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ORIGINAL INVESTIGATION

A 7-min video training intervention improves worker short-term radiation safety behavior during small animal diagnostic radiography

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Abstract

Although manual restraint for small animal diagnostic radiography is common, worker protection is often not optimized, particularly for hands and eyes. Radiation safety training videos generally include hours of material on content other than personal protective equipment (PPE), have limited content, if any, on reducing dose to the lens of the eye, and are presented at the level of veterinary professionals. The objectives of this prospective, observational study were to develop a short, open access video training intervention at the layperson level, focused on proper use of PPE, and to test the effectiveness of the training video in changing behavior of workers. The use of PPE, optimal head position, and body position relative to the source of scattered radiation were compared before and after the video training was completed by workers. Results of unconditional and multivariable analyses were similar. In final multivariable analysis, workers wore gloves correctly more frequently (odds ratio [OR] = 2.09; 95% confidence interval [CI], 1.68-2.59; $P < .001$) and wore eyewear more frequently (OR = 1.85; 95% CI, 1.23-2.78; $P = .003$) after completing the training intervention. Workers also had an optimal head position more frequently (OR = 1.27; 95% CI, 1.03-1.58; $P = .03$) and stood straight or leaned back more frequently (OR = 1.85; 95% CI, 1.48-2.23; $P < .001$) after completing the training. The video training developed in this study is an effective tool that can be incorporated into a radiation protection program to improve worker radiation safety behaviors during manual restraint for small animal diagnostic radiography.

1 | INTRODUCTION

Optimization is one of the three principles of radiation protection, and it is defined by the International Commission on Radiation Protection (ICRP) as the process of keeping the likelihood of exposure, the number of people exposed, and the magnitude of individual doses as low as reasonably achievable, taking economic and societal factors into account.[1] However, studies have shown that optimization of protection is not consistently a high priority in veterinary practice; manual restraint and lack of adequate shielding, particularly of the hands

Abbreviations: CI, confidence interval; DVM, Doctor of Veterinary Medicine; ICRP, International Commission on Radiation Protection; NCRP, National Council on Radiation Protection and Measurements; OR, odds ratio; PACS, picture archiving and communications system; PPE, personal protective equipment.

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and eyes, is common.[2–7] In the clinical environment, priority may be given to workflow, owner cost constraints, perceived risk of sedation, and immediate physical risks such as being bitten or scratched, to the detriment of protecting workers from exposure to ionizing radiation. The reported suboptimal use of hand and eye shielding and other behaviors, such as placing body parts in the primary beam, highlight the need for an intervention to address these behaviors. The use of eye shielding by veterinary workers acquiring diagnostic radiographs of small animals is very low; eyeglasses were worn for 1.7% of radiographic studies in a study at a veterinary teaching hospital,[2] and 95% of workers reported never wearing eyeglasses in a survey of veterinary workers in clinical practice.[3] Surveys of equine veterinarians have found similar low use of eye shielding; only one of 37 practices in Norway using equine mobile radiography reported using lead glasses, and lead glasses were not identified as a radiation protection device used by equine veterinarians in Australia.[8,9] Eye shielding is not recommended in veterinary radiation protection guidelines published by Health Canada and the National Council on Radiation Protection and Measurements (NCRP); however, these recommendations were based on an estimated threshold for cataract formation at >8 Gy for protracted exposures.[1] Recent review of evidence has led to an estimated threshold of 0.5 Gy for chronic exposures, and speculation that cataract formation could be a stochastic effect, with no dose threshold.[10,11] In 2012, the ICRP lowered the recommended annual occupational dose limit to the lens of the eye from 150 to 20 mSv, averaged over 5 years, with no single year greater than 50 mSv.[10] In 2016, the NCRP lowered the recommended annual occupational dose limit to the lens to 50 mGy, with the expectation that the actual annual dose would be less than this limit with optimization.[11] The International Radiation Protection Association currently recommends that protective eyewear be considered for workers receiving annual doses in excess of 3 mSv.[12] Two studies estimating dose to the eye region in veterinary workers involved in diagnostic radiology suggest that doses greater than this level can be received by workers in high-volume practices.[13,14]

