A Comparison of Tissue Doses from Colloidal Sn-117m, P-32, Y-90, Re-186 and Er-169 for Radiosynoviorthesis Using Monte Carlo Simulation

Richard E. Wendt III
UT MD Anderson Cancer Center, Houston TX
and
Nigel R. Stevenson
Serene, LLC, The Woodlands TX

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Radiosynoviorthesis Radionuclides

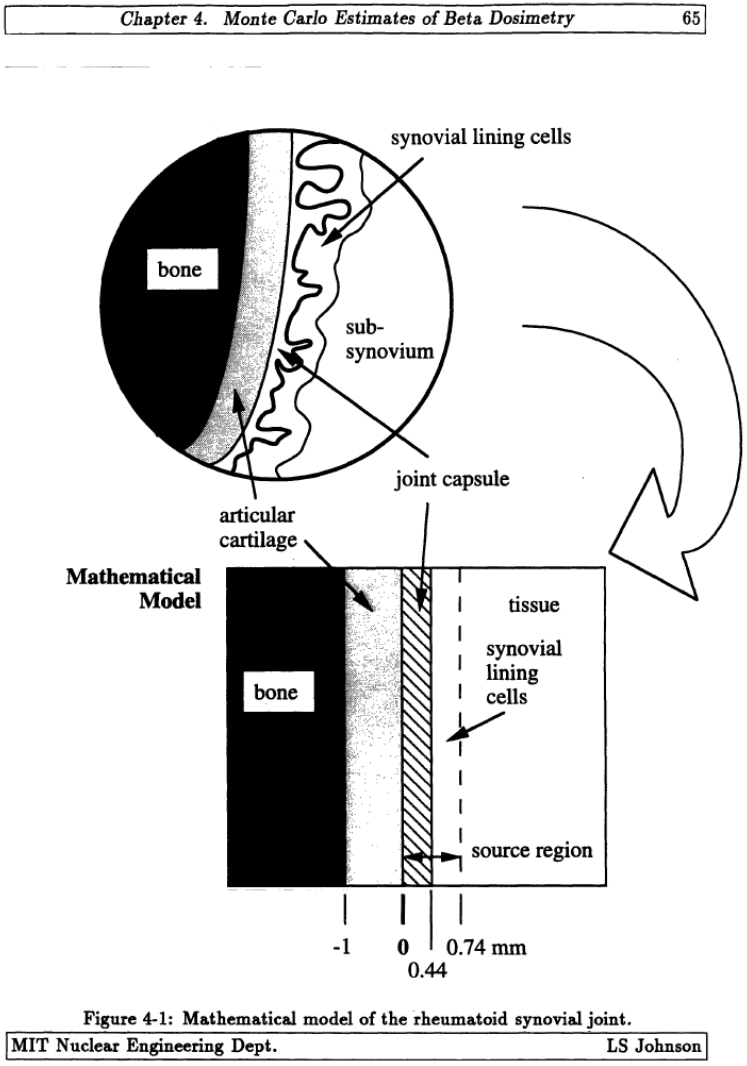
Radionuclide	Application	e^-	Electron Range in ICRU 4-Component Tissue* (avg.; max. mm)	Half-life (days)
Y-90 (citrate)	Large (knee)	β	(4.05; 11.4)	2.67
P-32 ($Cr0_4P$)	Large (knee)	β	(2.78; 8.3)	14.3
Re-186 (sulfide)	Medium (elbow)	β	(1.06; 4.79)	3.72
Er-169 (citrate)	Small (fingers and toes)	β	(0.14 [0.3†]; 1.07)	9.40
Sn-117m (6 µm colloid)	Canine elbow (investigational)	CE	(0.241; 0.290)	14.0

