学位論文要約

External exposure to persons involved in small animal veterinary nuclear medicine in Japan

日本国内の小動物の核医学検査における放射線診療従事者と飼い主に対する外部被ばく

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Nowadays, there are a few studies concerning occupational radiation exposure to veterinary staff, and no specific studies have been reported for an animal owner or public exposure. In Japan, Kitasato University Veterinary Teaching Hospital (KUVTH) is the only hospital that performs Veterinary Nuclear Medicine in dog and cat. Using Technetium-99m (^{99m}Tc) and ^{18}F-fluorodeoxyglucose (^{18}F-FDG) are the most widely used radioisotopes in diagnostic nuclear medicine. Rules of quarantine after using radioisotope are not currently standardized within the veterinary community. According to Japanese legislation, administering ^{18}F-FDG and ^{99m}Tc dose under 150 MBq need to quarantine the patient for 24 hours after injection. Disadvantages to this restriction include prolonged extra hours of detention in hospital after injection, increased procedural cost, and increased equipment and room use. Therefore, the purpose of the present study was to investigate the character and quantity of radiation dose rate near a radioactive animal patient, the relationship of position and distance between animal and veterinary staff, rationale to quarantine 24 hours period in the hospital, and the risk assessment of pet owners.

The present study is divided into three chapters. The title of each chapter is as follows; Chapter 1: External exposure of veterinary staffs and pet owners from feline ^{99m}Tc-MAG3 renal scintigraphy, Chapter 2: Effects of sedation on radiation external exposure in veterinary staffs under feline renal scintigraphy, Chapter 3: External exposure to veterinary staffs and pet owners from ^{18}F-FDG Positron Emission Tomography.

Chapter 1: External exposure of veterinary staffs and pet owners from feline ^{99m}Tc-MAG3 renal scintigraphy

Twenty-eight cats, age 5.7 ± 3.2 years with body weight 4.1 ± 0.86 kg, were grouped into a healthy normal control (C; n = 8) and renal patients (R; n = 20). Cats were performed ^{99m}Tc-MAG3 renal scintigraphy (93-141 MBq/head) for 20 minutes under sedation with Alfaxalone. A semiconductor survey meter was used for measurements a surface dose rate (SDR) from body locations of the head, thorax, and abdomen and the ambient dose rate (ADR) at 50 cm and 100 cm distances within at post-scanning, during the daytime when the veterinarian checked physical examination (at least 2 times), and 24 hours after injection. The estimated dose rate was calculated by the decay correction of ^{99m}Tc physical half-life (6.01 hours).

The SDR after scanning from the abdomen, range 122 to 368 μSv/h, was significantly greater than thorax and head in both C and R which the SDR of thorax and head of R was significantly higher than C ($p < 0.05$). ADR demonstrated a significant decrease up to about 100-fold by keeping a distance from the patient at 100cm. The SDR-time course followed within the degradation curve with a physical half-life (6.01 h) and all cats showed SDR was less than 115 μSv/h in 24 h post-injection, where cumulative SDR till infinity was less than dose limit to the public of 1mSv. Urination had a conspicuous effect on SDR at 24 h (0.38-10 μSv/h) and all urinated cats showed less than 1/10 of the limit of the yearly external public exposure. There is an overregulation of 24 h detention time after MAG3 injection and detention criteria should base on the maximum SDR for each patient.