Although expert-developed radiation safety training for veterinary workers involved in diagnostic radiography is available online, these training videos generally involve hours of training using slide presentation with voice-over, are aimed at veterinary professionals with content such as physics and radiographic techniques to reduce dose, and have limited content, if any, on reducing dose to the lens of the eye and, other than maximize distance, on adjusting body and head position relative to the source of the radiation. Viewer engagement with online videos is higher when a human face is visible than for slide presentations and has been shown to decrease after 6-9 min[15]; our goal was to keep the length of our training video to under 9 min by limiting content to use of personal shielding and the risks associated with lack of use. In a previous veterinary study, 15% of workers involved in acquiring radiographs identified as volunteers or some other type of veterinary personnel without a Doctor of Veterinary Medicine (DVM) or veterinary technologist education.[3] An even greater percentage of workers with no professional training in veterinary medicine may be found at other practices and institutions. For this reason, the training video content was developed at a layperson level. In addition to maximizing distance from the source of the radiation, the position of the worker's body and head can affect the level of shielding provided by an apron and eyeglasses. Aprons usually do not fully protect the sides of the body, and if a worker is turned sideways to the source of radiation they may not be adequately protected. As well, if a worker turns their head away from the source of radiation, they will reduce the effectiveness of protective eyewear.[16,17] These points were included in the video. Additionally, based on the recent evidence supporting lower threshold radiation doses for cataract formation, we elected to recommend use of eye shielding during diagnostic radiography in the training video.

The first objective of our study was to develop an open access training intervention that addresses the limitations of the currently available training. The second objective of this study was to test the effectiveness of the training video in improving radiation safety behaviors during diagnostic radiography in a veterinary teaching hospital. Our hypothesis was that the video training module would modify worker behavior in a manner that decreases radiation exposure during manual restraint for small animal radiography.

2 | MATERIALS AND METHODS

The study was a prospective, observational design. The sample was composed of workers from the Veterinary Medical Center at the University of Saskatchewan, Saskatoon, Canada, who were involved in taking an after-hours radiograph of a small animal during a 17-week period between March 2, 2019 and June 30, 2019. After-hours was defined as after 5:00 PM and before 8:00 AM on weekdays, and 24 h a day on weekends and holidays. The decision to observe after-hours behavior was based on a previous study at the same workplace that found lower frequency of use of shielding equipment during after-hours compared to regular working hours.[2] This study was determined to meet the requirements for exemption status by the University of Saskatchewan Behavioral Ethics Board (BEH ID 36), and consent for use of recorded behavior was not required. All decisions for subject inclusion or exclusion were made by an analytical epidemiologist, an occupational medicine specialist (NK, Royal College of Physicians and Surgeons of Canada), and a board-certified veterinary radiation oncologist (MM, American College of Veterinary Radiology, Radiation Oncology).

2.1 | Worker training

A 7-min worker training video describing correct use of worker shielding equipment and optimal radiation safety behaviors during small animal radiography was developed by the authors with the University of Saskatchewan Teaching and Learning Media Production unit. The video was developed in English (https://vimeo.com/380783835), then translated into French (https://vimeo.com/418119385), Spanish (https://vimeo.com/418153230), and Portuguese (https://vimeo.com/

475520997). The video included sections on body and thyroid protection, hand protection, and eye protection. Veterinarians in the Department of Small Animal Clinical Sciences, veterinary students at the Western College of Veterinary Medicine, and staff members of the Veterinary Medical Centre were enrolled by the University radiation safety officer in a mandatory course administered through Blackboard Learn. The course consisted of the training video and a five-question multiple-choice quiz based on the video contents, with an 80% grade required to pass the course, and was released to the workers on April 4, 2019. The date and time of course completion was recorded for each worker.