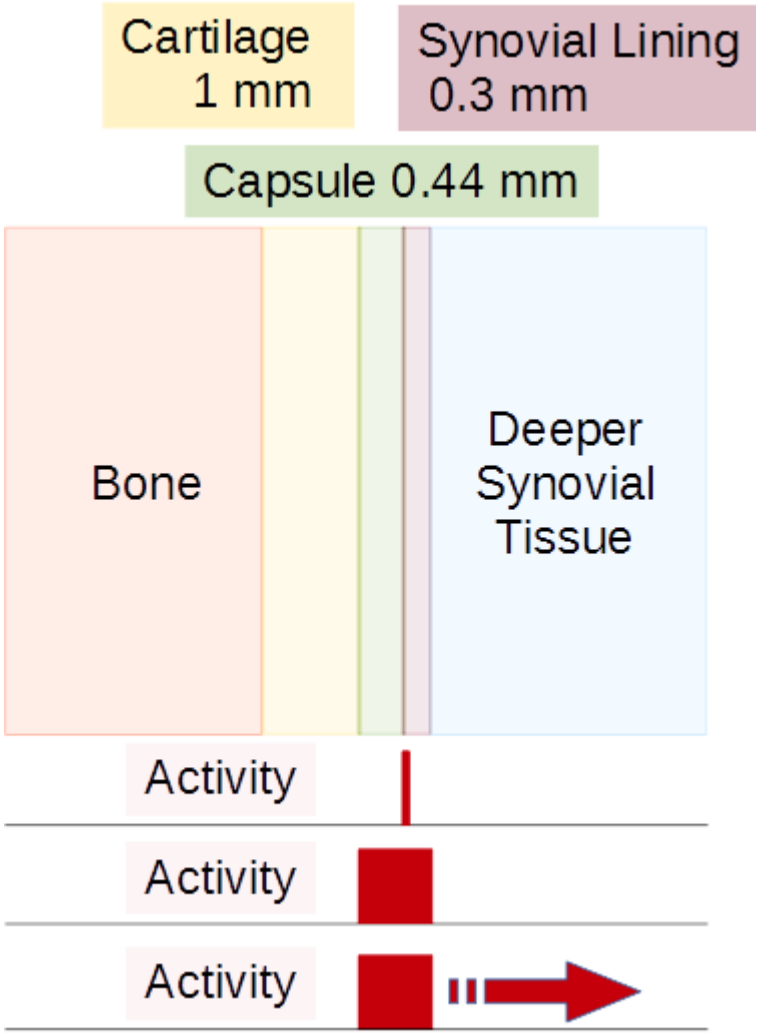
*NIST ESTAR database for electron CSDA ranges:
http://physics.nist.gov/PhysRefData/Star/Text/ESTAR.html
†Numerous sources state that the average range of Er-169 in tissue is 0.3 mm

Premise and Hypothesis

- Conventional Premise: One should choose a radionuclide that has an electron range in tissue that is commensurate with the size of the joint synovium.
- Hypothesis: Migration by macrophages containing longer-lived, short-range radioactive particles into all of the layers of the synovial tissues delivers therapeutic absorbed doses throughout the synovium.

