Early and Increased Training in Veterinary Radiology Increases Student Interest in the Specialty But May Provide Little Short-Term Gain in Radiology Knowledge

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ABSTRACT

There is a lack of consensus among educators regarding the ideal structure of radiology training in veterinary medicine. Research in the medical field suggests that early integration has positive short- and long-term impacts on student interest in radiology. This study evaluated the effect of a new radiology course in the first year of the veterinary curriculum. Authors hypothesized that students taught radiology in years 1 and 2 would have greater interest in and appreciation for the specialty of radiology and would perform better on tests of basic knowledge of medical imaging principles, entry-level image interpretation, and anatomy identification than students who were not taught until year 2. An online questionnaire was administered to different classes of students after completion of their radiology courses. Students with early and increased radiology training were significantly more likely to respond that radiology was more interesting than other veterinary specialties. Unexpectedly, students with early and increased training performed significantly better than students with less and later training on only one out of nine content knowledge questions, though they did perform significantly better on additional knowledge questions compared to students with only early exposure. This suggests early and increased training in radiology may increase student interest in and appreciation for the specialty, but may not lead to increased short-term knowledge retention compared to a traditional curriculum format.

Key words: veterinary radiology, preclinical curriculum, veterinary specialist training

INTRODUCTION

The curriculum for first-year veterinary students at the Cummings School of Veterinary Medicine at Tufts University includes basic sciences covering gross anatomy, biochemistry, and immunology in addition to courses focused on developing clinical skills and exploring human–animal relationships. Over the past several years, the institution has started combining courses such as histology and cell biology with the goal of a more integrated and collaborative approach to teaching. In the past, radiographic anatomy was taught to first-year students as part of the year-long Gross Anatomy course. Radiology residents taught in small groups with students rotating between cadaver dissection sessions and radiograph and skeleton correlations. The residents also gave a few didactic lectures highlighting important anatomic landmarks on radiographs. Radiology faculty were not involved in delivering this first-year content. Prior to 2012, required, dedicated, preclinical diagnostic imaging courses were limited to the 23-hour second-year Diagnostic Imaging course (20 hours didactic lecture, 3 hours laboratory exercises) and the third-year Diagnostic Ultrasonography course. In 2012, a new course, Working Principles of Medical Imaging, was added to the first-year curriculum. The new course introduced physics and radiation safety of all imaging modalities and covered basic radioanatomy of small and large animals, and as a result, radiographic anatomy was no longer taught as part of the Gross Anatomy course. This same year, in response to the new first-year course, the second-year Diagnostic Imaging course changed to a 20-hour course (17 hours of lecture and 3 hours of laboratory sessions), and it has remained unchanged in terms of content delivery and contact hours since that time. The following year (2013), Working Principles of Medical Imaging was not taught due to changes in staffing, resulting in a class of students (class of 2017) who did not receive any formal instruction in physics and radiation safety or radioanatomy during their first year. These students did participate in the recently modified second-year Diagnostic Imaging course (20 hours total). In 2014, the first-year imaging course was reorganized to better integrate, both in terms of timing and content, with the gross anatomy course and was renamed Clinical Radioanatomy and Principles of Imaging. This revised 31.5-hour first-year course (14.5 hours of lecture, 15 hours small group sessions, 2 hours laboratory sessions) was taught by radiology faculty with some resident assistance during the laboratory sessions. Implementation of this course in 2014 resulted in a class of students (class of 2018) who participated in both the 31.5-hour first-year Clinical Radioanatomy course and the 20-hour second-year Diagnostic Imaging course.

An informal email discussion among residency coordinators of the American College of Veterinary Radiologists (ACVR) indicated that the majority (17 of 21) of the responding universities incorporate some radiology material in their first-year curriculum. However, there was wide variation in the number of contact hours (ranging from 0 hours to 35 hours), the content covered, and the type of instruction used. For example, one institution delivers 27 hours of lecture and 8 hours of laboratory sessions as a dedicated first-year course, while another provides students with PowerPoint files for self-teaching small animal radioanatomy material and has didactic large animal radioanatomy material taught by equine surgeons during the first year. This lack of consensus and the absence of pedagogical evidence highlights the difficulty in justifying a curricular approach to teaching veterinary radiology.

The importance of introducing radiology into the preclinical medical curriculum before clerkships (equivalent to veterinary clinical rotations), integrating it with the teaching of gross anatomy, and using case-based discussions was highlighted in a consensus statement from several educational experts in the United Kingdom.[1] It has also been noted that radiologists may be in a unique position to provide medical students with an integrated and comprehensive overview of the diagnostic process for a given patient.[2] Some even advocate for teaching radiology earlier in the preclinical curriculum to help with students' understanding of normal and pathologic anatomy and disease processes.[3] The short-term benefits of increasing the amount of radiology integrated into first-year anatomy and neuroscience courses in the medical field have been documented with students showing more interest in radiology, a higher opinion of the specialty material,[3] and better retention of anatomy material.[4] Early integration of radiology may also have long-term benefits, with medical students more likely to take radiology electives in the clinical curriculum, maintain a positive opinion about specialty medicine, and understand the need for consultation with and referrals to specialists to improve patient care.[5]

Within the field of veterinary medicine, there is a shortage of veterinary radiologists with a particular decline in academic radiologists. If early integration of radiology into the curriculum can have a positive impact on students' understanding of and appreciation for the specialty within our academic setting, then the ACVR could see a benefit from increased student interest in pursuing a career in veterinary radiology.

