Guidance For Industry

Management of Radioactive Companion Animals During an Emergency Evacuation.

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Introduction

Due to the rising inclusion of radionuclides in veterinary medicine, and the widespread possibility of disasters, it is necessary for the general public to know how to evacuate with their animal safely in an emergency. This document shall provide veterinary or general emergency response teams with the information to inform them of the potential risks of these radioactive companion animals in emergency situations. This document will also provide information on the role of emergency response teams should be, what their responsibilities are, and how to communicate effectively with the public.

Background

With the turn of the 21st century, there has been an increase in the importance of companion animals in society within developed countries. According to a survey by the *American Pet Products Association* it was found that 90.5 million Americans families own a pet. (2021). The pet industry is a multi-billion dollar industry due to the amount spent on the health and wellness of animals. Along with the rise in societal importance, animals are now being treated with advanced therapeutics similar to humans. There has subsequently been an increase in the use of radionuclides to treat cancer within the field of veterinary medicine. This increase in veterinary healthcare has increased so much that issues may arise with not being able to meet the demands of the public, especially in cases of emergency situations. (Dunning et.al, 2009).

When a companion animal is undergoing radiotherapy, there are specific procedures veterinary specialists and pet owners must follow to ensure human and pet safety. Many post-treatment guidelines include isolating the pet for an allotted period of time, and using proper hygiene practices to maintain safety from the animal. Although there are established post-treatment guidelines for radiotherapy, there lacks guidance on what pet owners and veterinary response teams should do in the case of an emergency evacuation.

Principles of Risk Assessment

There are three components to completing a risk assessment. The first component consists of identifying the hazard. Hazard identification will pose as the foundation of information found and recommended based on any adverse effects on the at risk groups. The second component is exposure, which determines how much, and by what route the hazard can have on the at risk groups. The last main component is risk characterization, which uses information about the hazard and exposure to determine what type of risk at risk groups may have. In this design, risk is defined as the likelihood of an adverse event to a human following the exposure to a radioactive companion animal.

1. **Hazard**

   A hazard is defined as a substance that has an intrinsic potential to cause adverse health effects on a human or living being. This assessment will consist of two subcategories: hazard identification and hazard characterization.

   a. *Hazard Identification*

      Hazard identification consists of finding the exact substance to which causes the adverse effect in this situation. Radiation is the main hazard in this scenario, however it will be necessary to dissect the components of radiation that are hazardous to humans. The factors that go into identifying this hazard include:

      - Ionizing Radiation
        - Beta Particles
        - Gamma Rays

   b. *Hazard Characterization*

      Hazard characterization consists of the correlation and relationship between the dose of the hazardous material someone is exposed to and the probability of an adverse effect happening. In general, there is not a concrete dose relationship known between radiation exposure and adverse effects. However, there are three main dose-relationship models:

      - Linear-No Threshold
        - This states that any radiation exposure, no matter how small quantitatively, can have adverse effects. This model specifically highlights the ability for radiation to induce cancer.
      - Linear-Threshold
        - This model uses data collected to determine that no effects are seen below a certain threshold. At the threshold is when an increase linear relationship develops between dose and exposure.
      - Linear Quadratic
        - This theory is a generalized model that states that at low levels of radiation exposure the relationship is linear, but at higher doses the dose relationship is quadratic.

2. **Exposure**

   Exposure is defined as how a hazard comes in contact with a target. For this case scenario, a specific exposure situation is highlighted. In order to find the risk of radiation exposure, there first needs to be discussion on methods of potential exposure.

a. **Methods of Exposure**
Determining the methods one could potentially become exposed to a hazard will aid in strategizing how to minimize said exposure. Methods by which a human could come in contact with a radioactive companion animal during an emergency includes:
- External
  - Being in close proximity to the hazard source.
  - Surface contamination on the hazard source.
- Internal
  - Inhalation of excreted contamination.