Model of the Synovial Joint



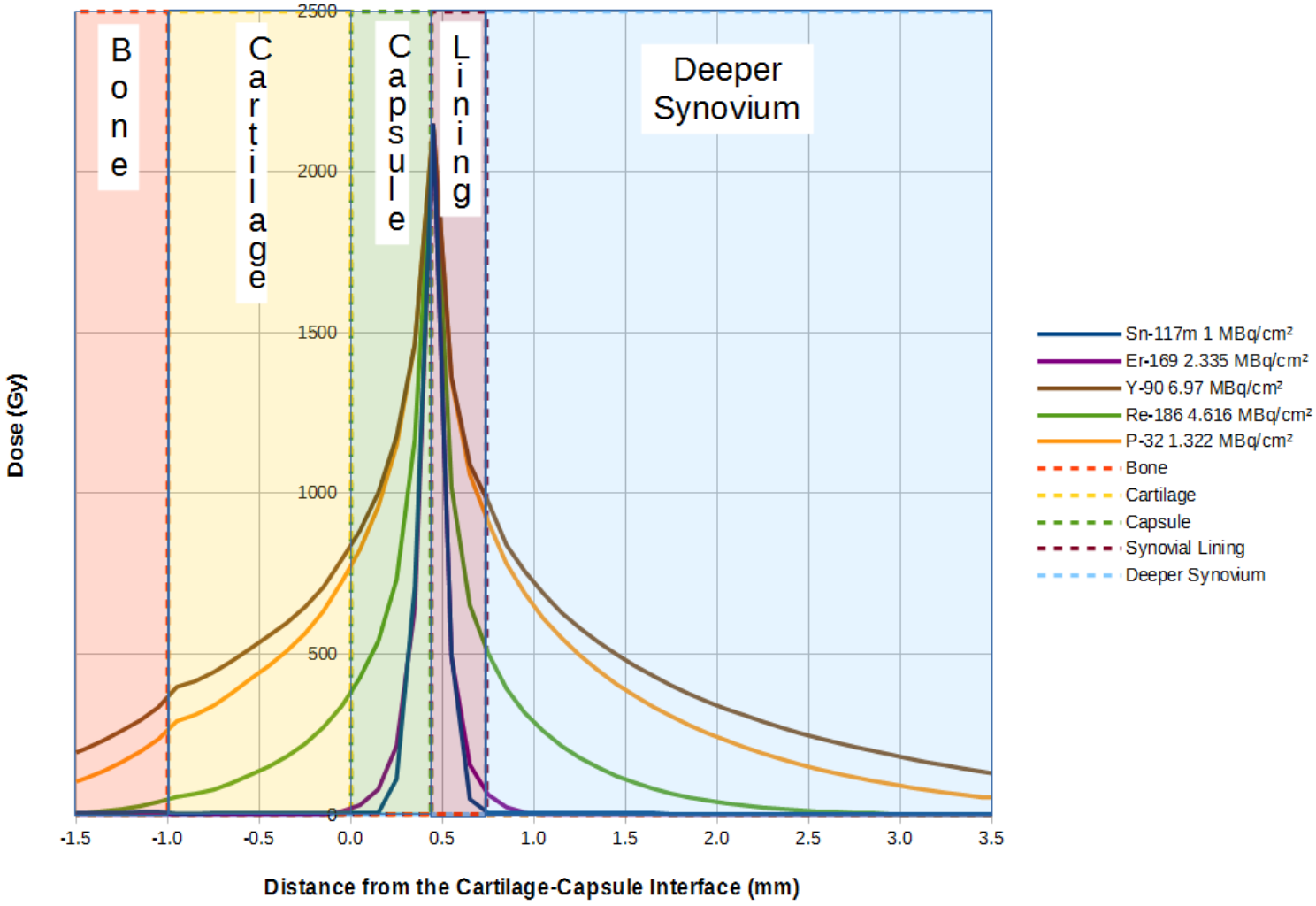


LS Johnson, *Beta-Particle Dosimetry in Radiation Synovectomy and Use of the $^{10}B(n,\alpha)$ Nuclear Reaction to Examine the Pathology of Rheumatoid Arthritis*, PhD, Massachusetts Institute of Technology, 1994, p. 65. Figure used with the permission of Dr. Johnson.

