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Evaluation of radiation exposure from fluoroscopic examination in small animal veterinary staff using thermoluminescent dosimeters

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Abstract: The purpose of this study was to evaluate the occupational radiation exposure levels of veterinary staff during fluoroscopic examination using thermoluminescent dosimeters (TLDs). A prospective study was conducted to measure radiation doses in three positioned persons (two restrainers and one observer) using TLDs. The TLDs were placed on the inside and outside of the lead-equivalent protective devices of the panorama mask, thyroid shield, apron and arm shield. The TLDs were placed at five anatomic sites (eye, thyroid, breast, gonad and hand). Radiation exposure was measured in 65 fluoroscopic examinations at 80 kVp and 100 mAs. The doses (mSv) (outside/inside the shield) measured in restrainers A and B and observer C were 3.09/0.59, 3.80/0.65 and 0.63/0.44 in the eye; 2.20/0.73, 1.88/1.10 and 0.79/0.45 in the thyroid; 3.42/0.44, 3.94/2.35 and 0.61/0.34 in the breast; 1.84/0.45, 1.69/0.23 and 0.46/0.36 in the gonad; and 5.56/3.16, 8.29/2.99 and 0.79/0.34 in the hand, respectively. Out of all the lead protection devices, the radiation dose of the hand was the highest in all three participants, with the thyroid radiation dose value being the same as the hand in the observer C. Radiation doses received by the eyes of all three participants were also not negligible. Veterinary workers exposed to radiation through not only radiography but also fluoroscopy should wear protective gear, especially for the eyes.

Keywords: eye exposure; radiation exposure; thermoluminescent dosimeter; small animal; fluoroscopy

Fluoroscopy is a device that uses X-rays to provide real-time images. In small animal clinics, fluoroscopy is used for interventional procedures or diagnostic purposes. Fluoroscopy is considered the gold standard in the diagnosis of conditions such as tracheal collapse (Macready et al. 2007), dysphagia (Pollard 2012) and oesophageal diseases (Levine et al. 2014). When fluoroscopy is used with a contrast medium, anaesthesia should be avoided in the patient due to the inherent alteration in swallowing function and the risk of aspiration pneumonia (Pollard 2012). When using a contrast medium, the presence of restrainers is an absolute requirement. Restrainers are exposed to scatter radiation during fluoroscopy and the long examination time increases the radiation dose.

Several studies have been performed on the radiation exposure of restrainers in veterinary medicine (Wagner et al. 1994; Lindell 1996; Nikolic et al. 2000; Vano et al. 2008; Dendy and Heaton 2011; Barber and McNulty 2012; Canato et al. 2014; Oh et al. 2018). The International Commission on Radiological Protection (ICRP) has released recommendations on the maximum annual occu-

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pational radiation dose. Although the use of protective equipment has become commonplace due to an increased appreciation of radiation exposure risk, the use of protective equipment still varies depending on various factors such as the presence of a supervisor and the category of staff. Further, differences have been reported in the use of various protection devices; there was a low rate of use described for leaded eyeglasses and a high rate described for the protective apron (Mayer et al. 2018).

The biological risk of radiation exposure can be divided into stochastic and deterministic effects. The stochastic effect is DNA damage by radiation exposure; if a normal cellular repair mechanism fails to repair the damage, it can lead to increased risk of oncogenesis or a genetic problem (Lopez et al. 2018). The deterministic effect is the harmful tissue reaction to high radiation doses above the threshold, such as cataracts caused by radiation exposure (Merriam and Worgul 1983). To the authors' knowledge, there has been no direct study of the radiation exposure of veterinary restrainers during fluoroscopy. Thus, in the present study, we discuss the actual risk of exposure by directly presenting the radiation exposure levels experienced by the restrainers according to specific body parts. In addition, we compared the radiation dose differences inside and outside of the protective gear to determine the effectiveness of the radiation protection equipment; we assumed that the dose measured inside the protective equipment represented that received by the workers' bodies.

MATERIAL AND METHODS

This prospective study was approved by the Animal Care and Use Committee of Chonbuk National University (CBNU-2018-00186) and was conducted in Chonbuk Animal Medical Centre over the course of nine months (from January, 2017 to September, 2017). Included experiments were any procedures involving fluoroscopy over the study period, regardless of the reason for the examination. Patients who were not cooperative or in a critical state were excluded from the study. For every fluoroscopy examination, the duration of radiation exposure time was recorded.