Chapter 2: Effects of sedation on radiation external exposure in veterinary staffs under feline renal scintigraphy

Patients which have severe renal impairment, are considered handling and restraint techniques during ^{99m}Tc-MAG3 renal scintigraphy (93-141 MBq/head) for 20 minutes. This method is no recovery time but requires close monitoring of animals immediately after the MAG3 injection until scanning completed. On the other hand, the sedation procedure allows the veterinarian to remote monitoring and close contact with a radioactive patient after scanning during the recovery period. The study is to investigate the difference in radiation dose received in different working patterns. Thirty-three cats with kidney disease problems were performed renal scintigraphy, age was 6.4 ± 3.5 years with bodyweight 3.8 ± 0.82 kg, which cats with weak body condition were grouped into a non-sedated cat (N; n = 6, average Cr 13.4 ± 7.7 mg/dl) and renal patients under sedation with Alfaxalone (1 mg/kg IV bolus, followed by continuous infusion, 0.1 mg/kg /min), under ECG monitoring (S; n = 27, average Cr 3.3 ± 3.5 mg/dl). The SDR and ADR measurement as described in Chapter 1.

The highest SDR post-scanning was abdominal surface, followed by thorax and head in both N and S. There was no significant difference in SDR of the abdomen and head between N and S. Significant higher dose rate from thorax was observed from N than S ($p < 0.05$). The average working time and the cumulative occupational radiation dose/case in N were significantly greater than S ($p < 0.05$) which average working time was 30 ± 6.2 min and 13 ± 6.9 min and the estimated cumulative dose/case from 50 cm distance was 4.8 ± 0.9 μSv and 1.6 ± 0.7 μSv in N and S, respectively. The sedation method has the effect of reducing time to close contact with animals under renal scintigraphy that resulted in a 3-fold decreasing radiation dose to staff who close proximity to the patient, compared to the restraint method.

Chapter 3: External exposure to veterinary staffs and pet owners from ^{18}F-fluorodeoxyglucose (18F-FDG) Positron Emission Tomography

^{18}F-FDG is a commonly used oncologic PET tracer that emitted two coincident 511 keV annihilation photons associated with positron decay (109.8 min half-life of ^{18}F). Occupational exposure to veterinary staff needs to concern along with the sequence of the protocol. 14 Patients were divided by body weight and species type into 3 groups: large dog ≥ 20 kg (L, n = 3), small dog < 20 kg (S, n = 7), and cat (C, n = 4). There are 2 working methods. Method 1 (M1) can be divided as follows:

injecting FDG (116-242 MBq/head), putting the animal in low-light, quiet small cage and waiting for ^{18}F-FDG uptake period (approximately 60 min), sedating animal and moving to scan table, performing PET scan and remote monitoring in another room. Method 2 (M2) is performing general anesthesia and FDG injection and start PET scan immediately. Dose rate measurements were performed post-scanning as described in Chapter 1.

The Abdomen was the highest SDR compared with the thorax and head in S and C ($p < 0.05$). There was no difference among 3 parts of the body surface in L. Three parts of SDR, ADR of 50 cm and 100 cm distances were significantly higher from C and followed by S, and L, respectively ($p < 0.05$). Although the advantages of M1 were shorter sedating time (51 ± 16 min) and reducing the procedural cost, the staff was close proximity to the patient 3 times, injecting FDG, sedating method (7.3 ± 3.3 min), and recovery period post-scanning (34 ± 30 min). The advantage of M2 was close proximity to the patient 2 times at injecting FDG, and recovery period (47 ± 32 min) which prolonged extra hours of anesthesia under PET scan (2.8 ± 0.3 hour). The estimated cumulative dose of S from M2 decreased up to 2-fold radiation dose compared with S from M1. All cases showed SDR was less than 1 μSv/h in 24 hours post-injection which is overregulation of 24 hours detention time.

Conclusions; Japan legislation as to 24 hours detention time in Veterinary Nuclear Medicine is overregulation for both ^{99m}Tc and ^{18}F-FDG. Body weight, body location, distances, reducing time close proximity to animals by using sedative drugs, and the work patterns have a significant effect in reducing the radiation dose to veterinary staffs in both PET and renal scintigraphy procedure. Radiation dose from FDG PET was higher than scintigraphy. Urination had a large effect on decreasing radiation dose in scintigraphy. This study can be used to consider radiation safety practices in veterinary nuclear medicine to veterinary staffs and pet owners or public.