Production of ^{47}Sc Through Proton Irradiation of ^{48}Ti target

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INTRODUCTION

Scandium offers different radioisotopes having proper nuclear decay properties to perform both imaging and therapeutic studies aimed at the development of new theranostic radiopharmaceuticals. In particular, ^{47}Sc ($\tau_{1/2}$= 3.35 d) has suitable features both for SPECT imaging, due to the 159 keV γ-ray emission, and for treatment of small-size tumours, owing to the intense β^{-}-emission (mean β^{-} energy: 162.0 keV). Its efficacy has been demonstrated at preclinical stage in former studies, however the low availability has up to now limited the clinical applications of ^{47}Sc-labelled radiopharmaceuticals. For such a reason, different ^{47}Sc-production routes are currently investigated. The proton irradiation of ^{nat}V targets has been previously studied, also considering the co-production of other Sc radioisotopes and their contribution to the absorbed dose to the patient [1]. This activity has been now also performed supposing proton irradiation of fully enriched ^{48}Ti targets.

MATERIALS AND METHODS

The yields of Sc radioisotopes obtained by ^{48}Ti thick target bombardment with proton beams of different energy were calculated, considering different irradiation times, using experimental cross sections data from EXFOR nuclear database [2] and recently measured data. A ^{47}Sc-labelled DOTA-folate conjugate (^{47}Sc-cm10) was used as an example of radiopharmaceutical for the dosimetric analysis. Biodistribution data of tumor-bearing mice treated with ^{47}Sc-cm10 [3] were used to perform dosimetric calculations with the OLINDA v.2.2 code using the human adult male phantom [4].

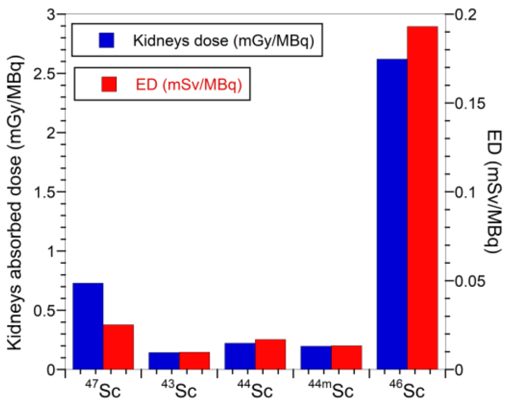

Fig. 1. AD to the kidneys and ED for the ^{xx}Sc-cm10 radiopharmaceutical and the adult male phantom.

RESULTS

Figure 1 shows the summary of the dosimetric calculation results for all the Sc-radioisotopes (^{43}Sc, ^{44}Sc, ^{44m}Sc, ^{46}Sc, ^{47}Sc) produced by irradiation of ^{48}Ti target at E_P < 40 MeV. For each ^{4x}Sc-radioisotope, the organ receiving the highest absorbed dose (AD) following ^{4x}Sc-cm10 injection is the kidney. In this organ, the AD per unit of injected activity of ^{46}Sc is a factor 3.6 higher compared to ^{47}Sc, while it is lower for all the other produced radioisotopes. The effective dose (ED) for ^{46}Sc results a factor 7.6 bigger than that of ^{47}Sc (0.0252 mSv/MBq).

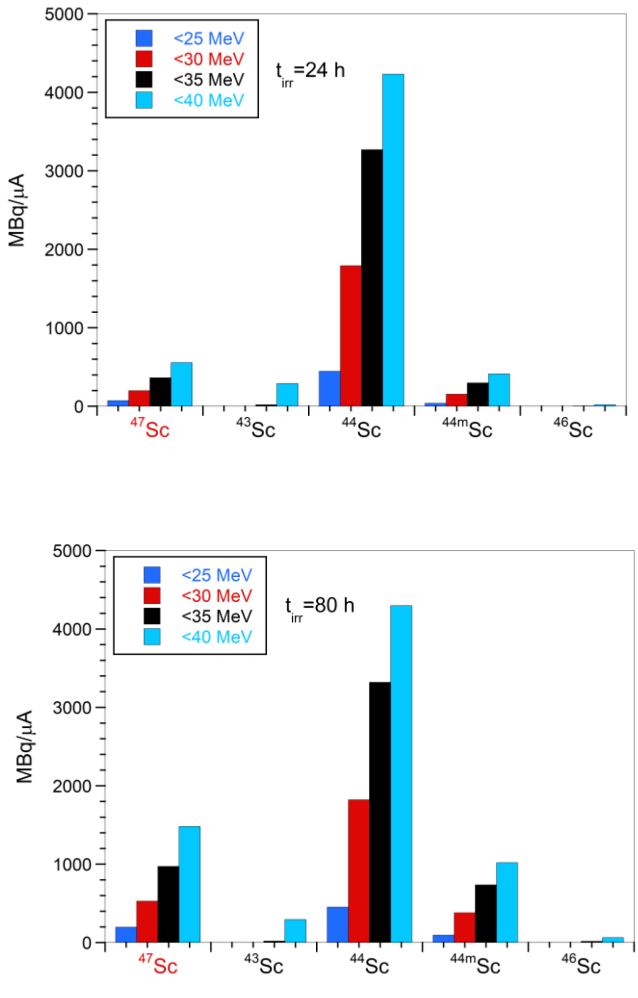

Fig. 2. Yields of ^{4x}Sc radioisotopes expected by irradiation of ^{48}Ti target at different proton energies and irradiation times.