Concerns will arise in emergency scenarios where specific examples of exposure may not be foreseeable. A human may need to carry the hazardous animal on their lap while evacuating, or they may not have access to properly dispose of excreted urine or feces. These factors are important to note when recognizing the variability and potential dangers of this situation.

b. **Frequency**
Frequency by definition describes the amount of times an exposure event may occur. Frequency is often categorized by the occurrence of an event. In this case an acute exposure would be considered a singular exposure event, a sub-chronic exposure would be considered an event that occurred multiple times, and a chronic event would occur many times over at least ninety days. For the purpose of this discussion, the main concerns are acute or sub-chronic exposures.

c. **Vulnerable Groups**
Humans are the primary at risk group focused on in this discussion. The specific groups that own companion animals undergoing radiotherapy treatments. Subpopulations may include pregnant women, fetuses, and young children- which will be discussed more thoroughly in a later section.

Overview of Radionuclides

A. Iodine- 131

One of the most common types of diseases found in felines is hyperthyroidism. Hyperthyroidism is a disease in which the thyroid produces excessive amounts of the T3 and T4 hormones. In felines, hyperthyroidism can have adverse effects on the metabolism and will need to be cured by a veterinarian. The most recommended therapeutic option to treat hyperthyroidism in felines is radioactive iodine ablation (RIA) treatment. This treatment is a type of radiation therapy that uses the radioisotope Iodine-131. The Veterinary Specialty Center explains the process of the radiation therapy iodine-131 treatment as the following "The I-131 is absorbed and metabolized by the hyperactive thyroid tissue only (even ectopic tissue) and destroys the abnormal hyperfunctioning thyroid cells. The normal cells are suppressed by the hyperactive tissue; therefore they don't uptake the I-131 and are spared. The I-131 does not travel more than 3 mm in tissue so adjacent structures are not affected" (Gelb,Howes and Powers). RIA treatment is non-invasive and a safer method for treating hyperthyroidism in felines compared to the alternatives of undergoing surgery or giving daily pills to the feline.

Due to the fact that Iodine-131 is a radioactive material, there are sets of necessary post-treatment protocols. Cornell University College of Veterinary Medicine has written in-depth, guidelines for those who have a feline undergoing treatment for hyperthyroidism. The most crucial guidelines for the safety considerations of human owners include not allowing the feline to sit or sleep on anyone after being discharged from the vet. Owners should minimize time in close proximity to the animal, and while seldom contact is acceptable, all contact should be minimized. After a week, most healthy adults are able to relax the quarantine and have more contact with the feline. However, pregnant women and young children should avoid contact with the animal, its food dishes, toys and litter for three weeks. (Cornell University)

These guidelines are crucial for the safety of those most at risk to prolonged or higher radiation exposures. These guidelines do create a question of where can the feline sit within a vehicle to evacuate from an emergency situation if there is a person who is pregnant or vulnerable to radiation doses. Furthermore, how will one avoid contact with the feline's objects if they are the sole provider to the animal, due to the fact that the feline will not be able to pack their objects up themselves? Another guideline that Cornell University wrote that is very important for the general public and occupational populations' safety is the following: "Store waste in a well-ventilated space away from your primary living areas, and hold for an additional 2 weeks so natural decay will reduce radioactivity to background levels. Then the litter may be disposed of with normal trash. Landfills do not allow the disposal of low-level radioactive waste and are equipped with sensitive radiation detectors. You may be charged over $1000 if radioactivity is detected in your cat's litter at the landfill. Please use extra care when cleaning the litter box to avoid getting soiled litter on your hands. Use disposable plastic gloves and litter box liners to help prevent contamination. Wash with soap and water after cleaning the litter box. All used disposable gloves should be stored with the waste—treat them as if they are contaminated. Please keep your cat indoors if the cat uses garden areas as a litter box"(Cornell University). In an emergency situation, there is limited access to the materials necessary to keep the population safe from the doses that may come from the waste excreted by the feline. If in a rural area for evacuation, there is a high probability of no running water to wash the hands of the owners. As well as there is normally a crowded area of displaced individuals seeking help due to the fact that it is economically understood that prices of hotels in crisis situations skyrocketed. These crowded areas will contain a lot of single-use materials due to the fact that these are shelf safe and kept for emergency situations. The protocol written in the project must account for the need for owners to take responsibility for their feline waste to protect the people around them from any dose that might be given from the waste. The protocol also needs to take into account, if there shall be a designated area for this waste to be held until it has decayed to a safe level.