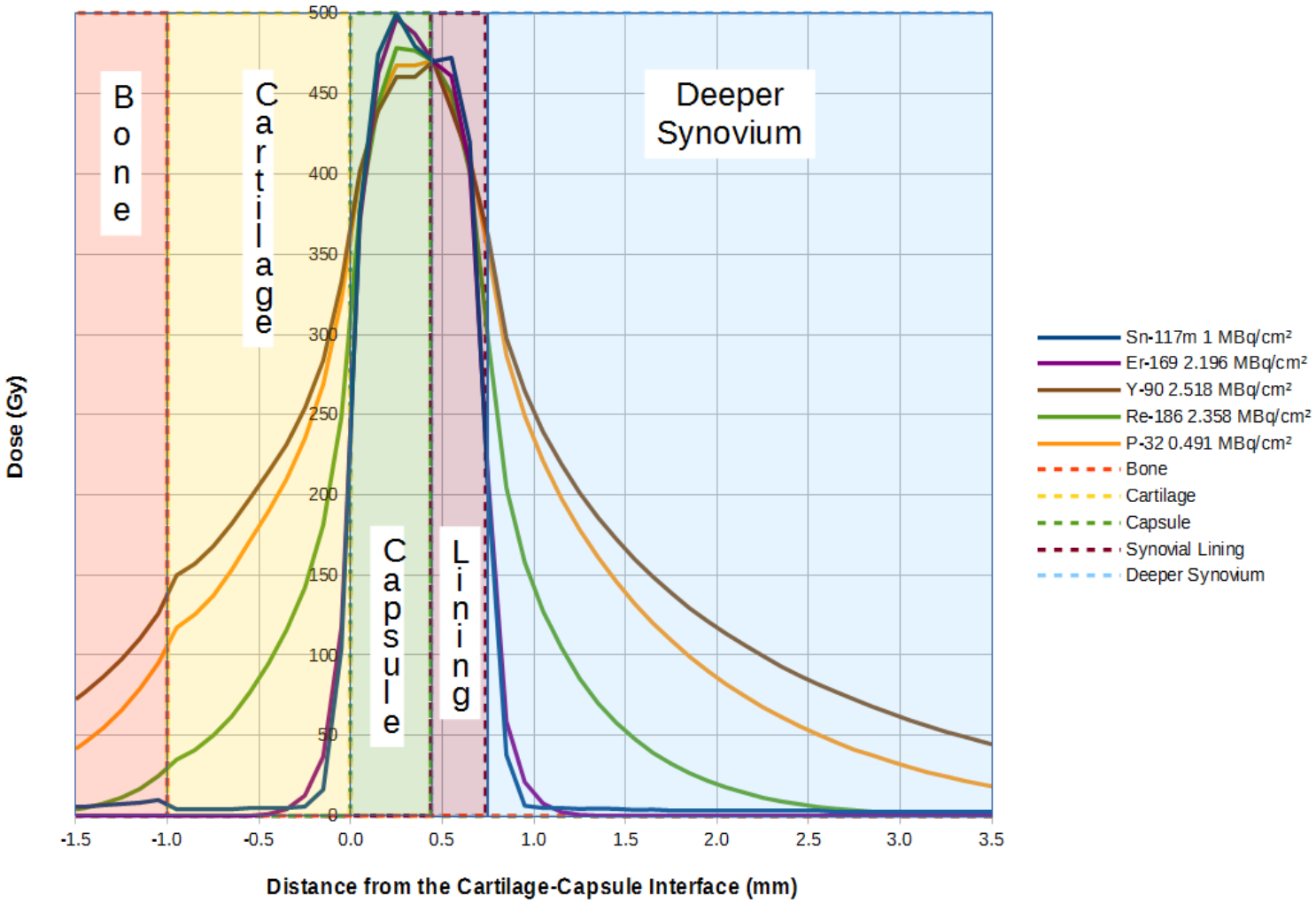
Monte Carlo Simulation

- GATE 8.0 Monte Carlo simulations
  - The source definitions were built using the complete radionuclide emissions data from ICRP 107.
  - Johnson's model was built as a stack of 4 cm-diameter disks of the specified thicknesses for each layer.
  - The spatial resolution perpendicular to the synovial tissue was 0.1 mm.
  - The GATE materials were "Rib Bone" for the bone, "Cartilage" for the cartilage, "Water" for the capsule and "Muscle" for the synovium.
  - The QBBC_EMY physics list was used.
  - Two million events were simulated for each scenario.

