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Case report: PET imaging of dog exposed to artificially created search and rescue setup contaminated with FDG

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Abstract

Environmental contamination with radioactive material can lead to internal radioactive contamination, which occurs when radioactive material is taken into the body through inhalation, ingestion, and/or transfer through the skin. Urban search and rescue dogs (USAR) used as part of an emergency response team may be susceptible to internal radioactive material contamination under such working conditions. The exact routes and bio-distribution of such internal radioactive contamination within the body as well as the risks posed to these dogs have not been studied in depth. This research describes the purposeful exposure and examination of a canine to a radioactive contaminated environment. A scene was created to replicate a post-disaster scenario followed by introduction of the dog to the scene. After exposure to the contaminated environment, the canine was then imaged using PET/CT to quantify internal and external contamination on and within the body. Radioactivity was mainly external, limited to the paws as well as around the mouth, esophagus, and stomach due to ingestion. There was minimal or no radioactivity associated with inhalation. Since this study includes only a single test subject, further studies with large sample size would be needed to validate these results as well as test environments with higher concentrations of radioactive material, and include the use of different long and short-acting radioisotopes.

Keywords

radioactive; contamination; imaging; PET/CT; FDG; exposure

Abbreviations

CT: Computed tomography; ECG: Electrocardiogram; FDG: 18F-Fludeoxyglucose; IACUC: Institutional animal care and use committee; PET: Positron emission tomography; ROI: Region of interest; SUV: Standard uptake value; USAR: Urban search and rescue

Introduction

Radiation accidents that result in radioactive material being released into the environment can cause varying amounts of exposure and contamination in humans and animals [1-3]. Radioactive contamination occurs when material that emits ionizing radiation is deposited in any place where it is not intended [1]. Surface radioactive contamination could possibly lead to internal contamination, which occurs when radioactive material is taken into the body through inhalation, ingestion, and/or transfer through the skin [4,5].

Urban search and rescue (USAR) dogs are a critical emergency response component to saving lives after a destructive event. Search and rescue areas that contain radioactive material can result in USAR dogs working in such environments to be exposed to surface radioactive contamination, possibly leading to internal contamination. No study has been able to document the exact routes and bio-distribution of internal radioactive contamination under working conditions. Previous research has focused on sedated canines exposed to radioactive aerosols for morbidity and mortality of the animal and how it relates to humans [5,6].

This case report describes an artificially created search and rescue environment that resulted in a dog being contaminated with 18F-Fludeoxyglucose (FDG). Following the contamination, Positron Emission Tomography (PET) imaging was employed to accurately assess the extent of external and internal contamination, as well as the distribution of radioactivity within the dog's body. Prior to this study it was hypothesized that the dog exposed to FDG contamination would have significant internal contamination from the external environment via inhalation, ingestion and skin absorption.

Case Presentation

FDG contaminated room setup and materials used

In order to create a rubble pile within the room, a 3.05 m by 3.05 m (10 ft by 10 ft) area was filled with different items such as a rubber ball, four car tires, a plastic rubbish bin, paint bucket, storage container, child's play pool, drainage pipe section, three crates, and a cat carrier. Scented food containers and boxes as well as crushed kibble were also added to the pile in order to create a deeper desire in the dog to explore and sniff. Please refer to Figure 1 for the setup of the room. The study also utilized corn starch to simulate the typical air and ground environment during a search and rescue. About 100 grams (1 cup) of corn starch was applied to the entire area using a hand pump garden duster with a fan tip. The garden duster aerated the corn starch, so that it created puffs of dust that then fell and coated the debris pile.

FDG was used to create a simulated contamination environment. FDG was used because it is currently the standard radiotracer employed for PET neurological and oncological imaging [8]. FDG was chosen due to the half-life of 109.6 minutes, which allowed for sufficient time for exposure and scanning. FDG was acquired from Cyclotope, Houston. Approximately 5.419 mCi of 18F was mixed with 473 ml of water in a hand-pumped weed sprayer with a misting tip for 60 seconds and sprayed for 109 seconds over the entire area of the pile and its objects. After spraying, the rubble pile was left to dry to ensure the pile had a layer of corn starch that could potentially be inhaled. After 37 minutes moisture was no longer visible on the pile, and the dog and handler were free to enter. The dog and the handler spent a total of 9 minutes and

22 seconds inside the contaminated area, after which the canine began to show a desire to leave the room.