The fluoroscope used for this study was the NL Integris H00G (Philips, Amsterdam, Netherlands). Five major body parts were selected as points to measu-

Figure 1. Picture showing the positions of the two restrainers and the observer. Restrainer A was near to he cathode (–) and restrainer B was near to the anode (+) of the X-ray tube. The observer was 150 centimetres from the X-ray tube (C)

re the radiation exposure of the participants, specifically the eye, thyroid, breast, gonad and hand. The participants consisted of two restrainers and one observer. The restrainers held the patients' forelimbs and hindlimbs during the examination,

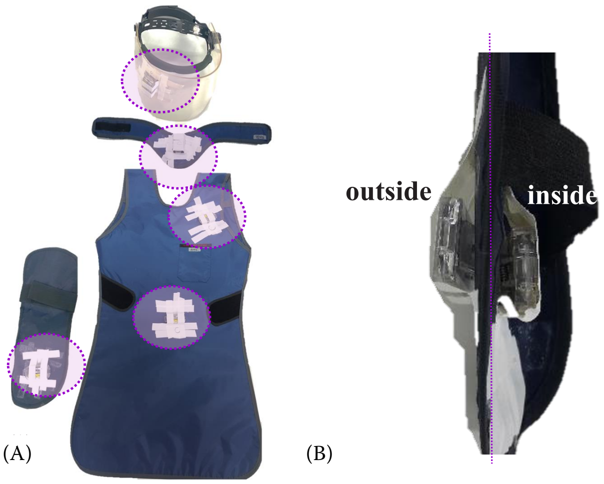

Figure 2. Picture (**A**) shows the lead protective devices. Lead mask, thyroid shield, apron and hand shield with location marker where the TLDs were fixed. (**B**) shows the TLDs fixed to the inside and outside of the protective devices

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Figure 3. An example of a thermoluminescent dosimeter used in this study

with restrainer A near to the cathode and restrainer B near to the anode of the X-ray tube. The observer was 150 cm away from the X-ray tube (Figure 1). All experiments were conducted by the same three people in the same roles.

Four types of radiation protective equipment were used: a panorama mask (400PSM, Protech Medical Co., Florida, United States), thyroid shield (PA09-2, Longkou double eagle medical device Co., Shandong, China), leaded apron (PA07, Longkou double eagle medical device Co., Shandong, China) and arm shield (MSLRS03, Guangzhou Medsinglong Medical Equipment Co., Guangzhou, China). The Pb equivalents were 0.10 mm for the panoramic mask and 0.35 mm for the thyroid shield, apron and arm shield (Figure 2).

The radiation exposure measuring equipment consisted of a series of badge-type_thermoluminescent dosimeters (TLD, UD-802AS, Panasonic Co., Osaka, Japan) composed of lithium borate elements and calcium sulfate elements (Figure 3). The TLD was attached using an adhesive plaster tape on the inside and outside of the protective equipment. The exact locations were the panoramic mask eye position, the centre of the thyroid shield, the chest and gonad areas of the lead apron and the hand area of the open palm-type arm shield (Figure 2). All the TLDs used in the experiment were calibrated and supplied by a radiometer-specialised company (Orbitech Co., Seoul, Republic of Korea), and the TLDs were collected every three months and sent to the same company. The company used an automatic TLD reader (UD-716AGL; Panasonic Co., Osaka, Japan) to measure the accumulative radiation dose for the period. The TLD reader calculates the cumulative radiation exposure using the unique element correction factor for each TLD stored in the database and a calibration dosimeter for which residual irradiation is eliminated according to the TLD system heating profile condition.

Participants in the exposure study were fully aware of the risk of radiation exposure and agreed to undergo exposure. Although only two restrainers should be included in a procedure according to the As Low As Reasonably Achievable principle, a third person is often involved in operating the machine or injecting contrast medium during the actual filming so the radiation exposure rate of the observer was also measured.

