External Radiation Exposure Following Sn-117m Colloid Intra-articular Injections

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Abstract

Radiosynoviorthesis (a.k.a. radiosynovectomy) is an established treatment for arthritis. We are studying the use of Sn-117m ($T_{1/2}$ = 14 days) to treat smaller arthritic joints in animals and human beings. Its therapeutic conversion electrons (mean 135 keV, 114% abundant) have a maximum range of about 300 µm in tissue. Its photon energy (159 keV, 86% abundant) is useful to confirm the placement of the colloid, but it also produces an external radiation exposure to animal owners and the caregivers of human patients that must be evaluated and managed.

In an ongoing study, dogs with osteoarthritis are being treated with 0.74-3.75 (mean=2.07, σ=0.88) mCi (in three dosing groups of 1.00, 1.75 and 2.5 mCi, scaled to weight) of a homogeneous Sn-117m colloid (ca. 6 µm) in the intra-articular space of the arthritic elbow. The external exposure rate was measured close to the surface of the treated joint and at 1 m from the elbow. The radiation dose to animal owners or human caregivers was analyzed using a variety of occupancy factor scenarios.

Exposure rate measurements were in the range of 41-526 (mean=189, σ=118, n=35) uR/hr @ 1m, decay-corrected to the time of administration. The ratio of actual exposure rate to the theoretical exposure rate of the unshielded administered activity in air was fitted by the equation

$$\text{Transmission} = -0.0034 \times \text{Weight (kg)} + 0.54$$

Dogs were boarded for observation and data collection purposes. However, under the commonly used veterinary release limit of 500 µR/hr @ 1m, 34 could have been released immediately and one would have required isolation for a single day. The public dose limit of 100 mrem (1 mSv) applies to the animal owners, while a higher limit of 500 mrem (5 mSv) may be applied to those exposed to human patients. Four three-phase scenarios for each of two dogs, a large working dog and a small lap dog, were considered assuming a transmission of 0.54 in both cases. In essence, with little or no isolation (Phase 1) and exposure for two hours a day at three feet thereafter, the owners should minimize time close to the dogs for 1.5-2.5 weeks (Phase 2) after which the owners could spend two hours a day close to the large dog or six hours a day close to the small dog (Phase 3). A human patient receiving the higher dosage under these assumptions would have no specific restrictions.

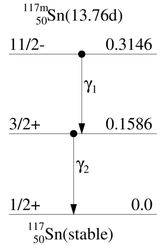
The external exposure from Sn-117m intra-articular injections can be kept below the relevant safety limits by imposing reasonable restrictions on close proximity to the patient, whether canine or human, for the first few weeks after treatment.

Radiosynoviorthesis

Inflammation of the synovial membrane may be treated by ionizing radiation that is delivered via intra-articular injection of colloidal particles that bear electron-emitting radionuclides.

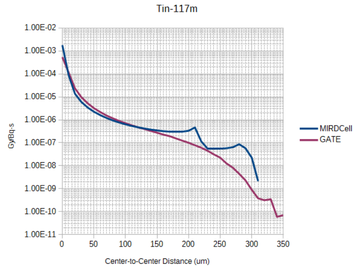
The radiolabeled particles are removed from the synovial fluid by macrophages and transported into the synoviocytes near the surface of the synovium and also into the inflamed synovial tissue. The release of energy that occurs within the synovial tissue relieves the inflammation through ablation of the tissue.

Tin-117m



Emission	Abundance	Energy (keV)
γ-1	2.11%	156
ce-K, γ-1	66.3%	126.8
ce-L1, γ-1	13.7%	151.6
ce-L3, γ-1	10.6%	152.1
γ-2	86.4%	158.6
ce-K, γ-2	11.9%	129.4

Decay scheme and prominent emissions of Sn-117m from ICRP 107[1] and the MIRD Decay Schemes[2]



Dose kernels calculated using MIRDcell[3] and GATE[4]. The maximum range is about 300 µm while the majority of the energy is deposited within about 30 µm.

Canine Treatments

Three veterinary clinics are participating in a clinical trial to treat Grades 1 or 2 osteoarthritis of the canine elbow with a Sn-117m colloid having a nominal particle size of 6 µm.

