Contact Doses from Dogs That Have Been Treated with Sn-117m Radiosynoviorthesis

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Radiation synoviorthesis is a promising treatment for canine osteoarthritis. Its effective use requires an estimation of the contact dose to those who touch the treated dog in order to determine for how long such contact should be avoided following treatment.

This report reviews the results of a Monte Carlo simulation of an idealized synovial joint in which the synovial tissue bears Sn-117m. It makes recommendations for the safe touching of treated dogs.

Monte Carlo Simulations

The GATE Monte Carlo simulation software (1,2) Version 8.0 was used for this study. The definition of the Sn-117m source material was derived from the emission data in ICRP 107(3). Unlike many simulations that have been reported in the literature, which ignore emissions with energies less than 15 or 20 keV or with abundances of less than 1%, every emission that is tabulated in ICRP 107 has been included in this simulation. Two billion events were simulated. This corresponds to 61.856 million disintegrations.

In order to validate the simulations, a point source of Sn-117m in air was simulated at the center of an annular cylinder of water with an inner radius of 1 meter and an outer radius of 1.1 meters. The dose rate constant that was determined from this simulation is 1.54×10^{-17} Gy-m^2/Bq-s. This was at a depth of 1 cm into the cylinder of water. This value falls within the range of those that have been published in the literature, which lie between 1.20×10^{-17} Gy-m^2/Bq-s(4) and 1.89×10^{-17} Gy-m^2/Bq-s(5). There is a nice discussion of why the literature often contains such a wide range of values for the dose rate constant of a particular radionuclide in an AAPM report on PET shielding(6). From this example, we conclude that the simulations are producing reasonable results.

The dose rate in tissue that is in contact with the treated joint was estimated. A stylized model of a synovial joint was constructed and is shown in Figure 1 below. It consists of a ball and a socket (bright and dark yellow, respectively) with radii of 1.5 cm on the ends of cylindrical bones (gray), each covered with a 1 mm thick layer of cartilage (red and magenta). The otherwise empty space within the joint was filled with water (blue outline) to represent the synovial fluid. A superficial layer of tissue (gray outline) surrounds the entire limb. The activity was uniformly distributed in the synovial tissue, which was modeled as an infinitesimally thin-walled cylinder at the outer surface of the synovial fluid colored blue in Figure 1. A block of tissue that is 5 cm thick, 10 cm wide and 30 cm high was placed against the joint as shown in Figures 2 and 3.

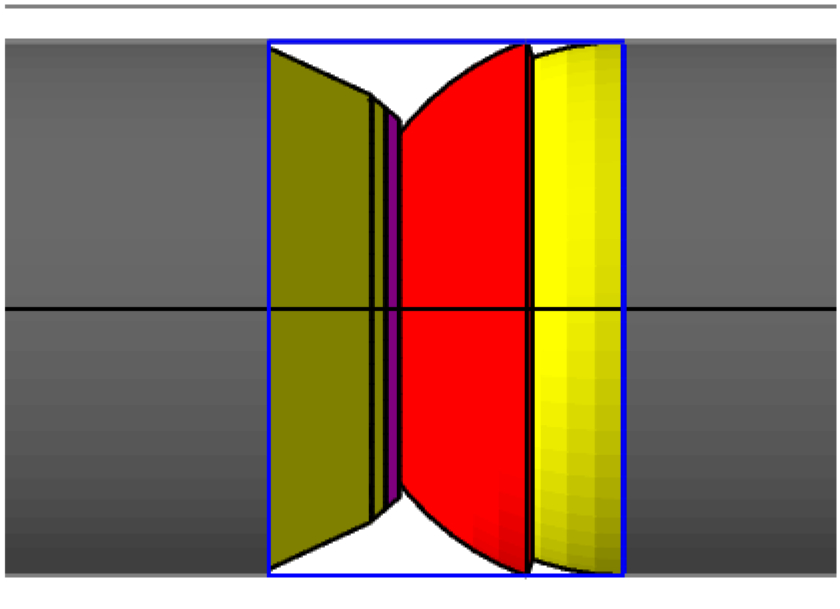

Figure 1: Stylized model of a synovial joint.