Animal details

A 6-year-old male Labrador retriever weighing 33 kg was used for this study. The animal underwent a physical exam with biochemical analysis (complete blood count, chemistry profile, and urinalysis), chest radiographs, and an electrocardiogram (ECG) prior to the study to ensure the animal was healthy and able to undergo full anesthesia.

Anesthesia protocol

Animal was fasted for approximately 12 hours overnight prior to anesthesia. An IV catheter was placed in the cephalic vein and covered for protection. Following contamination of the room used to create the radioactive environment, the dog was allowed to freely explore the contaminated area for 9 minutes and 22 seconds. Following the allowed time in the contaminated area, the animal was then given a 0.2 mg/kg intravenous dose of the sedative Butorphanol followed by a 6 mg/kg intravenous dose of Propofol and intubated for mechanical respirations. The animal underwent positron emission tomography and computed tomography (PET/CT) imaging under general anesthesia in ventral recumbency. This study was reviewed and approved by the Texas A&M University's Institutional Animal Care and Use Committee (IACUC).

Imaging

PET/CT scans were obtained on the 128-slice Siemens Biograph mCT scanner (Siemens Healthineers, USA) located at Texas A&M Institute for Preclinical Studies (Texas A&M University). Following a localizer tomogram, a non-contrast CT (for attenuation correction of PET images) was performed. A PET scan was then obtained over a period of 28 minutes with 3.5 minute scan duration per bed. Following this, a post contrast CT after administration of 50ml of intravenous iodine-based contrast iohexol (Omnipaque 300; GE Healthcare AS, Oslo, Norway) was performed. Parameters for the CT images were 120kV and 120mAs with slice thickness of 5.0mm and acquisition window of 32 x 1.2mm. Post processing of the images was performed on the Siemens Syngo PET/CT workstations (Siemens Healthineers, USA) as well as Siemens Inveon Research Workplace software (Siemens Healthineers, USA).

The standard uptake values (SUV, unit of measurement of radioactivity) for areas throughout the body were calculated by drawing regions of interest (ROI) of similar volumes over several representative areas. The basic expression for SUV is

$$\mathrm{SUV} = \frac{r}{\left(\frac{a'}{w}\right)}$$

where r is the radioactivity concentration [kBq/ml] measured by the PET scanner within a ROI, a' is the decay corrected amount for the radiolabeled FDG [kBq], and w is the weight of the animal [g].

Results

SUVs of several representative areas are seen below in Table 1. Radioactivity was significant on the front and hind paws as well as within the stomach. The radioactivity was mainly external, limited to the paws only (Figure 2) with no signs of skin absorption. SUVs of the paws were: right front paw, 3.803; left front paw, 2.804; right hind paw, 3.294; and left hind paw, 3.410. There was also considerable ingestion of radioactive material, with activity seen around the mouth, esophagus (Figure 3), and stomach (Figure 5) with SUV values of 0.125, 0.647, and 3.510, respectively. Since the study was done soon after exposure, radioactivity was not expected to be seen in the rest of the bowel. There was also not significant activity seen within the airways to suggest considerable inhalation and none seen within the heart (Figure 4). SUV of the lungs was 0.000 and trachea was 0.018.

Table 1: Illustrates the SUV values calculated in representative organs/tissues in the body as a measure of radioactivity.

Location	Standard Uptake Value (for body weight)
Right front paw	3.803
Left front paw	2.804
Right hind paw	3.294
Left hind paw	3.410
Around mouth	0.125
Esophagus	0.647
Stomach	3.539
Trachea	0.018
Right lung	0.000
Left lung	0.000
Liver	0.008
Spleen	0.000
Left kidney	0.006
Right kidney	0.000
Bladder	0.002

Figure 1: Photo showing the set-up of the rubble pile that was contaminated during this experiment. It consists of everyday items such as trashcans, tires, and a swimming pool.