RESULTS

Over a period of nine months, a total of 65 exposures and 7630 sec were accumulated. The average exposure time was 117 sec (45 sec to 310 sec) per examination. All 65 patients were dogs (31 Maltese, 17 Yorkshire Terriers, 8 Labrador Retriever, 2 Golden Retriever, 3 Shih Tzu, 4 mixed breed) and the mean body weight of the patients was 4.52 kg. Fluoro-scopy examination was performed under conditions of 80 kVp and 100 mAs. From the procedures, 81.5% (53/65) of the examinations were plain fluoroscopies for the diagnosis of tracheal col-

Table 1. Cumulative equivalent doses (mSv) for each body part and the average in each participant over the study period

Body part	Restrainer A (–)		Restrainer B (+)		Observer	
	outside lead protection	inside lead protection	outside lead protection	inside lead protection	outside lead protection	inside lead protection
Eye	3.09	0.59	3.80	0.65	0.63	0.44
Thyroid	2.20	0.73	1.88	1.10	0.79	0.45
Breast	3.42	0.44	3.94	2.35	0.61	0.34
Gonad	1.84	0.45	1.69	0.23	0.46	0.36
Hand	5.56	3.16	8.29	2.99	0.79	0.34

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Table 2. Reduction (%) of the radiation dose when using protective gear

Body part	Restrainer A	Restrainer B	Observer
Eye	80.91	82.89	30.16
Thyroid	66.82	41.49	43.26
Breast	87.13	40.36	44.26
Gonad	75.54	86.39	21.74
Hand	43.17	63.93	56.96

lapse, 18.5% (12/65) were contrast-enhanced video fluoroscopies for the diagnosis of dysphagia and oesophageal abnormalities. The cumulative radiation doses (mSv) (outside/inside the shield) measured in restrainers A and B and observer C were 3.09/0.59, 3.80/0.65 and 0.63/0.44 for the eye; 2.20/0.73, 1.88/1.10 and 0.79/0.45 for the thyroid; 3.42/0.44, 3.94/2.35 and 0.61/0.34 for the breast; 1.84/0.45, 1.69/0.23 and 0.46/0.36 for the gonad; and 5.56/3.16, 8.29/2.99 and 0.79/0.34 for the hand, respectively (Table 1). Overall, in all participants, cumulative radiation dose outside the lead protection was highest in the hand.

The radiation reduction ratio (%) of protective equipment was calculated by comparing the radiation dose inside and outside the protective equipment (Table 2). The radiation reduction ratio measured in restrainers A and B and observer C were the 80.91, 82.89 and 30.16 in the eye; 66.82, 41.49 and 43.26 in the thyroid; 87.13, 40.36 and 44.26 in the breast; 75.54, 86.39 and 21.74 in the gonad; and 43.17, 63.93 and 56.96 in the gonad, respectively.

DISCUSSION

The cumulative radiation dose for the study period was converted from nine months to one year to allow comparison with the annual dose recommended by the ICRP. For the hand of restrainer B, which showed the highest equivalent dose outside lead protection, the annual average was 11.05 mSv, which is only 2.21% of the ICRP annual radiation dose recommendation (500 mSv). Compared to other body parts, the radiation dose of the hand inside the protective gear of the restrainers was high, which was probably due to the scattered radiation that could reach inside the open palm-type arm shield. According to the results of this study, it was predicted that the closer the body part is to the table, the greater the radiation dose is because of scattered radiation. However, this did not apply to the thyroid. This may be due to the thyroid shield overlapping with the apron in the restraint position. In other words, the loose-fitting protective gear worn by restrainer B could be linked to the lower dose reduction for the breast and thyroid.

Additionally, the calculated value of the radiation dose for the eye outside the shield in the present study was 25% of the recommended annual dose for the lenses of the eyes which is 20 mSv/year (Stewart et al. 2012). Even though this is less than the cumulative value for one year recommended by the ICRP, this dose should not be ignored because of the principle of optimisation. Both the present study on radiation exposure of fluoroscopy and a previous study of radiation exposure in digital X-rays (Oh et al. 2018) showed significant radiation doses in both eyes.

The radiation dose outside and inside the protective equipment of the observer were not significantly different and both yielded very low values. In order to check the effectiveness of the equipment, the value of the observer's radiation reduction ratio was excluded. The average radiation reduction rate of protective equipment for the two restrainers was 81.9% for the eye, 54.2% for the thyroid, 63.7% for the breast, 81.0% for the gonad and 53.5% for the hand. Radiation protective equipment was found to be most effective for the eyes.

