Abstract
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Neutron dose equivalent increase from the use of range shifter in proton fields.

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BACKGROUND: Proton therapy of superficial targets often require the addition of a range shifter (RS) to bring the proton energies in the necessary range, at the cost of neutron production. These neutrons are a concern due to their high radiobiological effectiveness and the risk for second cancer induction.

PURPOSE: To **evaluate the neutron dose increase due to RS** in patients treated with proton beam scanning (PBS).

MATERIAL AND METHODS

BRAIN CASE

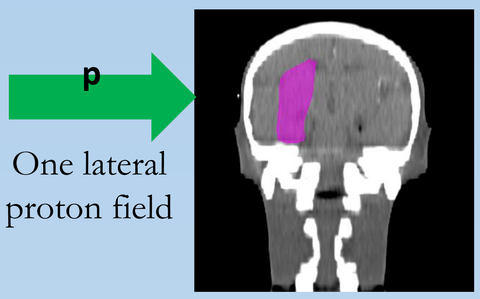

Fig. 1. Shallow target (4 cm depth, 84.4 cm^3 volume) in brain.

- Planned by Eclipse™.
- Prescription: 54.5 Gy.
- Energy layers:
  - Plan without RS (NRS): 21 between 60 and 97 MeV.
  - Plan with RS (RS): 14 between 93 and 124 MeV.
- RS: 3.1 cm WET Lexan

NEUTRON EVALUATION

- Neutron dose equivalent (H_n) from full Monte Carlo simulation (using MCNP 6.2 code).
  - Actual spot distribution.
  - Simulation layer by layer.
  - Production in patient and RS assessed separately.

Fig. 2. MC voxel phantom created from CT images using the Schneider method (1).

RESULTS

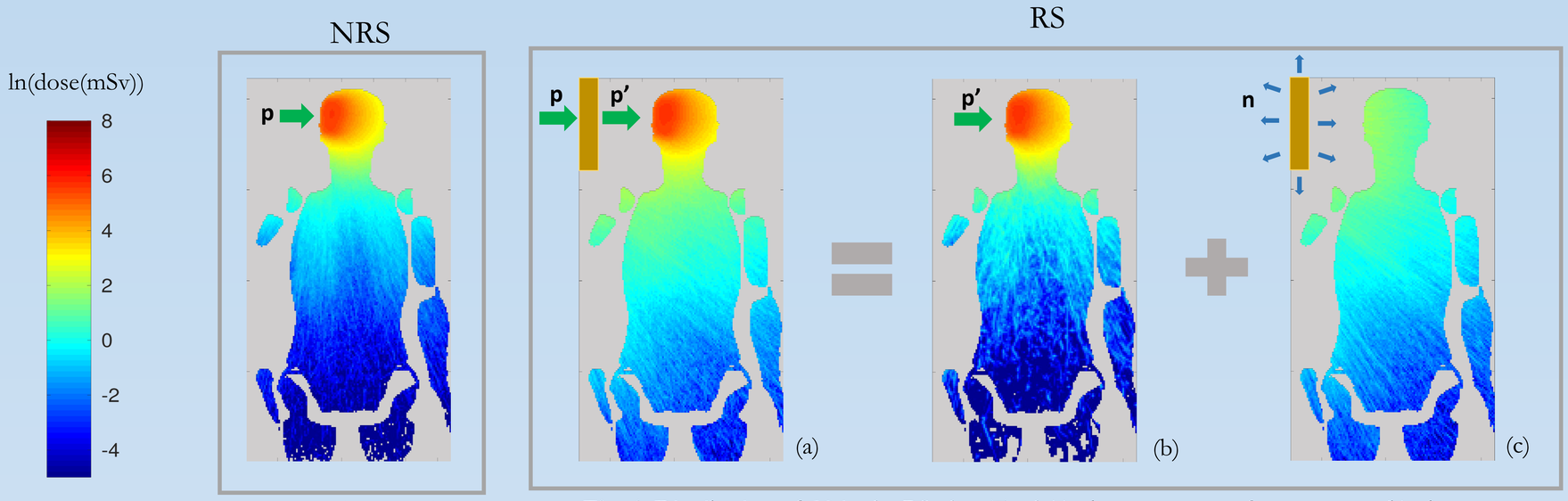

Fig. 3. Distribution of H_n in the NRS plan.

