Radiotherapeutics and Radiodiagnostics: Yin and Yang?

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Since 1946, iodine-131 NaI has been used for the treatment of thyroid carcinoma and has become a cornerstone of the modern thyroid cancer treatment[1]. This radiopharmaceutical has a high specific uptake in the thyroid, the target organ. In the last decade, a renewed interest in radiopharmaceuticals for therapy has risen. With the development of peptide receptor radionuclide therapy (PRRT)[2-3] that makes use of the overexpression of specific peptide receptors and antibody labelling[4] it became possible to hit new targets with sufficient specificity. In this way a relatively high radiation dose can be delivered to the targets without damaging the surrounding healthy tissue.

Although a lot of similarities exist between diagnostic and therapeutic radiopharmaceuticals, there are also clear differences which have to be noted. For diagnostic radiopharmaceuticals, the absorbed radiation dose should be as low as possible. On the other hand, for therapeutic radiopharmaceuticals, the radiation dose delivered to the target should be high enough to kill the cancer cells. Ideal diagnostic radiopharmaceuticals emit gamma radiation which has a high penetration through the tissue. Radiotherapeutics make use of isotopes of which the energy is absorbed over a small distance. Therefore, isotopes emitting beta radiation (mm to cm range in tissue) and recently alpha radiation (µm range) are preferentially used in therapy. Nevertheless, the presence of a gamma component in the decay scheme of a beta or alpha emitters can be advantageous as it allows imaging to be performed following the therapy administration. A lot of isotope couples are now available for diagnosis and therapy (f.e. I-123-MIBG/I-131-MIBG, In-111 Zevalin/ Y-90-Zevalin, Ga-68-DOTATATE/ Lu-177-DOTATATE, Ga-68-PSMA/Lu-177PSMA, Bi-213-PSMA)

For radiodiagnostics, the amount of activity accumulated in the target organ is less important if the rest of the activity is cleared rapidly from the surrounding tissue or in other words if a good target to background ratio is reached in an acceptable time frame. For some radiodiagnostics such as heart and brain perfusion tracers the uptake of the pharmaceutical in the target organ is less than 5%. For therapeutics this is unacceptable as radioactivity that not accumulates in the target will irradiate other healthy parts of the body. Furthermore one should carefully look at the way these radiotherapeutics are eliminated as adsorbed dose in excreting organs can go up significantly. For instance kidneys are the critical and dose limiting organs in PRRT as radiotherapeutics for PRRT are cleared mainly by the urinary system.

Gamma radiation is difficult to stop and heavy metals such as lead or tungsten can be used to protect manipulators for the radiation. Handling particle emitting isotopes demands for specific manipulations. Beta radiation can be stopped easily by light materials such as perspex or aluminium, the use of heavy materials for the shielding of beta radiation is rather contraindicated as it causes more "Bremstralung". A combination of light and heavy materials can be recommended. Close contact with Beta emitting isotopes (for instance manipulation with the fingers or spill on the skin) can cause high dose absorption in these areas and therefore lead to radiation damage. Alpha emitters can be stopped by a sheet of paper and therefore are not dangerous, with the exception of internal contamination. Alpha and beta radiation decay however is sometimes accompanied by gamma emission. Therefore, it is high important and recommended that one looks at the total decay scheme for each isotopes that is being manipulated in order to see which protection measures should be taken.

Both diagnostic and therapeutic radiopharmaceuticals require the manipulation of radioactive sources for labelling, dispensing and administration to patients. However, the particularities of the emitted radiation by the isotopes used for therapy require different radioprotection measures for the staff working in the radiopharmacy, such as the use of different shielding materials, compared to the protocols (procedures) used when manipulating of isotopes used for diagnostic imaging.

References

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