Background and Objective

Proton beam range verification by positron emission tomography (PET) has been discussed in several publications in the past. As in off-line PET imaging, the activity in the tissue is subjected to the biological wash-out, implanted markers are supposed to avoid this limitation [1]. This study investigates the activation of titanium-based implants which are used in surgical resection prior to the proton therapy because of their biocompatibility and can be found especially in CT images of brain tumor patients.

Methods

The general potential of titanium implants for field verification has been demonstrated with the irradiation of a slanted angle phantom and a PET scan of the titanium sheet in a small animal PET [2].

Transfer to clinically geometries

• Using a human PET scanner (Siemens Biograph64 Vision600) for the activation study and scanning the complete phantom (not only titanium parts) while 4 h after irradiation
• Irradiation of the slanted angle geometry with two different proton fields
  1. Quasi-monoenergetic field which stops inside the phantom (10 CGyE to the Bragg peak)
  2. SOBP-like dose distribution on a cubic target volume (5 CGyE to the target volume)
• Irradiation of a second phantom with four dedicated implants (sheets) with a SOBP-like dose distribution to a virtual target volume (2 CGyE to the target volume)
• Irradiation of an anthropomorphic head phantom with one single proton field (2 CGyE to the virtual target volume)

Results and Discussion

Activity over time

• PET scan in time intervals of 5 min
• Fitting an exponential model for the decay in the complete phantom, the PMMA and the titanium sheet in the slanted angle geometry
• Identify three half-lives: 2.07 min, 20.66 min and 203.45 min

Short-lived: O-15 and C-11, long-lived from titanium (not in PMMA areas)

Titanium activation gives signal after 3 hours

Dose reduction and absolute activities

• Dose reduced to clinical fraction doses (approx. 2 CGyE)
• Titanium gives signal in an anthropomorphic phantom without statistical limitation

Conclusion

• PET imaging based on titanium implants has a potential for proton beam range verification and absolute dose verification
• PET scan should be taken several hours after treatment due to the tissue activation
• Future steps: multiple treatment fields and sensitivity tests, Monte Carlo predictions of the activity (distributions)

References