B. Cobalt-60

Cobalt-60 is another radionuclide commonly used in veterinary medicine. This radionuclide is generally used as an external source of radiation exposure. This treatment uses a linear accelerator, which delivers an external beam to the patient's treatment area. Cobalt-60 is a great source to deliver high doses to tumors at different depths in the body. Radiotherapy that uses external beams is common in treating humans and animals both due to its effectiveness at reducing the size of malignant tumors, while keeping the surrounding tissue cells unaffected.

However, recent studies have shown that in veterinary medicine, there is a lack of safety considerations regarding proper protocols for canines undergoing Co-60 treatment. Researchers have concluded that ideal guidelines for treatment and post-treatment has not yet been developed. (Correa, 2003). Unlike RIA treatment, there are no set guidelines for post-treatment care, let alone in an emergency situation. There is also no data proved in this article of what the activity of these canines would measure post the treatment of cobalt 60. In an article from Michigan State University and Michigan Agricultural Experiment Station, titled Blood and Tissue Partition of Cobalt 60 in Dogs. The activity of the canines being studied after being injected with cobalt was found to be the following; "Tissue distribution of Co-60. Twelve hours after inorganic Co-60 was injected intravenously a high concentration of Co-60 was found in the liver, intestinal track, kidney, urine and bile. The Co-60 activity in each gram of liver (wet weight) was found to be 23.2 times as much as that found in each milliliter of plasma. The corresponding ratio for the intestinal wall or for the intestinal contents varied between 1.6 and 7.0. For the bladder urine, kidney or bladder bile it was between 1.9 and 3.6. (Lee, and Wolterink). It is clear that there is an activity that is produced within the canine's urine hours post-injection of the cobalt. This is needed to be accounted for when in an evacuation situation.

C. Yttrium-90

Yttrium-90 is also a radioisotope used in veterinary medicine. This source is commonly placed in a capsule and administered near the patient's tumor. Since the half-life of Y-90 is only 2.66 days, this is a safe method to treat tumors deep in tissue, or in sensitive areas of the body effectively, without receiving too much of a dose over a long period of time. This type of treatment is called Brachytherapy, and is used in human patients as well. Although an effective treatment, there should be safety considerations for humans near the animal at time of treatment.

This may raise even more concern for pet owners if there was an emergency, and the animal has a radioactive source implanted in it.

Overview of Radioactive Feline Scenario

Iodine-131 is administered to a feline. The set variables are the following; A large feline is 20 pounds or heavier, a medium feline is 10 to 20 pounds, and a small cat is 1 to 10 pounds. The owner of the feline is 30 years old with no outstanding pre-risk to cancer. The following scenario takes place with three different weights of felines. A wildfire breaks out and evacuation is set in place as the owner is getting the feline home from treatment and needs to leave within the hour. What would the dose be if the ____ size feline sat in the owner's lap for 2 hours?

Dose Calculations

In dosimetry, radioactive sources can be treated as a point, line, or surface. In this scenario, the companion animals are the source and will be best suited as a point source due to radiation being emitted from a single point (the thyroid predominantly) then outward to surrounding areas.

A. Iodine-131

Calculation 1.

$$X_0(R) = \frac{A*G}{R^2}$$

Where:

$X_0(R)$ is the attenuated exposure rate, absorbed dose rate, or dose rate in terms of Roentgen.

A is the source activity =1.9 mci

G is the gamma constant =0.22 mr/h at 1 meter per mci

R is the distance from point source 0.2 meter

$$X_0(R) = \frac{1.9mci*0.22mr/h \text{ at } 1 \text{ m per mci}}{0.2^2 m} = \frac{0.418}{0.04^2} = 2.61 mr/hour \text{ per a meter}$$

B. Cobalt-60

Calculation 2.

$$X_0(R) = \frac{A*G}{R^2}$$

Where:

$X_0(R)$ is the attenuated exposure rate, absorbed dose rate, or dose rate in terms of Roentgen.

A is the source activity =0.35 mSv/GBq per hour at 1 meter

G is the gamma constant =G= 13.2 R-cm^2 /hr-mci

R is the distance from point source 1 meter

A= 0.35 mSv/GBq per hour at 1 meter

G= 13.2 R-cm^2 /hr-mci

$X_0(R) = 0.35\ mSv/GBq/hour\ per\ a\ meter$

C. Yttrium-90

Calculation 3.