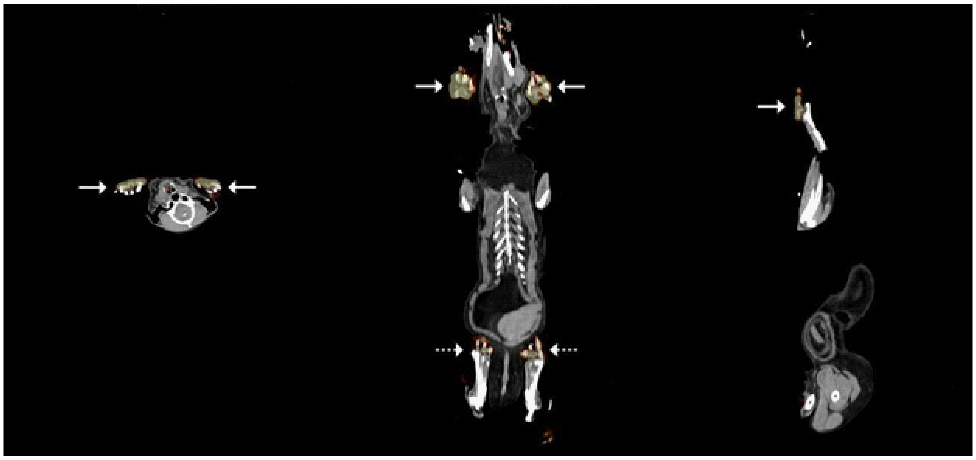

Figure 2: Axial, coronal and sagittal PET/CT images showing radioactivity in the front (arrows) and hind paws (dashed arrows).

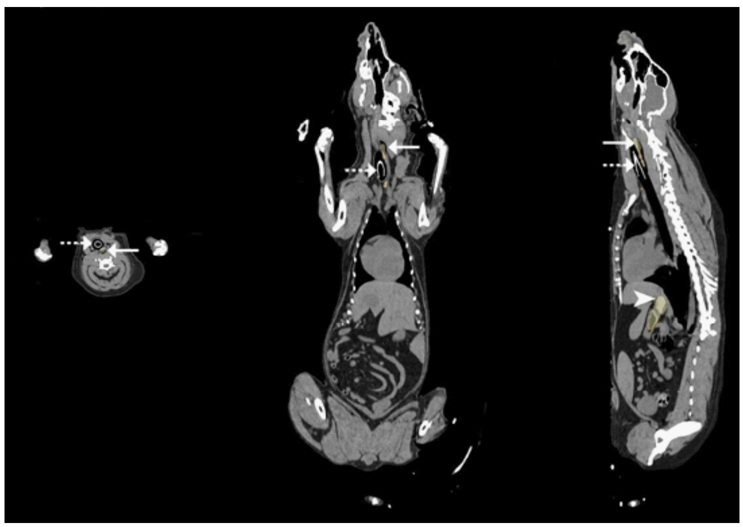

Figure 3: Axial, sagittal and coronal whole body PET/CT images show radioactivity within the esophagus (arrows) and stomach (arrowhead). No significant radioactivity is seen within the trachea (dashed arrows). Endotracheal tube is seen within the airways.

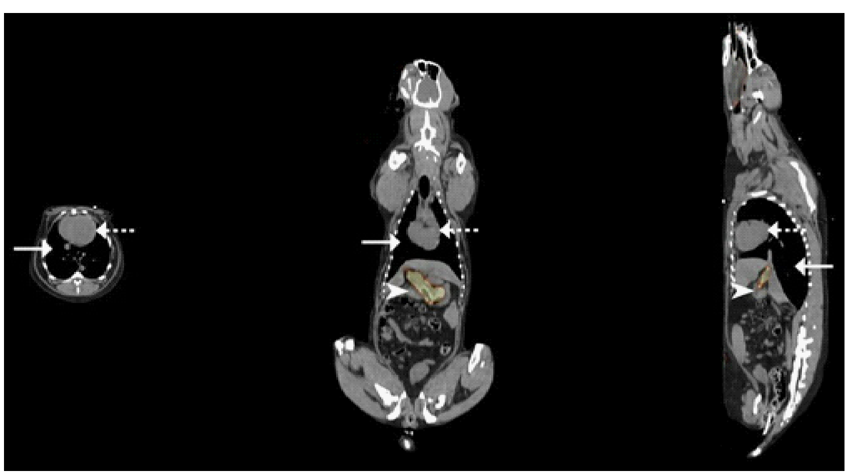

Figure 4: Axial, sagittal and coronal whole body PET/CT images show significant radioactivity in the stomach (arrowheads) and no significant radioactivity seen within the heart (dashed arrows) and lungs (arrows). Endotracheal tube is seen within the airways.