2.2 | Data recording

Two motion-triggered video cameras were positioned to observe worker behavior and use of personal protective equipment (PPE) (Figure 1). Workers were aware that cameras in the main Radiology room were being used to capture video of worker behaviors for the purpose of a research study but were not aware of the exact dates that the cameras were on. Cameras recorded color video, were equipped with night vision, and operated 24 h a day in the main radiology imaging room. Leaded PPE available in the radiology room included aprons with and without attached thyroid shields, thyroid shields, gloves, and standard and fit-over eyeglasses. All video recordings were examined by a single investigator (a graduate student). The student was the only member of the research team who was aware of worker identification.

Data collected for each radiographic study included type of radiographic study (thorax, abdomen, front limb, hind limb, hip, spine, and full body), species, weight, administration of sedatives prior to imaging, appearance of sedation (no voluntary movement by the animal), and if the animal was under general anesthesia (presence of an inserted endotracheal tube). A radiographic study was considered a set of radiographic images, including one or more views, of a single anatomical location.

For each X-ray exposure, the number of workers in the room at the time of exposure, use of manual restraint, use of restraining devices (ropes or sandbags used to restrain animal), the number of exposures sent to the Picture Archiving and Communications System (PACS), the presence of visible gloves or human body parts on the image, and the number of spectators in the room at the time of exposure were recorded. Radiographs were examined for the presence of gloves or human body parts in the primary beam before the images were processed and sent to PACS. Workers were considered spectators if they were in the room during the exposure with no contact with animal or cassette.

For each exposure-worker observation, worker completion of video training module and use of a lead apron, a securely closed thyroid shield, gloves, and eyeglasses was summarized. Glove use was categorized as gloves used correctly (gloves worn on both hands with hands fully inserted into gloves) or gloves used incorrectly (no gloves worn, or gloves worn in any way other than what was considered to be correct use). Data were also collected on worker body position (leaning forward vs standing straight or leaning back) and head position (facing patient directly versus head turned to side). Workers were categorized as a veterinary technologist, DVM, or DVM student.

FIGURE 1 Still images captured from two motion-triggered video cameras, showing two workers acquiring a lateral thoracic radiograph of a cat. The video recordings were used to collect data on use of personal protective equipment (for this exposure, both workers wore lead aprons, only one worker wore lead gloves, and use of thyroid shields and lead eyeglasses is not shown to prevent worker identification), head position (facing patient directly vs head turned to side, not shown in this image to maintain anonymity), and body position (leaning forward, as shown by the worker on the left, vs leaning back or standing straight, as shown by the worker on the right) [Color figure can be viewed at wileyonlinelibrary.com]

2.3 | Data analyses

All data analyses were completed by an analytical epidemiologist using commercial software (Stata SE version 16, StataCorp, College Station, TX).

Radiation safety behaviors were summarized for each unique X-ray exposure-worker observation, for all X-ray exposures with at least one worker in the room. Examined behaviors included use of lead gloves, use of lead eyeglasses, optimal head position at the time of exposure, and body position at the time of exposure. Head position was considered optimal if the worker was facing patient directly if wearing lead eyeglasses or turned their head to the side if not wearing lead eyeglasses. Potential risk factors considered for these behaviors included training video completion (before or after), study type (thorax, abdomen, front limb, hind limb, hip, spine, or full body), worker category (nonradiology technologist, DVM, or DVM student), species (canine, feline, or exotic), patient weight (<10, 10-25, and >25 kg), sedation, and anesthesia. Apron and thyroid shield use were not examined as they were worn for all exposure-worker observations.

Generalized estimating equations were used to evaluate the differences between categories accounting for repeated measures for individual workers. The model included a logit link function, assumed a binomial distribution, and an autoregressive (1) correlation structure to account for the order of the observations. Results were reported as odds ratios (OR) with 95% confidence intervals (CIs). Initially the associations between each risk factor and behavior were examined using bivariate or unconditional analysis. A multivariable model was built using stepwise, manual backward elimination. Variables with $P \leq .20$ were considered in building the final model but only retained if $P \leq .05$. Any variable that when removed from the model changed the effect estimates for other factors of interest by more than 20% was also retained as a confounder. Risk factors that were very highly correlated were examined in separate models.

