel therapeutic targets and refine radio pharmacokinetics, further advancing the landscape of cancer management.

3. AUTHOR CONTRIBUTION STATEMENT

Dr B Sreedevi conceived the study and was responsible for the overall direction, analysis, and planning. Dr N Kishore Scarried out the implementation. Dr. Somenath Ghosh Mahmood took the lead in writing the manuscript. Gurman Kaur provided critical feedback, reviewed, and helped in the final corrections of the manuscript.

4. CONFLICT OF INTEREST

Conflict of interest declared none.

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