Stationary Activity on the Surface of the Synovial Lining

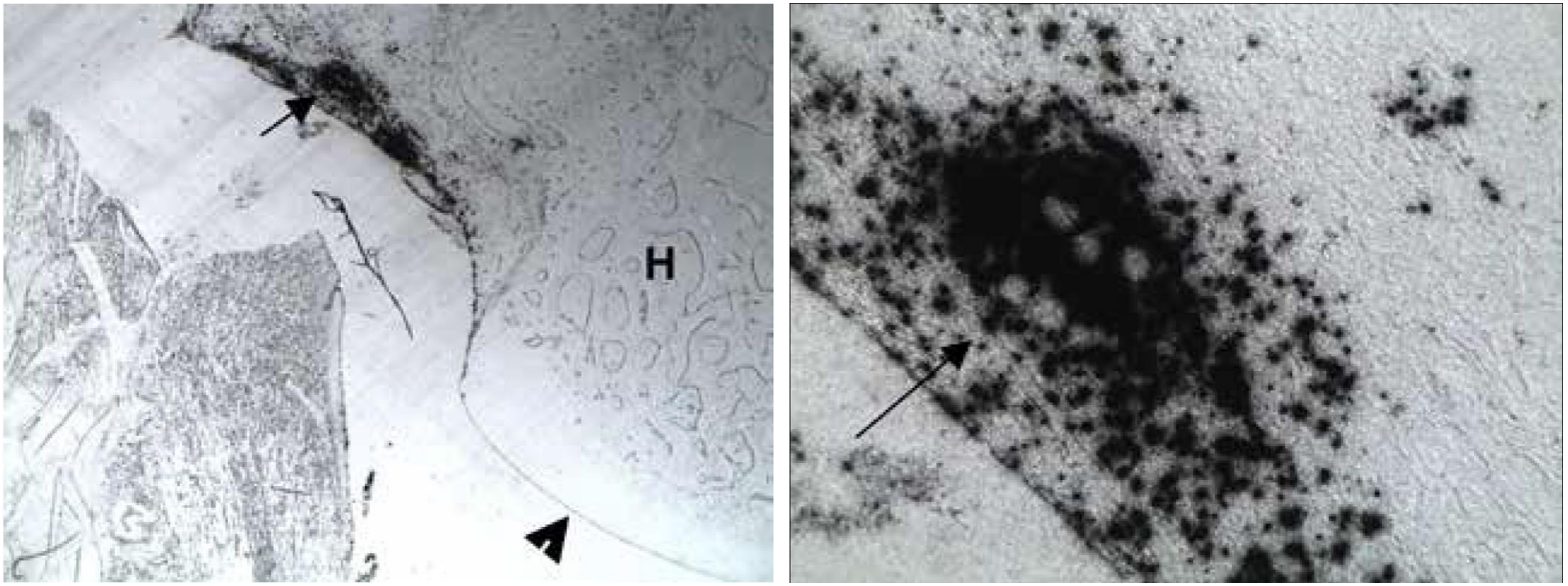


Stationary Activity in Capsule and Lining



Macrophage Action

- Radioactive colloidal particles are collected on the synovial lining and then transported deeper into the synovial tissue.

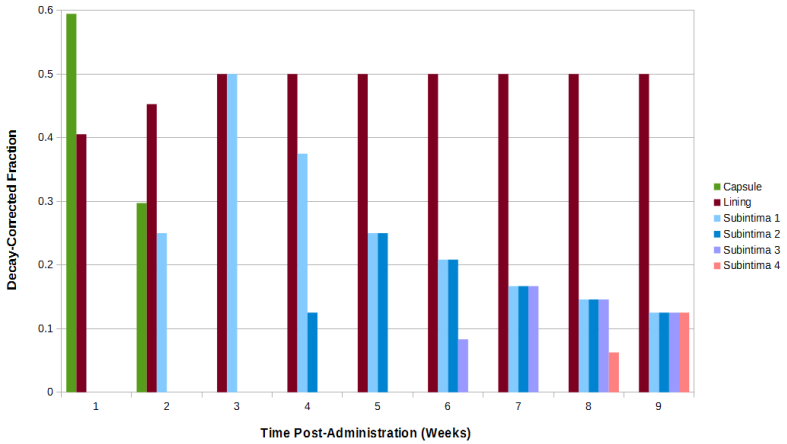


100×

400×

The arrow (→) indicates an area of inflammation in the autoradiographs.

