Targeted Alpha Particle Therapy: Imaging, Dosimetry and Radiation Protection

M. Lassmann[a], U. Eberlein[a]

[a]*University of Würzburg, Department of Nuclear Medicine, Germany; e-mail: Lassmann_m@ukw.de*

Abstract-Alpha-particle emitters are highly potent therapeutical agents that are fundamentally novel in their mechanism and, most likely, overcome radiation resistance as the alpha particles emitted have a short-range (50 to 100 μm,) and a high linear energy transfer (LET). Alpha particles induce numerous DNA double-strand breaks along the respective tracks. Therefore, alpha emitters are becoming of increasing importance for the application in therapeutic nuclear medicine. The use of alpha emitters in a clinic environment requires extra measures with respect to imaging, dosimetry and radiation protection. This will be shown for the example of Ra-223-dichloride therapy. Ra-223-dichloride ("Xofigo®") is a radiopharmaceutical for the treatment of patients with castration-resistant prostate cancer, symptomatic bone metastases and no known visceral metastases. Radium is accumulating in bone when administered. Ra-223 decays to Pb-207, with four alpha emitters and two beta minus emitters present in the decay chain. The half-life of Ra-223 is 11.4 days, which is significantly longer than for any of the daughter radionuclides. Six administrations, four weeks apart, of 55 kBq/kg of body weight are foreseen for treatment. After an intravenous injection, Ra-223 leaves blood, is rapidly taken up in bone and bone metastases, and is mostly excreted via the intestinal tract.
Ra-223 can be imaged with a gamma camera. Several authors suggest that the imaging should be performed as a whole body scan at a low speed, with the camera equipped with either a medium- or a high energy collimator and with a 20% wide energy window centered on 82 keV. Dosimetry for alpha particles has to be performed on a small scale due to the short range of the alpha particles and a high local absorbed dose for determining the relative biological effectiveness (RBE) of a treatment. For obtaining this quantity, the differences in efficacy and toxicity to the conventional treatment using beta particles need to be assessed. Dosimetry based on compartment modelling shows that, after a series of six treatments for a 70 kg person with an administered activity of 55 kBq/kg Ra-223 each (overall: 23 MBq Ra-223) results in an absorbed alpha dose of approximately 17 Gy to the bone endosteum. The corresponding absorbed alpha dose to the red bone marrow is approximately 1.7 Gy. During the administration, special care must be taken to reassure that no spill is present on the skin of neither the patient nor staff and that there is no extravasation of the radiopharmaceutical. The treatment is normally performed on an outpatient basis; the patient should receive written information about the therapy and radiation protection.