Y-90= 0mR/Hr at 30 cm

D. Excreted Concentrations

Another possible method of exposure is through the inhalation or accidental ingestion of excreted materials from the feline. This section includes calculations from a study completed at Louisiana State University (LSU), where felines being treated with I-131 for hyperthyroidism were studied. This study additionally reviewed and physically measured the I-131 concentration in urine and feces sample from six patients. Since physical lab studies were not able to be conducted in this project, these measurements from LSU are helpful in determining the dose one could obtain through the exposure to a feline's excreted waste.

Figure 1.

Table 3.7. Percent activity excreted

	% Activity Excreted								
	1st 24 hours				2nd 24 hours				Cumulative Total
Cat	Litter	Pad	Feces	Total	Litter	Pad	Feces	Total	
1	0.64±0.02	*	0.60±0.02	1.24±0.03	2.71±0.09	*	**	2.71±0.09	3.95±0.09
2	1.58±0.05	*	**	1.58±0.05	3.86±0.12	*	**	3.86±0.12	5.44±0.13
3	1.09±0.03	*	**	1.09±0.03	2.22±0.07	*	0.10±0.00	2.32±0.07	3.41±0.08
4	9.25±0.39	*	0.04±0.00	9.29±0.39	9.51±0.40	*	**	9.51±0.40	18.80±0.56
5	7.50±0.24	0.46±0.02	**	7.96±0.24	8.04±0.26	5.05±0.16	3.45±0.11	16.54±0.32	24.50±0.40
6	4.17±0.13	*	**	4.17±0.13	4.27±0.14	*	1.48±0.05	5.75±0.15	9.92±0.20

Values are reported as the expected value plus/minus its uncertainty.
*Urine-pad activity was measured if visual or tactile inspection indicated the presence of urine.
** Some feline patients did not produce fecal samples throughout the 24-hour period.

Note: From "*Evaluating F aluating Feline Release Criteria F eline Release Criteria Following Iodine-131 Ther ollowing Iodine-131 Therapy For Hyperthyroidism* " by Anthony Davila, 2019, LSU Master's Theses. 5009.

Verification

This section will review and compare annual and hourly dose limits to the findings of the dose calculations. This is essential to determining the risk of exposure in this scenario, and the main goal is to ensure the safety of animal owners and make sure dose limits are not exceeded in such an event.

It is documented in table 2. The data from tangible felines that were given Iodine-131 to treat hypothyroidism that there was a dose detected from each feline. Cat 2 had the highest dose at 2.48 ± 0.1 mR per hour at one meter. This cat is the closest to the hypothetical feline created in the scenario and calculated in calculation 1 which found a hypothetical feline around ten to twenty pounds producing a 2.61 mR per hour at 1 one meter.

Table 1.

Whole Body (TEDE)	5,000 mrem/yr
Any Organ (TODE)	50,000 mrem/yr
Skin (SDE)	50,000 mrem/yr
Extremity (SDE)	50,000 mrem/yr
Lens of Eye (LDE)	15,000 mrem/yr
Embryo/Fetus of DPW	500 mrem/yr
Member of the Public	100 mrem/yr

This table is all of the Occupational Dose Limits that the United States Nuclear Regulatory Commission has set in place.

Table 2.

	2 mR/hr distance [m]		
Cat	Day 0	Day 1	Day 2
1	0.35±0.02	0.31±0.02	0.26±0.01
2	0.48±0.01	0.46±0.01	0.41±0.01
3	0.37±0.02	0.33±0.01	0.32±0.01
4	0.34±0.02	0.31±0.01	0.25±0.01
5	0.46±0.01	0.45±0.01	0.44±0.01
6	0.43±0.01	0.44±0.01	0.39±0.01

Values are reported as the expected value plus/minus its standard error. A pet owner standing this distance from their pet for 1 hour would be exposed to 2 mR.

This table is the data found of six cats that were given radioactive Iodine-131 to treat Hyperthyroidism at the Louisiana State University in 2019.

Risk Assessment

I-131 emits energetic γ-rays that pose an external exposure hazard while the β- particles can cause internal exposures if inhaled or ingested. It can be determined that I-131's preferential uptake in the thyroid along with its biological half-life of 80 days in humans can irradiate the thyroid cells and potentially lead to thyroid cancer. Stochastic effects, such as cancer and genetic modifications, are the main concern of exposure to radiation.