The number of workers in the room at the time of exposure was recorded for all exposures. Potential risk factors considered for the number of workers in the room during an exposure included study type (thorax, abdomen, front limb, hind limb, hip, spine, or full body), worker category (nonradiology technologist, DVM, or DVM student), species (canine, feline, or exotic), patient weight, sedation, anesthesia, and use of restraining devices. Training video completion was not examined as a risk factor for the number of workers in the room because exposures with zero workers in the room were included in this analysis (if no workers were in the room, there was no data on worker completion of training video). The model was built as above with generalized estimating equations adjusting for repeated measures within the same animal using a log link function and assuming a Poisson distribution. The effect estimate was exponentiated and reported as relative difference in counts with 95% CI.

3 | RESULTS

3.1 | Radiographic study and exposure data and personal protective equipment use

Data were collected for 374 radiographic studies (1478 exposures) of 310 animals: 75.2% (233/310) dogs, 21.0% (65/310) cats, and 3.9% (12/310) exotics. Radiographic study types included 38.5% (144/374) of the thorax, 39.3% (147/374) of the abdomen, 5.3% (20/374) of the front limb, 7.0% (26/374) of the hind limb, 5.3% (20/374) of the hip, 1.9% (7/374) of the spine, and 2.7% (10/374) of the full body. Animals were not sedated or anesthetized for 69.5% (260/374) of studies, had sedatives administered prior to imaging or the appearance of sedation for 25.4% (95/374), and were under general anesthesia for 5.1% (19/374).

Manual restraint of the animal was used for 78.2% (1156/1478) of exposures, restraining devices were used during 12.0% (177/1478) of exposures, both were used in 1.2% (18/1478) of exposures, and neither was used in 11.0% (163/1478) of exposures. Of the 1478 exposures, 80.7% (1193/1478) were sent to PACS for diagnostic interpretation.

For 21.7% (321/1478) of exposures there was no worker present in the radiology room during the exposure, for 26.0% (385/1478) of exposures there was one worker present, for 50.7% (750/1478) of exposures there were two workers present, and for 1.5% (22/1478) of exposures there were three workers present. A worker was present in the room as a spectator for 3.6% (53/1478) of exposures. Gloves were visible in the primary beam on the radiographic image in 1.1% (13/1157) of exposures with at least one worker present, and in no instance were unshielded human body parts visible in the primary beam on the radiograph.

At least one worker was present in the room for 78.3% (1157/1478) of exposures. For these 1157 exposures, individual worker observations were summarized as 1769 unique imaging exposure-worker observations (eg, one imaging exposure with two workers present would count as two unique imaging exposure-worker observations).

An apron with a securely closed, attached thyroid shield was worn for 100% (1769/1769) of exposure/worker observations. Of the 74.2% (1313/1769) of observations when gloves were used incorrectly, workers wore no glove on either hand for 80.6% (1058/1313) of exposure/worker observations and wore a glove on one hand for 13.4% (176/1313) of observations. For 6.0% (79/1313) of exposure/worker observations in which no gloves were worn, the workers laid a glove on top of one or both hands during the exposure.

The behaviours of 53 workers who completed the video training were observed: 32% (17/53) DVMs, 34% (18/53) nonradiology veterinary technologists, and 34% (18/53) DVM students.