Model of Moving Radioactivity



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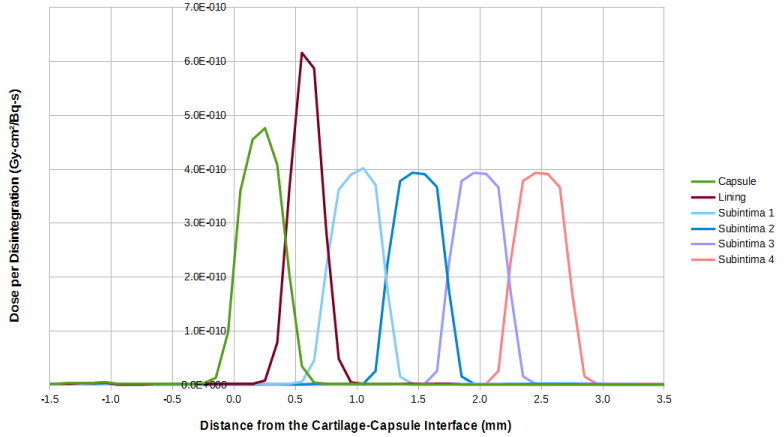

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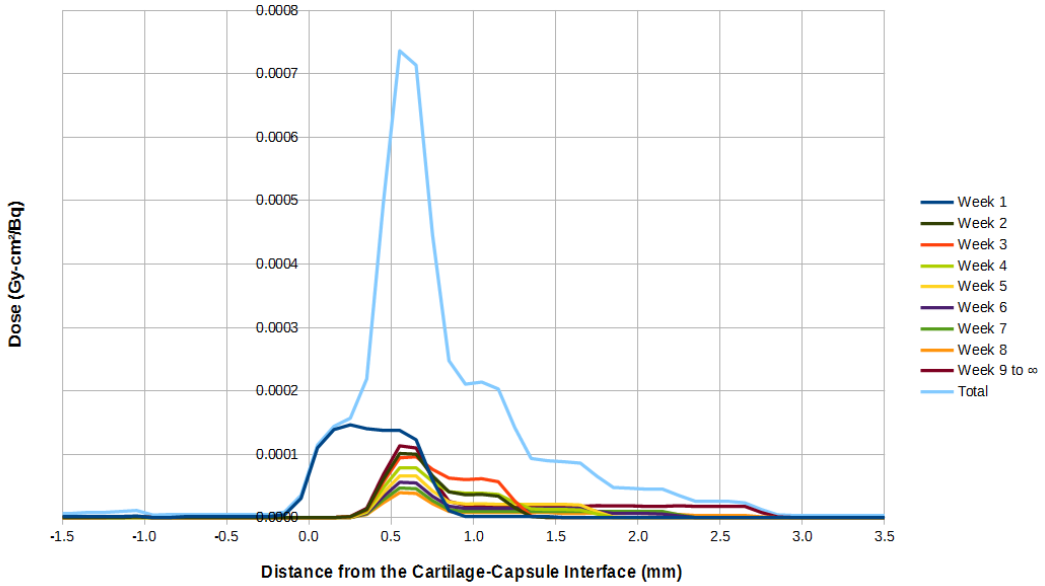
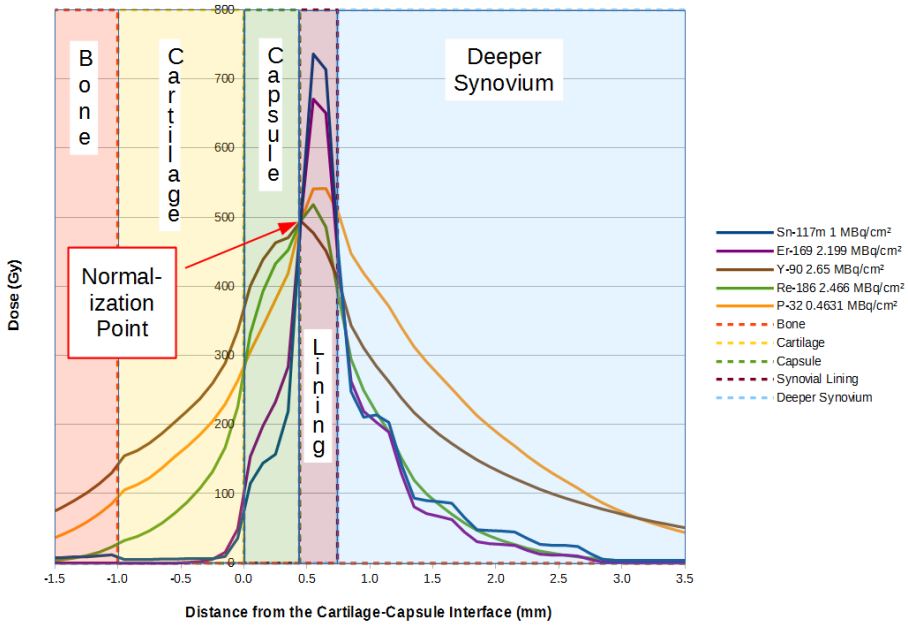
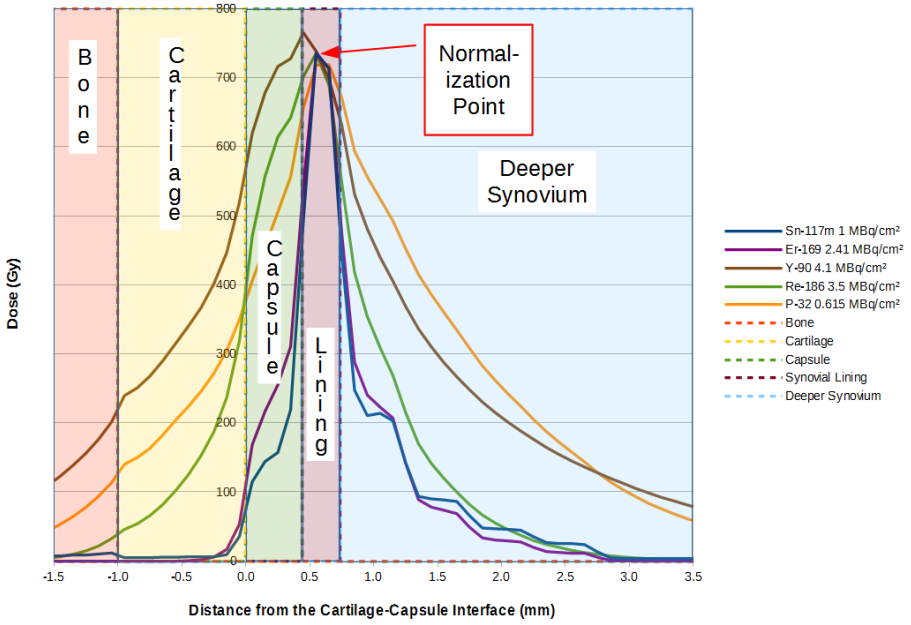


Moving Source Dose Distributions



Nuclide	Rel. Act.
Sn-117m	1.00
Er-169	2.20
Y-90	2.65
Re-186	2.47
P-32	0.463



Nuclide	Rel. Act.
Sn-117m	1.00
Er-169	2.41
Y-90	4.10
Re-186	3.50
P-32	0.615

Discussion and Conclusion

- The relatively long half-lives of P-32, Er-169 and Sn-117m potentially allow them to be carried well into the synovial tissue before depositing all of their energy, assuming a suitable particle size.
- With the movement model in this study, the dose distributions of Er-169, Re-186 and Sn-117m are very similar.
- The further investigation of Sn-117m for the radiosynoviorthesis of medium-sized as well as smaller-sized joints is warranted.