The limitation of this study is that it was performed in a teaching hospital. In this study, the frequency of exposure was approximately two times a week. Although the frequency and usage patterns may be different in small clinics, the frequency and time of use in clinics can be compared with the data provided in this paper to determine if there is less or more radiation exposure.

A study of radiation exposure in restrainers and observers to digital X-rays (Oh et al. 2018) showed that the radiation dose for the eye was the highest in all participants. A study on the usage rate of personal protective equipment under different circumstances in a radiology room (Mayer et al. 2018) showed that the use of radiation protective equipment was lowest for the eyes. According to these papers, while radiation exposure can be reduced significantly by wearing protective gear, protective gear for the eyes is not frequently used. Protective gear must be worn by radiology workers who use both fluoroscopy and digital radiography,

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especially for the eyes. Such use is not only effective but also necessary to prevent occupational hazards. Even though the exposure rate in the observer was the lowest of all three participants, the role of observers is not necessarily standardised, so the use of protective devices is always recommended.

REFERENCES

Barber J, McNulty JP (2012): Investigation into scatter radiation dose levels received by a restrainer in small animal radiography. Journal of Small Animal Practice 53, 578–585.

Canato GR, Drumond LF, Paschuk SA, Asfora VK, Andrade MEA, Denyak V, Schelin HR (2014): Occupational exposure assessment in procedures of portable digital veterinary radiology for small size animals. Radiation Physics and Chemistry 95, 284–287.

Dendy PP, Heaton B (2011): Radiobiology and generic radiation risks. In: Dendy PP, Heaton B (eds): Physics for Diagnostic Radiology. 3rd edn. CRC Press, Boca Raton. 397–426 pp.

Levine JS, Pollard RE, Marks SL (2014): Contrast videofluoroscopic assessment of dysphagic cats. Veterinary Radiology and Ultrasound 55, 465–471.

Lindell B (1996): The risk philosophy of radiation protection. Radiation Protection Dosimetry 68, 157–163.

Lopez PO, Dauer LT, Loose R, Martin CJ, Miller DL, Vano E, Doruff M, Padovani R, Massera G, Yoder C (2018): ICRP publication 139: Occupational radiological protection in interventional procedures. Annals of the ICRP 47, 111–113.

Macready DM, Johnson LR, Pollard RE (2007): Fluoroscopic and radiographic evaluation of tracheal collapse in dogs: 62 cases (2001-2006). Journal of the American Veterinary Medical Association 230, 1870–1876.

Mayer MN, Koehncke NK, Belotta AF, Cheveldae IT, Waldner CL (2018): Use of personal protective equipment in a radiology room at a veterinary teaching hospital. Veterinary Radiology and Ultrasound 59, 137–146.

Merriam GR, Worgul BV (1983): Experimental radiation cataract – its clinical relevance. Bulletin of the New York Academy of Medicine 59, 372–392.

Nikolic B, Spies JB, Lundsten MJ, Abbara S (2000): Patient radiation dose associated with uterine artery embolization. Radiology 214, 121–125.

Oh H, Sung S, Lim S, Jung Y, Cho Y, Lee K (2018): Restrainer exposure to scatter radiation in practical small animal radiography measured using thermoluminescent dosimeters. Veterinarni Medicina 63, 81–86.

Pollard RE (2012): Imaging evaluation of dogs and cats with Dysphagia. International Scholarly Research Network, ISRN Veterinary Science ISRN, doi: 10.5402/2012/238505.

Stewart FA, Akleyev AV, Hauer-Jensen M, Hendry JH, Kleiman NJ, MacVittie TJ, Aleman BM, Edgar AB, Mabuchi K, Muirhead CR, Shore RE, Wallace WH (2012): ICRP publication 118: ICRP statement on tissue reactions and early and late effects of radiation in normal tissues and organs-threshold doses for tissue reactions in a radiation protection context. Annals of the ICRP 41, 1–322.

Vano E, Gonzalez L, Fernandez JM, Haskal ZJ (2008): Eye lens exposure to radiation in interventional suites: caution is warranted. Radiology 248, 945–953.

Wagner LK, Eifel PJ, Geise RA (1994): Potential biological effects following high X-ray dose interventional procedures. Journal of Vascular and Interventional Radiology 5, 71–84.

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