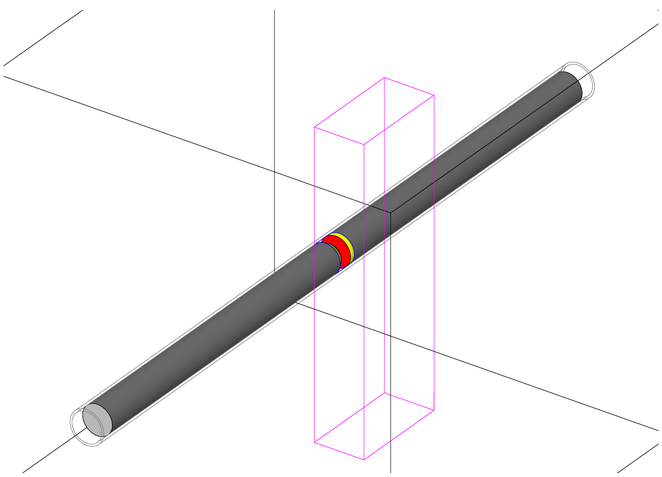

Figure 2: Stylized joint with a block of tissue, outlined in light magenta, pressed against the joint.

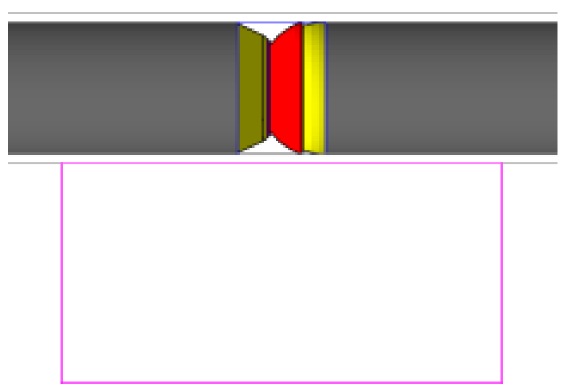

Figure 3: A top-down view of the joint and tissue block in Figure 2.

The dose was registered in the tissue in a “dose actor” that had a spatial resolution of 1 mm × 1 mm in the plane of the tissue block that is parallel to the limb (the horizontal direction in Figure 3) and a spatial resolution of 10`µm in the direction perpendicular to the limb (the vertical direction in Figure 3). The dose in the central plane of the first 5 mm of the tissue block that is perpendicular to the limb is shown in Figure 4.

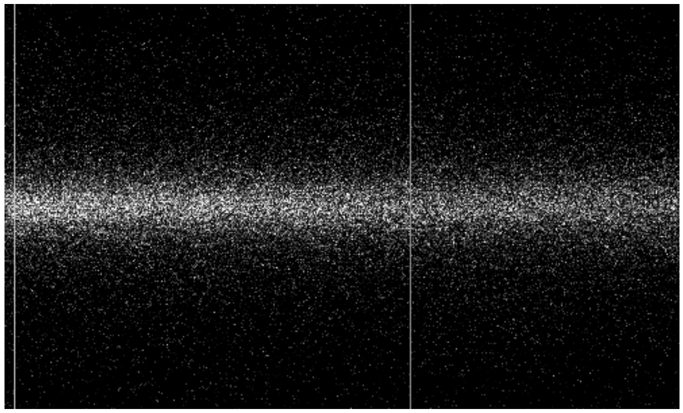

Figure 4: The 5 mm of the tissue block that is closest to the joint. Dose is depicted in shades of gray with brighter indicating a higher dose. The horizontal axis of this figure is the vertical axis of Figure 3. The joint is touching the left hand end of this figure. The two gray, vertical lines show the planes at 70 µm and 3 mm from the joint. The horizontal direction is expanded 100× compared to the vertical direction.