In order to complete the risk assessment, several factors must be identified. The first factor is that radiation, specifically the radionuclide I-131 is the main hazard considered in this scenario. The effects once more are cancer and genetic modifications to those exposed to the hazard. Companion animals often interact with the full spectrum of people with different levels of risk from radiation. The groups most at risk have been identified as a fetus with a pregnant woman and young children. This has been based on previous research that shows that fetuses and children have a higher risk of developing cancers than older people.

As seen in *table 1.* A member of the public has a dose limit of 100 mrem per year. If a member of the emergency veterinary response team interacts with felines that have been doses with Iodine-131 for 5 hours at a 0.2 meter then the person would have reached 13% of their annual dose. When emergency situations arise an emergency response personnel will work days at a time with minimal breaks to evacuate an area. The question of how many felines with an active dose of Iodine-131 will the response team personnel come into contact with. As for pregnant women and fetuses they shall not have any contact with the feline with the active dose, although there is a higher dose limit there are also higher risks that accompany a fetus. The International Commission on Radiological Protection's (ICRP) 84th publication states that " Prenatal doses from most properly done diagnostic procedures present no measurable increased risk of prenatal death, malformation, or impairment of mental development over the background incidence of these entities. Higher doses, such as those involved in therapeutic procedures, can result in significant fetal harm"(ICRP 84). The threshold of dose allowed to pregnant women and fetus is lower than the general public as well as the occupational population. For the purpose of these guidelines, the focus is on the potential implications Iodine-131 has on pregnant women and fetuses. Organization of Teratology Information Specialists (OTIS) from Brentwood Tennessee has a factsheet on mother to baby on Iodine-131. The OTIS states "Iodine-131 is avoided during pregnancy when possible. The developing baby can absorb radioactive iodine into their thyroid starting at about 10 weeks of pregnancy, and this can result in severe thyroid gland damage and thyroid hormone deficiency. Thyroid hormone is very important for the baby's development" (OTIS,2022). This avoidance of Iodine-131 for pregnant women and fetuses include the Iodine-131 that felines excrete and potential surface contamination.

Recommendations

A. Communication with the General Public

In an emergency situation, first responders are often the first contact the general public has and therefore this profession has a significant responsibility to provide assistance and incident resolution. During an emergency, response teams need to assess the situation, understand potential risks, communicate effectively, and provide any guidance they can.

As an emergency responder, it is important to know what actions should be prioritized, and in most cases the first priority always is to ensure that humans are evacuated and brought to safety. In an emergency, there are two concerns responders aim to minimize: physical harm and psychological distress. In this specific scenario, evacuation managers will also need to ensure the long term safety of pet owners by ensuring they use proper care to avoid excess exposure from their animals.

When communicating with the public it is necessary to remember and understand:

- The general public may not have a background that allows them to understand technical jargon.
- In emergency situations, humans undergo psychological behavioral changes that can affect the way they act, focus, or process information.
- Many people feel uncertain about radiation and the potential dangers.
- The majority of pet owners will want to evacuate with their animal, but may not know how to do so safely if their pet is radioactive.

Given these points, an emergency responder should be able to understand the perspective of a disaster victim and use it to communicate more effectively and successfully. Some key dialogue recommendations include:

- Question the pet owner regarding when the pet was discharged from the veterinary hospital.
- If discharge was within 24 hours, know that the animal has a dose that may have adverse effects on a fetus or young child. Follow up asking if anyone is pregnant in the family or if there are any young children.
- If the response is a yes, inform the pet owner that additional safety precautions must be taken.

- Guidance on pet emergency supplies should be revealed, which may include: a plastic cat carrier (as plastic is able to shield beta particles), plastic waste disposal bags, a thick plastic container to hold waste, latex gloves, water, and food.
- Additional recommendations, such as placing the feline as far in the car as possible is recommended, limiting time in the vehicle with the animal, and instructions on how to properly dispose of waste.

B. Use of Personal Protective Equipment.

Personal protective equipment (PPE) is necessary in occupational settings to prevent or minimize exposure to hazards. PPE is commonly used when being near radiation, and is recommended in this case for response teams.

