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Short communication

Theranostic approach - promoter of personalised medicine

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Introduction

Radiopharmaceutical preparations or radiopharmaceuticals are medicinal products which, when ready for use, contain 1 or more radionuclides (radioactive isotopes) included for a medicinal purpose (Ph.Eur.). Radiopharmaceuticals are intended to diagnose, stage a disease, monitor treatment, or provide therapy. Concerning diagnostics, nuclear medicine encompasses technologies such as positron emission tomography (PET) and gamma scintigraphy - including single photon emission computed tomography (SPECT) and planar gamma imaging - which rely on radionuclides emitting positrons or gamma rays to generate signals, enabling a whole-body scan to be performed in a single examination. For therapeutic purposes, emitters of alpha and beta particles, as well as Auger electrons, can be utilised. Targeted radionuclide therapy (TRT) is a systemic treatment that uses a radionuclide-labeled molecule to deliver therapeutic doses of radiation to malignant tumors (Jadvar, 2017; Velikyan, 2014; Stokke et al., 2022).

Theranostics in nuclear medicine

Theranostics is an approach in medicine in which disease is diagnosed, followed by treatment of disease-positive patients using therapeutic tools identical or similar to those used for diagnosis. (Aboagye et al., 2023)

The radiotheranostics is based on the following strategies:

- The use of radionuclides emitting both diagnostic and therapeutic radiations (e.g., ^{177}Lu [β^-, γ] or ^{64}Cu [β^-, β^+]), which enables the use of the same radiopharmaceutical for both imaging and therapy by adjusting the applied dose.
- The use of the same pharmacophore in combination with different diagnostic and therapeutic radionuclides (matched-pair constellation), e.g. ^{99m}Tc/$^{186/188}$Re or the currently most frequently used combination, ^{68}Ga/^{177}Lu.
- The use of different isotopes of the same element, for diagnostic and therapeutic applications, an isotopic pair (or true pair), e.g. ^{86}Y(β^+) and ^{90}Y(β^-), ^{123}I(γ) and ^{131}I(β^-), etc. (Brandt et al., 2018).

Iodine-131: the first theranostic radiopharmaceutical

The clinical significance of iodine-131 in both the diagnosis and treatment of thyroid disease was recognised in the early 1950s, and it has remained in continuous use ever since. Iodine-131 is produced by fission of uranium-235 or by neutron bombardment of stable tellurium in a nuclear reactor. Iodine-131 has a half-life of 8.02 days. It decays to stable

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xenon-131 by emission of gamma radiations of 365 keV (81.7%), 637 keV (7.2%) and 284 keV (6.1%) and beta radiations of maximal energy of 606 keV.

For thyroid disease, iodine-131 is available as sodium iodide [^{131}I] in two dosage forms for oral administration: a liquid solution and gelatin capsules (more common), and a solution for injection. As a diagnostic radiopharmaceutical, iodine-131 is used for examination of various thyroid disorders, with primary applications including: distinguishing hyperthyroidism from other types of thyrotoxicosis, visualizing ectopic thyroid tissue, determining the functionality of thyroid nodules, visualizing remnants of normal or cancerous thyroid tissue, detecting thyroid cancer recurrence or distant metastasis, restaging thyroid cancer typically occurs 6 to 12 months after thyroidectomy and radioactive iodine ablation therapy, assisting in the calculation of the appropriate ^{131}I therapy dosage, and determining the safest dosage of ^{131}I therapy for vital organs. Radioiodine thyroid therapy is indicated in adults and children for hyperthyroidism (treatment of Graves' disease, toxic multinodular goitre or autonomous nodules) and treatment of papillary and follicular thyroid carcinoma including metastatic disease (IAEA, 2009).

Other iodine-131 theranostic uses include iodine (^{131}I) iobenguane, often referred to as ^{131}iodine-metaiodobenzylguanidine (^{131}I-MIBG), for diagnostics and treatment of neuroendocrine tumours (pheochromocytoma, neuroblastoma, carcinoid tumours, medullary thyroid carcinoma) (Kayano and Kinuya, 2018).

Theranostic pair gallium-68 / lutetium-177

^{68}Ga/^{177}Lu is one of the most prominent theranostic pairs. Gallium-68 ($t_{1/2}$ = 67.71 min) is a positron-emitting diagnostic isotope, while lutetium-177 ($t_{1/2}$ = 6.647 days) is a beta-emitting therapeutic isotope. Radiopharmaceuticals based on these radioisotopes are prepared and available as preparations for intravenous administration. ^{68}Ga and ^{177}Lu-radiopharmaceuticals already have a recognised clinical value in nuclear medicine. Drugs with somatostatin analogues are applied for the diagnosis and treatment of neuroendocrine tumours, and preparations with prostate-specific membrane antigen (PSMA) are used for PET detection of PSMA-positive lesions and management of metastatic castration-resistant prostate cancer (mCRPC) (Zhang et al., 2025).

Conclusion

The concept of theranostics unifies molecular imaging and radiotherapy. This approach establishes a framework for individualised patient treatment, in which the presence and extent of a molecular target for a specific therapeutic modality are first determined using diagnostic tools, thereby considerably contributing to the advancement of personalised medicine.

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