3.2 | Factors associated with personal protective equipment use and head and body position

All unconditional analysis results are presented in Supporting Information 1-5, whereas all multivariable analysis results are included as tables in the main text. In unconditional analysis, correct glove use was significantly more likely for workers after completing the video training module, when imaging a hip or spine (vs a thorax), if they were a DVM student (vs a technologist), and if the patient weighed between 10 and 25 kg (vs <10 kg) (Supporting Information 1). Correct glove use was significantly less likely for workers when imaging a front limb

TABLE 1 Final multivariable model of the associations between risk factors of interest and whether or not lead gloves were used correctly summarized for 1157 exposures from 284 imaging studies completed on 265 animals by 53 workers (1769 unique imaging exposure/worker events)

	Frequency[a]	aOR[b]	95% CI[c]	*P*-value
Gloves used correctly	0.26 (456/1769)			
After training				
No	0.18 (131/729)	Reference category[d]		
Yes	0.31 (325/1040)	2.09	1.68-2.59	<.001
Study type				<.001
Thorax	0.26 (186/717)	Reference category		
Abdomen	0.25 (215/855)	0.93	0.76-1.14	.50
Front limb	0.18 (12/68)	0.31	0.15-0.60	.001
Hind limb	0.27 (17/64)	0.77	0.45-1.32	.34
Hip	0.55 (18/33)	3.07	1.57-6.00	.001
Spine	0.67 (8/12)	4.90	1.56-15.4	.006
Full body	0 (0/20)	Nonestimable		<.001
Worker category				<.001
Technologist	0.23 (239/1042)	Reference category		
DVM	0.22 (119/536)	0.88	0.69-1.12	.30
DVM student	0.51 (98/191)	2.67	1.88-3.80	<.001

[a]Relative frequency.
[b]Odds ratio, calculated adjusting using logistic regression adjusted for repeated measures within individual workers.
[c]95% confidence interval.
[d]The category to which all other categories for that risk factor were compared.

TABLE 2 Final multivariable model of the associations between risk factors of interest and whether or not lead eye shielding was used summarized for 1157 exposures from 284 imaging studies completed on 265 animals by 53 workers (1769 unique imaging exposure/worker events)

	Frequency[a]	aOR[b]	95% CI[c]	*P*-value
Eye shielding worn	0.03 (56/1769)			
After training				
No	0.008 (6/729)	Reference category[d]		
Yes	0.05 (50/1040)	1.85	1.23-2.78	.003

[a]Relative frequency.
[b]Odds ratio, calculated adjusting using logistic regression adjusted for repeated measures within individual workers.
[c]95% confidence interval.
[d]The category to which all other categories for that risk factor were compared.

(vs a thorax). Species, sedation, and anesthesia were not significantly associated with correct glove use ($P \geq .24$). In final multivariable analysis, workers wore gloves correctly significantly more frequently after completing the video training module (OR = 2.09), when imaging hip or spine (vs a thorax), and if they were a DVM student (vs a technologist) (Table 1). Correct glove use was significantly less likely for workers when imaging a front limb (vs a thorax).

In unconditional analysis, use of eyeglasses was significantly more likely for workers after completing the video training module (Supporting Information 2). Study type, worker category, species, weight, sedation, and anesthesia were not significantly associated with use of eyeglasses ($P \geq .15$). In final multivariable analysis, workers wore eyeglasses significantly more frequently after completing the video training module (OR = 1.85) (Table 2).

In unconditional analysis, optimal head position was significantly more likely for workers after completing the video training module, when imaging an abdomen (vs a thorax), and if the patient weighed >25 kg (vs <10 kg) (Supporting Information 3). Optimal head position was significantly less likely if workers were a DVM (vs a technologist) and if the patient was a cat or an exotic (vs a dog). Sedation and anesthesia were not significantly associated with optimal head position (*P*-values .14 and .44, respectively). In final multivariable analysis, optimal head position was significantly more likely for workers after completing the video training module (OR = 1.27), when imaging an

TABLE 3 Final multivariable model of the associations between risk factors of interest and whether or not head position was optimal[a] summarized for 1157 exposures from 284 imaging studies completed on 265 animals by 53 workers (1769 unique imaging exposure/worker events)