If there is a misunderstanding where a feline has been exposed to a radioactive source, then it shall be treated as a radioactive hazard until proven not exposed for three months post emergency. As seen in table two those who are members of the general population would include those a part of the veterinary response team who have a dose limit of 100 mrem/year. Although as seen in the calculation above the felines excrete minimal amount of radiation compared to this annual dose limits, PPE must be worn by the veterinarian response team, to protect from overexposure to radioactive sources in a year due to the fact that each individual get active doses through medical scans, different foods, background doses from the planet. To ensure that the members of the Veterinarian response team remain under the NRC annual dose limits they shall wear PPE while handling radioactive felines and the environment around them. Those who encounter a feline that has been treated by 1-131 shall wear proper PPE when handling the animal and their feces and urine and their used water.

The PPE that shall be worn include; high rubber boots or waiters, N-96 or N-95 mask and face shield to protect the lens of the eye from radiation. A key PPE that shall be worn are nitrile gloves when handling food and water that have been partially obtained by the radioactive feline and fabric gloves to protect from bites to the skin. The members of the response team shall wear long sleeves and long pants, the clothes shall be washed with a radioactive decontaminant spray foam and then washed with tap water before washed in a washer machine. While in the field for the duration of the emergency any worn clothes shall be sprayed with radioactive decontaminant spray foam and then bagged until tap water and washer machines become available after the emergency. If a member of the response team has an open wound or cut they shall not handle the radioactive feline. As for urine and feces the ideal situation would allow for those on the response team to follow the set protocol from Cornell University which includes “Store waste in a well-ventilated space away from your primary living areas, and hold for an additional 2 weeks so natural decay will reduce radioactivity to background levels. Then the litter may be disposed of with the normal trash. Landfills do not allow the disposal of low-level radioactive waste and are equipped with sensitive radiation detectors. You may be charged over $1000 if radioactivity is detected in your cat's litter at the landfill.Please use extra care when cleaning the litter box to avoid getting soiled litter on your hands. Use disposable plastic gloves and litter box liners to help prevent contamination. Wash with soap and water after cleaning the litter box. All used disposable gloves should be stored with the waste—treat them as if they are contaminated"(Cornell University). If these items are not available or there is limited access due to the emergency then the waste shall be placed in bags and then left outside away from any humans and food sources until the emergency has passed to a level that the waste can be disposed of effectively along with all used PPE.

Once the emergency has passed and the animal is returned to the owners the emergency response team will be responsible to clean the physical holder, and food and water bowls that have been used by the radioactive feline. The physical items shall be washed with water, soap and then sprayed radioactive decontaminant spray foam and whipped out then set out to dry for a minimum of three months post exposure to the feline. The tap water used to clean the items from I-131 will undergo osmosis which will take out any I-131 that is placed into the water system. The water that has been used shall not be placed in grass or any environment areas. If cell phone service is available then any questions that are not addressed in this protocol shall be directed to the NRC about radioactive materials and the radioactive animal.

As those who work with the radioactive felines as the veterinary response teams they must understand and agree that they will obtain a dose within the limit given by the feline. No pregnant professionals shall be exposed to felines with an active I-131 feline and shall focus their abilities on different efforts during the emergency. The fetus shall not be exposed to any I-131 radiation as explained in the risk assessment.

Conclusion

This design project aimed to inform and equip emergency veterinary response teams of the potential risks associated with evacuating a radioactive companion animal. Through a detailed analysis, responders were informed of the gaps in current procedure for radioactive animals during an emergency evacuation. Review of commonly used radionuclides was provided, where it was concluded that the isotope Iodine-131 posed the largest risk of exposure after being discharged. Iodine-131 is drawn to the thyroid, which could potentially lead to an increased risk of thyroid cancer in at risk groups. Then, dose calculations were done which focused on the primary methods of exposure routes: external and internal. The largest elimination pathway in felines is through urine, which has the highest percentage of radioactivity. Through the progression of this project, it has been concluded that there is a risk associated with exposure to I-131 via contact with radioactive companion animals, during an emergency situation.

Once provided with essential background knowledge, responders were provided with recommendations on how to effectively communicate with the general public about risk and items to be used as personal protective equipment.

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