Fig. 4. Distribution of H_n in the RS plan: Total (a), due to neutrons from protons (b), due to neutrons from RS (c). (Same colour scale of figure 3).

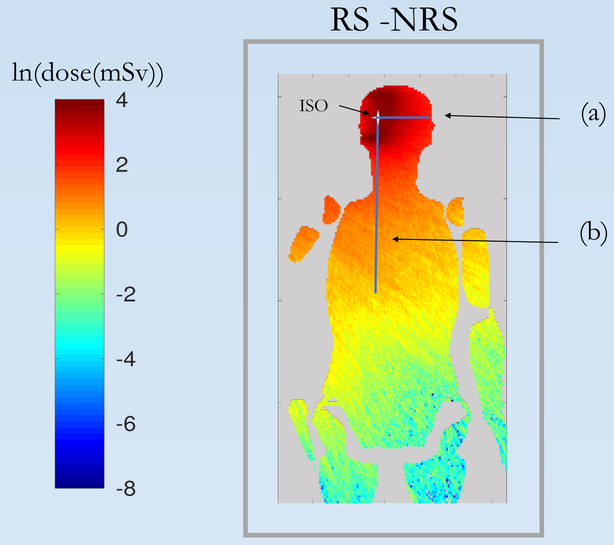

Fig. 5. Distribution of the increase in H_n.

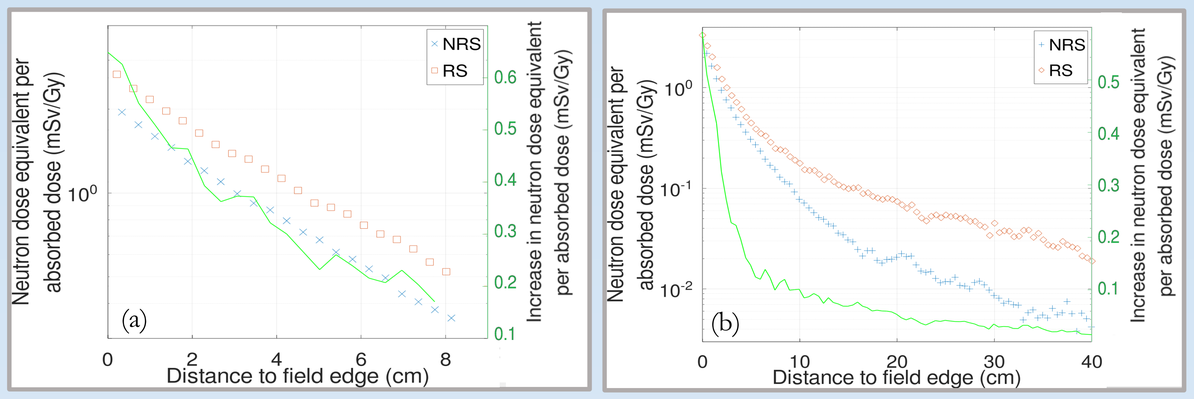

Fig. 6. H_n per absorbed dose (dots, left y-axis) and increase of H_n per absorbed dose due to RS (line, right y-axis) in the forward direction behind the isocenter (a) and in the axial direction at isocenter depth. (b).

CONCLUSIONS

- ✓ The contribution of RS to neutron production in PBS is low.
- ✓ For the characteristics of the target (volume and depth) and the RS (material and thickness), the maximum increase due to RS is around 1 mSv/Gy in the field edge.
  - Both H_n and increase in H_n decrease as the distance to field edge increases.
  - For a particular distance to field edge, H_n depends on the position relative to the proton beam, being highest in locations behind the target.

References: 1. PMB 2000 45 459–478.

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