	Frequency[b]	aOR[c]	95% CI[d]	*P*-value
Head position optimal	0.35 (611/1769)			
After training				
No	0.30 (222/729)	Reference category[e]		
Yes	0.37 (389/1040)	1.27	1.03-1.58	.03
Study type				.003
Thorax	0.31 (222/717)	Reference category		
Abdomen	0.39 (333/855)	1.43	1.16-1.77	.001
Front limb	0.26 (18/68)	0.65	0.36-1.19	.17
Hind limb	0.38 (24/64)	1.11	0.65-1.90	.70
Hip	0.24 (8/33)	0.68	0.31-1.50	.34
Spine	0.42 (5/12)	1.12	0.34-3.68	.85
Full body	0.05 (1/20)	0.22	0.03-1.75	.15
Worker category				<.001
Technologist	0.39 (406/1042)	Reference category		
DVM	0.26 (141/536)	0.61	0.47-0.79	<.001
DVM student	0.34 (64/191)	0.83	0.58-1.18	.30
Weight				.02
<10 kg	0.31 (254/822)	Reference category		
10-25 kg	0.34 (126/369)	1.03	0.79-1.35	.81
>25 kg	0.41 (227/560)	1.38	1.09-1.74	.007

[a]Head position was considered optimal if the worker was facing patient directly if wearing lead eyeglasses or turned their head to the side if not wearing lead eyeglasses.
[b]Relative frequency.
[c]Odds ratio, calculated adjusting using logistic regression adjusted for repeated measures within individual workers.
[d]95% confidence interval.
[e]The category to which all other categories for that risk factor were compared.

abdomen (vs a thorax), and if the patient weighed >25 kg (vs <10 kg) (Table 3). Optimal head position was significantly less likely if workers were a DVM (vs a technologist).

In unconditional analysis, optimal body position was significantly more likely for workers after completing the video training module, if the patient weighed 10-25 or >25 kg (vs <10 kg), and if sedation or anesthesia were used (Supporting Information 4). Optimal body position was significantly less likely if the patient was a cat or an exotic (vs a dog). Study type and worker category were not significantly associated with optimal body position (*P*-values .51 and .53, respectively). In final multivariable analysis, optimal body position was significantly more likely for workers after completing the video training module (OR = 1.85), if the patient weighed 10-25 or >25 kg (vs <10 kg), and if sedation or anesthesia were used (Table 4).

3.3 | Factors associated with number of workers in the room for each exposure

In unconditional analysis, there were significantly more workers in the room when imaging an abdomen (vs a thorax) and if the patient weighed 10-25 or > 25 kg (vs <10 kg) (Supporting Information 5). There were significantly less workers in the room when imaging a front limb, hind limb, hip, spine, or full body (vs a thorax), if the patient was a cat or an exotic (vs a dog), and if sedation, anesthesia, or restraining devices were used. In final multivariable analysis, there were significantly more workers in the room if the patient weighed >25 kg (vs <10 kg) (Table 5). There were significantly less workers in the room if the patient was an exotic (vs a dog) and if sedation, anesthesia, or restraining devices were used.

TABLE 4 Final multivariable model of the associations between risk factors of interest and whether or not workers stood straight or leaned back summarized for 1157 exposures from 284 imaging studies completed on 265 animals by 53 workers (1769 unique imaging exposure/worker events)

	Frequency[a]	aOR[b]	95% CI[c]	*P*-value
Standing straight	0.32 (569/1769)			
After training				
No	0.24 (178/729)	Reference category[d]		
Yes	0.38 (391/1040)	1.85	1.48-2.23	<.001
Weight				<.001
<10 kg	0.25 (205/822)	Reference category		
10-25 kg	0.37 (136/369)	1.43	1.09-1.87	.01
>25 kg	0.40 (224/560)	1.77	1.39-2.26	<.001
Sedation				
No	0.30 (467/1581)	Reference category		
Yes	0.54 (102/188)	2.54	1.86-3.49	<.001
Anesthesia				
No	0.32 (558/1752)	Reference category		
Yes	0.65 (11/17)	3.57	1.22-10.47	.02

[a]Relative frequency.
[b]Odds ratio, calculated adjusting using logistic regression adjusted for repeated measures within individual workers.
[c]95% confidence interval.
[d]The category to which all other categories for that risk factor were compared.