Three dosages are being investigated: 44 µCi/kg, 77 µCi/kg and 110 µCi/kg. The 35 dogs of various breeds ranged in weight from 12 to 67 kg, and the dosage ranged from 0.74 to 3.75 mCi (now capped at 3.5 mCi).

The colloid was in a volume of about 1 mL and replaced synovial fluid that had been withdrawn from the joint prior to administration. The administration site was compressed for two minutes afterward to prevent leakage through the needle track.

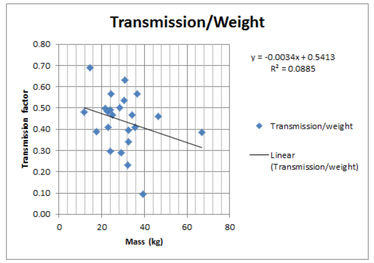
Exposure Rate Measurements

On the day after treatment, a calibrated Ludlum 9DP ionization exposure rate meter was used to read the exposure rate. Near field measurements were made 5 cm from the face of the meter and more distant measurements were made 1 m from the center of the meter chamber. In both cases, the distance was to the lateral aspect of the dogs' elbow. The readings were decay-corrected to the time of administration.

Transmission Factor at 1 m

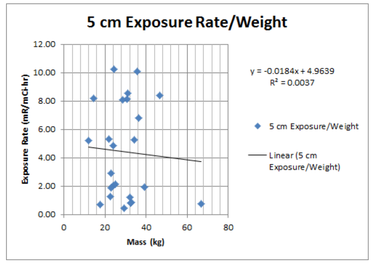
The measured exposure rates at 1 m were divided by the expected exposure rates that had been derived from the administered activities and the gamma ray exposure constant[5] of 169 µR/mCi-hr @ 1m. While there was a wide spread in the data and a modest coefficient of determination, the linear fit to the data was

$$\text{Transmission} = -0.0034 \times \text{Weight (kg)} + 0.54$$



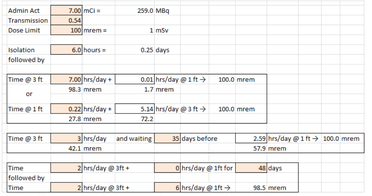
Nearby Exposure Rate

The exposure rate at 5 cm from the surface of the chamber of the meter was divided by the administered activity. The result was 4.38±3.15 mR/mCi-hr. A linear fit to body weight also had only a modest coefficient of determination.



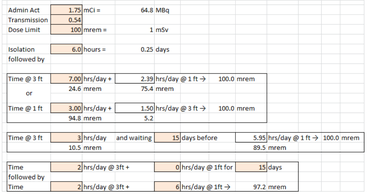
Release Restrictions

In a similar fashion to the release of radioactive human patients under the guidance of NUREG 1556[6], we have modeled post-release scenarios that make it unlikely that the most-exposed person would receive more than 100 mrem (1 mSv). A distance of three feet between the patient and humans was assumed for waking activities and of one foot for sleeping.



Example 1: Large dog, treated in both elbows

In the worst case scenario of the maximum administered activity to each elbow of 3.5 mCi and a six-hour isolation after administration, release would be unlikely to allow more than the public dose limit if the exposure to the patient were limited to 7 hours a day at 3 feet or to 13 minutes a day at one foot plus five hours a day at three feet. Alternatively, the owners might limit exposure to two hours a day at three feet for seven weeks and then add exposure for six hours a day at one foot.



Example 2: Small dog, treated in one elbow

In the case of a single elbow treatment of a smaller dog with 1.75 mCi, the restrictions are less onerous. The limitation on close proximity is only two weeks.

Discussion

It was difficult to obtain good exposure rate readings from some dogs because of their movement during the equilibration time of the meter. This implies that external exposure models that assume sources that are stationary for several hours may be too conservative.

Conclusion

There is no need for protracted isolation of radiosynoviorthesis patients following treatment. Veterinary patients may require a few weeks of limited contact in order for their owners to receive a radiation absorbed dose below 100 mrem (1 mSv). Human treatment would be unlikely to necessitate any restrictions after release because of the five-fold higher regulatory dose limit of 500 mrem (5 mSv) to the individual who is most exposed to a human patient.

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Acknowledgments

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