Yields of Sc radioisotopes obtained at different proton energies as well as irradiation times (t_{irr}) are plotted in Figure 2. The highest ^{47}Sc activity is obtained by using the larger energy window (i.e. <40 MeV) and the longer irradiation time (i.e. 80 h). For all the scenarios, the Radionuclidic Purity (RNP), initially very low, is rapidly increasing, due to the decay of the short half-life impurities ^{43}Sc and ^{44g}Sc (Figure 3). After about 30 h, the RNP rises more slowly, due to the decay of ^{44m}Sc. For E_P >30 MeV the RNP reaches a maximum (≈50-55%) and then decreases, due to contribution of the long half-life impurity ^{46}Sc. For E_P <30 MeV, the RNP is instead continuously increasing, as in this case ^{46}Sc is not produced, however a 99% value may be achieved only ≈1500 h after the EOB, corresponding to almost 20 half-lives of ^{47}Sc.

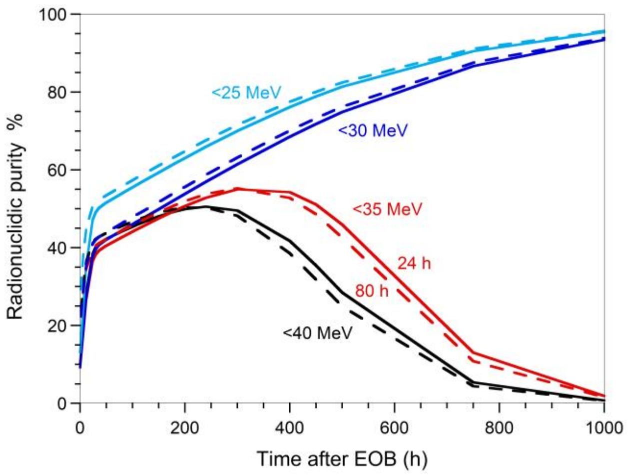

Fig. 3. Time evolution of Radionuclidic Purity (RNP) of ^{47}Sc obtained through irradiation of ^{48}Ti target at different proton energies and irradiation times (continuous lines: 24 h, dashed lines: 80 h).

DISCUSSION

The ^{47}Sc yield obtained by irradiation of ^{48}Ti is larger (971 MBq/µA for E_p<30 MeV and t_{irr}=80 h) when compared to the use of ^{nat}V target (279 MBq/µA for E_p=35-19 MeV and t_{irr}=80 h), which has been previously investigated [1]. Moreover, the long-lived contaminant ^{46}Sc, causing high AD, is not produced by ^{48}Ti irradiation for E_P <30 MeV. However, the RNP obtained for irradiation of ^{48}Ti target achieves values acceptable for medical purposes only at very long times after the EOB. On the contrary, irradiation of a ^{nat}V target with E_P <35 MeV guarantees a RNP>99% over an extended time window after the EOB (Figure 4). Besides, in these conditions, the dose increase caused by the presence of Sc-contaminants is maintained lower than 10%. This production route has also the advantage to employ a low-cost and commercially easily available target material (^{nat}V: ^{50}V, 0.250% and ^{51}V, 99.750%) and rather common medium-energy proton cyclotrons. The amount of ^{47}Sc activity produced through ^{nat}V irradiation is also much higher than that obtained after a comparable time of irradiation of a ^{46}Ca target at a high-flux reactor through the commonly employed ^{46}Ca(n,γ)^{47}Ca ($\tau_{1/2}$ = 4.536 d) → ^{47}Sc reaction.

CONCLUSIONS

As the RNP obtained for irradiation of ^{48}Ti target reaches values acceptable for medical purposes only after very long times after the EOB, when the ^{47}Sc yield becomes too low to have practical applications, this production route can not be considered a valid alternative to the use of a ^{nat}V target. However, cross sections measurements have been recently performed for proton irradiation of ^{49}Ti and ^{50}Ti targets and the analysis here described will be also extended to those production routes.

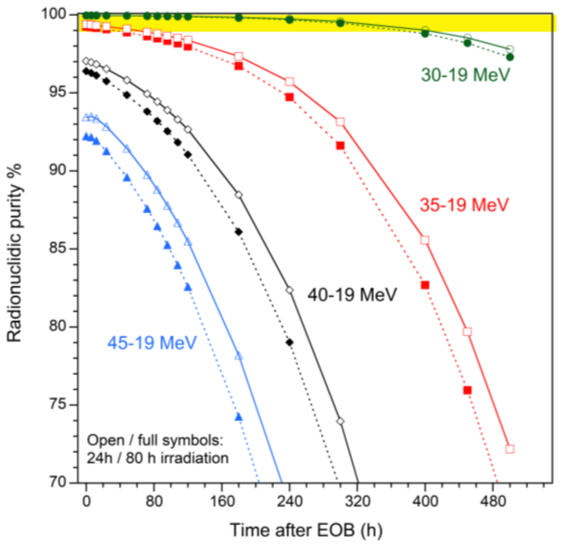

Fig. 4. Time evolution of Radionuclidic Purity (RNP) of ^{47}Sc obtained through irradiation of ^{nat}V target at different proton energies and irradiation times (continuous lines:24 h, dashed lines: 80 h).

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