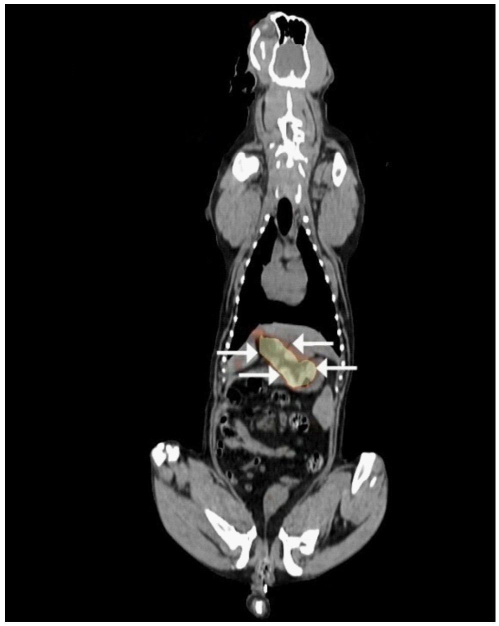

Figure 5: Coronal PET/CT image showing radioactivity in the stomach (arrows).

Discussion & Conclusion

In this study, it was possible to create a radioactive contamination scenario in a controlled environment. This is the first such case report of having created such a scenario with FDG and measured internal radioactive contamination in a canine model.

The purpose of setting up such an exposure setting was to understand the resulting routes of external and internal radioactive contamination and its distribution within the body. Studies have looked at radioisotope absorption into the human body with naturally occurring [1-3] or accidental [10] radiation exposure, or the use of point photon radiation sources [7], but these studies have not involved creating an artificial contamination setup to mimic a radiation disaster. A similar study was conducted that purposefully contaminated dogs through direct inhalation of a radioisotope [11] but did not take into account other routes of contamination including ingestion and skin absorption.

In terms of the techniques of measuring internal contamination, dosimetry has been used most widely to predict radiation absorption doses in an individual [9,12,13]. However, calculations of internal radiation contamination can be complex and vary by radionuclide, each source having its unique decay mechanisms, energy emissions and distribution patterns [15-19]. PET imaging, an accurate modality used to measure internal radioactivity in the different organs both quantitatively and qualitatively, is a far simpler option to accurately assess the route and bio-distribution of internal radioactive material contamination. A similar case report used a PET gamma camera to image the bio-distribution of radioactivity in an accidental contamination with FDG of a human [10].

This study showed the likely routes of radioactive contamination and the likely organs that radioactivity would be distributed to in the event of internal contamination. Knowledge that ingestion can pose a risk of internal contamination for the canine, can lead to recommendations such as keeping the dog well fed and hydrated while working, in order to mitigate a canine's desire to eat and drink while on the pile.

External contamination can also be reduced by utilizing canines that are trained to wear protective gear, or utilizing appropriate decontamination procedures focusing on the paws of the dog (or anywhere else that comes into constant and direct contact with radioactive contamination). While ingestion and inhalation are known to be potential exposure routes for radioactive contamination in humans and animals, there has not been a study to document that ingestion is a major route of exposure so this case report aims to establish that possibility. At the same time, if proven in larger numbers, the lack of significant internal contamination through inhalation is also crucial in determining the type of protective equipment that would aid dogs entering such search and rescue areas.

Although the artificial creation of a FDG contamination scene is unique in this case report, it can be easily recreated with this widely used isotope to confirm these results. With a larger sample size in the future, this study could be broadened to test higher radioactive doses of FDG, and include the use of different radioisotopes, both short and long acting, as well as vary physical factors in the contaminated room setup and correlate PET and dosimetry findings, to obtain a better understanding of the routes of contamination and bio-distribution as well as the implications on the animal's health status. This information can then be used to better protect both canines and humans involved in rescue operations in setups dealing with radioactive contamination.

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