TABLE 5 Final multivariable model of the associations between risk factors of interest and number of workers in the room summarized for 1478 exposures from 374 imaging studies completed on 310 animals

	Number of exposures	Median (5th, 95th percentile)	aRD[a]	95% CI[b]	*P*-value
Species					.01
Canine	1167	2 (0, 2)	Reference category[c]		
Feline	263	1 (0, 2)	0.94	0.82-1.08	.41
Exotic	48	1 (0, 1)	0.55	0.38-0.82	.003
Weight					.01
≤10 kg	728	1 (0, 2)	Reference category		
>10-25 kg	289	2 (0, 2)	1.12	0.99-1.27	.07
>25 kg	452	1 (0, 1)	1.19	1.06-1.33	.003
Sedation					
No	1107	2 (0, 2)	Reference category		
Yes	371	0 (0, 2)	0.44	0.38-0.52	<.001
Anesthesia					
No	1410	2 (0, 2)	Reference category		
Yes	68	0 (0, 2)	0.26	0.16-0.41	<.001
Restraining devices					
No	1301	2 (0, 2)	Reference category		
Yes	177	0 (0, 1)	0.14	0.09-0.22	<.001

[a]Relative difference in counts calculated adjusting using Poisson regression adjusted for repeated measures within individual workers with generalized estimating equations.
[b]95% confidence interval.
[c]The category to which all other categories for that risk factor were compared.

4 | DISCUSSION

This work resulted in an effective tool that can be incorporated into radiation safety programs to reduce ionizing radiation exposure of workers during small animal diagnostic radiography. The short training video is aimed at both professional (DVM and technologist) and other veterinary workers and is freely available online in four languages. The unconditional analyses (included as Supporting Information) and multivariable analyses were similar, with a few exceptions (optimal head and body positions were no longer less likely for cats than dogs, and the number of workers in the room was no longer higher for all other study types compared to thorax, in the multivariable analyses).

Although the video training significantly improved radiation safety behaviors, the frequency of use of gloves and eyewear, and head and body position relative to the source of radiation, remained suboptimal. After training, gloves were used for only about one third of exposure-worker observations, and eyewear was used for only 5% of exposure-worker observations. The after-hours worker population in this study was composed of DVMs, technologists, and DVM students with primary responsibilities outside of medical imaging. The DVMs, technologists, and DVM students hired by the clinic receive an orientation in radiation safety at the start of their employment, and DVM students are oriented at the start of their senior rotations and receive a 50-min lecture on radiation safety in their second year. However, after-hours workers do not work alongside dedicated radiology technologists, who lead by example and direct workers to use shielding and maximize distance to the patient, and there is also no direct supervision by radiology technologists or faculty during after-hours. The after-hour workers may prioritize immediate risks to themselves (eg, being bitten) and their critically ill patients over long-term risks, such as ionizing radiation exposure, and choose to restrain without shielding to hold patients more securely and acquire diagnostic-quality images more quickly and without sedation. Although the video training significantly improved PPE use and worker positioning and is therefore worth using, it is apparent that a one-time intervention alone is not enough to achieve optimal radiation safety behavior. This was not an unexpected finding as PPE compliance is impacted by environmental factors such as accessibility of properly fitting PPE and organizational factors such as communication of expectations, feedback, and enforcement, in addition to individual factors such as knowledge and perception of risk.[18]