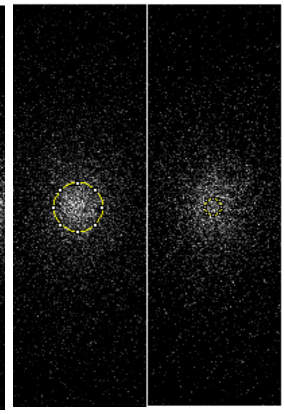

Figure 5: 10 cm^2 ROI at 70 µm into the tissue (left) and 1 cm^2 ROI at 3 mm into the tissue (right).

The average dose at a depth of 70 µm in the 10 cm^2 circular region of interest shown in Figure 5 was 3.33×10^{-14} Gy/Bq-s, while the average dose at a depth of 3 mm in the 1 cm^2 circular region of interest that is shown in Figure 5 was 3.44×10^{-14} Gy/Bq-s.

The highest anticipated administered activity to an elbow of 3 mCi would produce 3.996×10^{11} disintegrations (Bq-s) in the first hour, and thus over the course of that hour the dose at a depth of 70 µm would be 13.3 mGy while that at a depth of 3 mm would be 13.7 mGy. Although it seems to be counterintuitive at first glance that the dose farther away is higher, the dose at a depth of 3 mm is determined over a much smaller area that excludes many scattered, lower energy events.

Every two weeks after treatment, the dose from such contact would be halved, given the 14 day physical half-life of Sn-117m.

The duration of time after treatment during which people should avoid more than momentarily touching the dog's elbow may be calculated by solving the following expression for t_{avoid}. This equation sets the dose limit equal to the dose that is accumulated to infinity, taking into account the fraction of time that the contact takes place, E, decayed by the duration of avoidance.

$$\frac{\dot{D}_0 T_{1/2} E}{\ln(2)} e^{-\ln(2) t_{avoid}/T_{1/2}} = D_{limit} \qquad (1)$$

$$t_{avoid} = \frac{-T_{1/2}}{\ln(2)} \ln\left[\frac{D_{limit} \ln(2)}{\dot{D}_0 T_{1/2} E}\right] \qquad (2)$$

where $\dot{D}_0$ is the initial dose rate, $T_{1/2}$ is the effective half-life, E is sometimes called the occupancy factor, D_{limit} is the dose limit and t_{avoid} is the duration of avoiding contact so that the initial dose rate can decay to the point that the subsequently accumulated dose to infinity would remain below the dose limit.

Recommendation for Human Touching of the Treated Elbow

The annual doses to the skin and to the lens of the eye for members of the general public are not regulated in the United States. The International Atomic Energy Agency(7) and the International Commission on Radiological Protection(8) recommend that the dose limits for the skin and the lens for members of the general public be one-tenth of the occupational limits(9). Thus, prudent limits would be 50 mSv (5 rem) at a depth of 70 μm averaged over 10 cm^2 for the skin and 15 mSv (1.5 rem) at a depth of 3 mm averaged over 1 cm^2 for the lens of the eye, even though these are infrequent exposures of members of the general public to a treated dog and not the annual exposures that are anticipated in the occupational limits.

In order to remain below this skin dose limit for an hour's contact each day between the exact same 10 cm^2 of skin and the dog's treated elbow, such touching should be avoided entirely for 34 days. In order to remain below this lens dose limit for an hour's contact each day of an individual's eye with the dog's elbow, such touching should be avoided for 59 days. These durations assume reduction over time of the administered activity only by physical decay, which is appropriate for Sn-117m radiosynoviorthesis in which there is negligible “leakage” of the radionuclide from the joint.

It is extremely unlikely that either a person or a dog would tolerate the conditions of this ocular contact scenario, and it is quite improbable that the precisely same patch of the person's skin would be touching the dog's elbow for an entire hour each and every day. Even while sleeping, people change position on the average twice or more often an hour(10). There is evidence to corroborate the common perception that sleeping dogs not hold perfectly still for extended periods of time(11), Figure 8 of (12) and Figure 1 of (13).Thus these recommendations that assume contact for an hour a day are extremely conservative and are probably needlessly so.

If one were to suppose only an hour's contact of the precisely same areas each week, contact with the person's skin could commence immediately after treatment while contact with the person's eye should be avoided for 20 days.

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