Europium-154 contamination levels in Samarium-153-EDTMP for radionuclide therapy

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Abstract. \textsuperscript{153}Sm-EDTMP, a useful non toxic bone seeking isotope in the palliative radionuclide therapy for bone metastases, is produced by neutron activation of enriched of \textsuperscript{152}Sm\textsubscript{2}O\textsubscript{3} targets. During the large-scale formation of \textsuperscript{153}Sm, however, there is a co-production of some long-lived radio nuclides, among which \textsuperscript{154}Eu is a major and inevitable radionuclide impurity. The level of \textsuperscript{154}Eu contamination was evaluated performing a gamma-ray spectrometry of a radiopharmaceutical sample and the urine of an administered patient. As expected, gamma-ray spectra revealed the presence of \textsuperscript{154}Eu in all the samples. The specific activity of \textsuperscript{154}Eu in the urine sample collected at 6 hours after injection is 21 Bq/ml and is less than 1 Bq/ml in 24 hr. The contamination levels of \textsuperscript{154}Eu, normalized to the corresponding activity of \textsuperscript{153}Sm, were 0.0012\% in the residual and in the first urine sample and 0.0017\% and 0.0031\% at 30 and 54 hours after administration, respectively. The results of this study show that the level of the long-lived \textsuperscript{154}Eu impurity is not a limitation in the metastatic bone pain palliation due to the additional radiation dose burden, but could pose a cause of concern in case of discharging.

1. Introduction

The metabolic radiotherapy, with radionuclide linked to a bone seeker, is an alternative method to the external beam radiotherapy for the palliative or symptomatic treatment of skeletal metastasis-related pain.

For therapeutic purpose, the ethylenediaminetetramethylenephosphine acid (EDTMP) chelated with \textsuperscript{153}Sm properly fulfils the “optimal” requirements for the local palliative therapy. Samarium-153 emits medium-energy beta particles with an average penetration range of 0.83 mm in water and a 103 keV gamma photon with a physical half-life of 46.3 hr. Samarium-153 is obtained by thermal neutron irradiation of isotopically enriched \textsuperscript{152}Sm\textsubscript{2}O\textsubscript{3} targets and Europium-154 (t\textsubscript{1/2} 8.5 y) is a major co-produced radionuclide, as described by the nuclear reaction

\[ ^{152}_{\text{62}}\text{Sm}(n,\gamma)^{153}_{\text{62}}\text{Sm} \rightarrow ^{\beta}_{\text{46.284 h}}^{153}_{\text{62}}\text{Sm} \rightarrow ^{153}_{\text{63}}\text{Eu}(n,\gamma)^{154}_{\text{63}}\text{Eu}. \] (1)

This aspect needs to be taken into account while considering the acceptance of the additional radiation burden due to the long-lived radionuclide impurity.
Aim of the present study was the analysis of a sample of $^{153}$Sm-EDTMP and the urine of an administered patient in order to evaluate the level of $^{154}$Eu contamination.

2. Experimental
The residual activity left in the manufacturer’s glass vial after the patient injection was flushed into a 100 cc plastic vial and measured by a spectrometric system with NaI scintillator, calibrated in energy and efficiency.

Urine samples from the patient were collected at 6, 30 and 54 hours postinjection to measure the total body clearance of $^{153}$Sm-EDTMP. Evaluation of the gamma-ray spectrum of $^{154}$Eu started several days after the administration, in order to ensure complete decay of $^{153}$Sm. The activities were calculated at the time of the administration.

Gamma spectrum of the urine sample collected 6 hours after injection is shown in figure 1, where the 1230.1 keV peak of $^{154}$Eu is marked.

3. Results and discussion
The results of the pharmacokinetics of the $^{153}$Sm-EDTMP have shown a rapid excretion in urine within 24 hours, as previously reported [2].

As expected, gamma-ray spectra revealed the presence of $^{154}$Eu in all the samples. The specific activity of $^{154}$Eu in the urine sample collected at 6 hours after injection is 21 Bq/ml and is less than 1 Bq/ml in 24 hr. The contamination levels of $^{154}$Eu, normalized to the corresponding activity of $^{153}$Sm, were 0.0012% in the residual and in the first urine sample and 0.0017% and 0.0031% at 30 and 54 hours after administration, respectively.

The presence of $^{154}$Eu impurity is mainly due to the reactor irradiation conditions and the variation of neutron flux. Nevertheless, the behavior of $^{154}$Eu-EDTMP is identical to the pharmacokinetics of $^{153}$Sm-EDTMP [3, 4], showing a rapid excretion during the first day postinjection. No retention in any other organ or tissue, excluding bone, was observed. It was therefore considered that the additional dose accrued to skeleton and skeletal lesions is not a deterrent for treatments [5].
High contamination levels of $^{154}$Eu could cause problems, depending on local waste management regulations in discharging the residual and the urine samples[6].

At the above mentioned specific activity, no real radiation protection concern is expected for personnel. In severe radiation protection local regulation, owing to the presence of the long-lived $^{154}$Eu, the spent solution has to be considered as “radioactive waste”, even after the complete decay of $^{153}$Sm.

4. Conclusions

The level of the long-lived $^{154}$Eu impurity in $^{153}$Sm is not a limitation in the metastatic bone pain palliation due to the additional radiation dose burden, but could pose a cause of concern in case of discharging.

References

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