Additional measures that could be considered in addition to the training video include frequent informal workplace meetings, repeated messaging in other formats, employer requirement that PPE be used, ensuring that properly fitting PPE is available for every worker, and enforcement of PPE use. "Toolbox talks" refer to brief, informal, small group safety meetings often held at the start of a shift, common in many industries.[19] This form of training can use a participatory approach to involve workers in problem-solving, and has been shown to raise safety awareness, increase knowledge retention, and improve safety behaviors.[19] Repetition of the video training message could be achieved through signage in the radiology room, follow-up viewings of the video, or quizzes on the video content. Employers should ensure that workers know what PPE is required to be worn, and that adequate numbers of properly fitting PPE are readily accessible; a previous study[3] found that workers wore hand shielding significantly more frequently if required to do so by their employer, and workers in the same study suggested that making eye protection mandatory would increase its use. As well, poorly fitting PPE and lack of PPE for every worker were identified by workers as barriers to use in two previous studies.[2,3] Finally, workers should be aware of the consequence for failure to use required PPE. Methods other than enforcement should be preferentially used to improve safety behaviors; discipline only has a role when other methods have failed. Although the ultimate goal of these measures is perfect compliance, any improvement in protection will benefit workers; as cancer is a stochastic effect of radiation, with no dose threshold, any reduction in radiation dose will result in a lowered risk of occupationally related cancer over the lifetime of a worker.[1]

The best optimization of protection is achieved when workers are not in the room during an exposure, and Canadian and American federal guidelines recommend that the workers avoid regular manual restraint for radiography. However, given that most veterinary clinics in Canada do not practice hands-free radiography at this time, training on appropriate behavior during restraint is needed. The video training includes the federal guidelines recommendation and also the statement that a hands-free approach is optimal.

Use of sedation decreased radiation exposure of the workers. Workers were less likely to lean forward toward the source of scattered radiation when sedation was used, and there were fewer workers in the room at the time of exposure when a patient was sedated, consistent with the finding of a previous study at this workplace.[2] Although sedation can be used to avoid the need for manual restraint, it has also been suggested that with appropriate hands-free techniques and restraining devices, approximately 75% of nonsedated patients can be imaged without workers in the room.[20] The use of manual restraint for just over three quarters of exposures in the current study is consistent with previous reports in veterinary medicine.[3,5–7] Interestingly, the percentage of animals restrained manually was lower in this study than in a 2018 study[2] at the same workplace, which found that 92% of exposures involved manual restraint. This is likely due to the efforts of the radiology service to employ hands-free techniques whenever possible, although the impact of that effort is expected to be lower for after-hours radiography given that after-hours workers are not part of the radiology service.

A limitation of this study is the assumption that there were no, or minimal, variables that changed worker radiation safety behaviors over the study period other than the training intervention. Ideal study design would have included a control group that received no training intervention, to examine the contribution of factors other than the intervention to the changes in behavior. Our reasons for not using a control group included the small size of the study population, the possibility of workers who had received training influencing the behavior of workers who had not received training, and the possibility of workers in the control group viewing the video, given the unsupervised, online access. Another limitation is the lack of information regarding the duration of effect of the training video. The time required to collect data from the video recordings and the high after-hours worker turnover limited the time period over which the data were collected. Additionally, other than checking that the postvideo quiz was complete with a score equal to or greater than 80%, we were not able to assess whether a worker was actively involved with training video when it played. Due to the large number of workers and their diverse schedules, it was not possible to deliver the training video in a supervised environment. Some workers may have played the video without watching it, and this may have decreased the measured effect of the video.

In conclusion, the video training developed in this study can be incorporated into a radiation protection program as an effective tool to improve worker radiation safety behaviors during small animal diagnostic radiography.

LIST OF AUTHOR CONTRIBUTIONS

Category 1

(a) Conception and Design: Freitas, Koehncke, Waldner, Belotta, Lanovaz, Mayer
(b) Acquisition of Data: Freitas, Lanovaz
(c) Analysis and Interpretation of Data: Freitas, Koehncke, Waldner, Belotta, Lanovaz, Mayer

Category 2

(a) Drafting the Article: Freitas, Koehncke, Waldner, Mayer
(b) Revising Article for Intellectual Content: Freitas, Koehncke, Waldner, Belotta, Lanovaz, Mayer

Category 3

(a) Final Approval of the Completed Article: Freitas, Koehncke, Waldner, Belotta, Lanovaz, Mayer

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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