**INTRODUCTION**

In diffusing alpha-emitters radiation therapy (DaRT), unsealed sources (seeds) with radium-224 atoms embedded at a small depth below their surfaces release radionuclides emitting alpha, beta and gamma particles at the time of their decay. The alpha dose is critical for a successful treatment. The diffusion-leakage (DL) model (Arazi 2020) takes into account four physical processes (radioactive decay, desorption, diffusion, leakage), allowing to determine the spatial distributions of the emitters and the corresponding alpha dose under the assumption of a local deposition of the alpha particles’ energies.

**AIM**

- Present how variations, over clinically relevant ranges for various tumor types, of the DL model parameters related to desorption, diffusion and leakage processes affect the position of the clinically significant alpha particle 10 Gy isodose (see table 1 and figure 2).
- Present the effects of different modeling approximations:
  - Source geometry approximation (solid cylinder instead of hollow) (see figures 3 and 4).
  - Single-source dose maps superposition (instead of direct dose calculation for multiple sources) (see figure 1).

**METHOD**

A finite volume approach (Chevé et al 2023) was used to develop numerical schemes of increasing complexity based on the DL model. Reference solutions were calculated in 1D, 2D and 3D using the following set of parameters (Arazi 2020, Hegert et al 2023):

- Source geometry: \(D_{ox} = 0.40 \text{ mm} \), \(D_{oz} = 0.70 \text{ mm} \), \(L = 1 \text{ cm} \).
- Source activity: \(A_{0,seeds} = 3 \text{ Beq/cm}^3 \).
- Physical processes: (see ref. values in table 1).

Parameters related to physical processes were varied over clinically relevant ranges (Arazi 2020, Hegert et al 2023) (see table 1).

**RESULTS**

Table 1: Sensitivity of the 10 Gy isodose radial position to the diffusion-leakage model physical process parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rad. Position ((10^{-5} \text{ mm} ))</th>
<th>Rel. Error (% )</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A_{0,seeds} )</td>
<td>3 Beq/cm^3</td>
<td>0.1</td>
</tr>
<tr>
<td>(D_{ox} )</td>
<td>0.40 mm</td>
<td>1.5</td>
</tr>
<tr>
<td>(D_{oz} )</td>
<td>0.70 mm</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Figure 1: (Top) Alpha particle 2D (\(r, z \)) dose distribution for two sources separated by 5 mm. (Bottom) Relative error when comparing with the superposition of two single-source dose maps.

Figure 2: Alpha particle 2D (\(r \)) radial dose distribution sensitivity to variations in diffusion lengths.

Figure 3: Alpha particle 2D (\(r, z \)) dose distribution for a single source.

Figure 4: Absolute value of the relative error on the alpha particle 2D (\(r, z \)) dose distribution for a single source when comparing a solid source to a hollow source. Rel. err = (solid / hollow) - 1.

**DISCUSSION AND CONCLUSION**

- Alpha particle 1D (\(r \)) and 2D (\(r, z \)) dose distributions show that the 10 Gy isodose radial position \(r_{10} \approx 2.6 \text{ mm} \) (for source parameters and physical process parameters are set to their reference values).
- The physical process parameter affecting the most the 10 Gy isodose position is the diffusion length \(L_{D} \). Combined variations of \(L_{D} \) (over clinically relevant ranges) can displace the isodose position by \(\Delta r_{10} \approx 1.5 \text{ mm} \). This is ~3 times the effect of varying the leakage probability \(\Delta r_{10} \approx 0.5 \text{ mm} \) and ~55 times the effect of varying the desorption probability \(\Delta r_{10} \approx 0.05 \text{ mm} \). Source geometry approximation (solid instead of hollow cylinder) has a negligible effect on the 10 Gy isodose position \(\Delta r_{10} \approx 0.1 \text{ mm} \).
- Superposition of single-source dose maps (instead of direct dose calculation for multiple sources) has a negligible effect on the 10 Gy isodose position \(\Delta r_{10} \approx 0.1 \text{ mm} \) for clinically realistic inter-source spacings (in a homogeneous medium).

**ACKNOWLEDGMENTS**

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**REFERENCES**