This study's aims were to investigate the effect of a new, first-year radiology course on student attitudes toward the veterinary specialty of radiology and to determine if the addition of a first-year radiology course at the authors' institution had a positive impact on short-term retention of knowledge of basic imaging principles, radiograph interpretation, and anatomy identification. Although studies have looked at the impact of early radiology instruction in the preclinical medical curriculum,[3, 5] to our knowledge, this has not been evaluated in the veterinary field.

We hypothesize that students with early exposure to radiology (i.e., in year 1) and with increased exposure to radiology (i.e., in years 1 and 2) will be more interested in the specialty of diagnostic imaging, more likely to consider a career in radiology, and more likely to indicate that radiology has an important impact on the overall practice of medicine than students who were not exposed to radiology until their second year and with fewer hours of radiology instruction. Second, students with early and increased exposure to radiology will perform better on a test of basic imaging principles, radiograph interpretation, and anatomy identification than students who were taught only in year 2.

METHODS/MATERIALS

Student Survey

An online survey[a] was developed to assess students' attitudes toward the specialty of veterinary radiology and content knowledge of veterinary radiology (see survey questions in Appendix 1). Specifically, two multiple-choice questions gauged students' prior knowledge of veterinary radiology. Four multiple-choice questions evaluated students' interest in the field of veterinary radiology and likelihood of pursuing additional training and/or a career in radiology. Five multiple-choice questions evaluated students' content knowledge, including which radiology procedures utilize ionizing radiation (an occupational health concern), which might be performed by a veterinary radiologist, which require patient sedation, and which incur higher costs to the owner. Four additional content knowledge questions asked students to correctly diagnose a radiographic abnormality and identify anatomic structures on equine and canine radiographs. We also retrieved students' demographic information (gender, age at start of the study, and race/ethnicity) from the University's student information system in an effort to better characterize the demographics of a given veterinary class. Race/Ethnicity was aggregated into two categories: an underrepresented minority (Black/African American, Hispanic/Latino/a, Native Hawaiian/Pacific Islander, Native American/Alaskan Native, two or more races, or Other); and a non-underrepresented minority (White or Asian/Asian American).

The survey was administered a total of four times to students within the classes of 2017–2019 (Table 1). The class of 2019, before matriculation, with no previous radiology training, served as a control population ("control A"). The class of 2017 followed the traditional curriculum with radiology training starting in their second year and were surveyed 3 months after the final examination of their second-year Diagnostic Imaging course ("control B"). The class of 2018 was considered the experimental group, and was surveyed during the first 4 weeks following the final examination for their first-year Clinical Radioanatomy course ("treatment time 1" [TT1]) and then again 3 months after the final examination of their second-year Diagnostic Imaging course ("treatment time 2" [TT2]). To recruit students, an email was sent to each class of students explaining the

Table 1: Description of student populations surveyed and survey time points

Student population	Graduating class	Survey date	Population description
Control A	2019	Aug 2015	Pre-matriculation students with no prior formal radiology instruction
Control B	2017	May 2015	Students who completed the second-year Diagnostic Imaging course only
TT1	2018	May 2015	Students who completed the first-year Clinical Radioanatomy course only
TT2	2018	May 2016	Students who completed both the first- and second-year radiology courses

TT1 = treatment time 1;TT2 = treatment time 2

The class of 2019, before matriculation, with no previous radiology training, served as a control population (control A). The class of 2017 followed the traditional curriculum with radiology training starting in their second year and were surveyed 3 months after the final examination of their second-year Diagnostic Imaging course (control B).

study and including a link to the electronic survey. Weekly reminder emails were then sent to students who had not yet completed the survey, and the survey remained open for a total of 4 weeks during each survey period. This study was deemed exempt from approval by the primary author's Human Subjects Research Institutional Review Board.

Statistical Analysis

All analyses were performed using programs available online.[b] The primary comparison of interest was the responses of control B versus TT2 for questions regarding attitude toward and interest in the specialty of radiology (questions 3–6) and knowledge of imaging principles, radioanatomy, and radiograph interpretation (questions 7–15); however, comparison of TT2 versus TT1 for these questions was also provided to better identify whether any differences likely occurred during the first or second year of the curriculum. Results for control A provided a rough baseline of attitudes and knowledge for pre-matriculation students, but no statistical tests were conducted with these data. Similarly, no statistical tests were used to analyze questions regarding previous radiology experience. Due to small cell counts in many questions, Fisher's exact tests were used to compare groups (control B versus TT2 and TT2 versus TT1) for all individual question analyses. Since TT2 and TT1 surveys were given to the same groups of students, the assumption of independent observations is made by the Fisher's exact test; however, in this setting, that would likely make the test conservative in identifying treatment differences. In other words, the test would be less likely to find statistically significant differences. Still, given this limitation, results of tests comparing TT2 and TT1 should be interpreted with caution and viewed as more of a descriptive test.

There was a small number of incomplete surveys ($n = 12$). For survey questions about attitudes toward veterinary radiology (questions 3–6), respondents with missing data were only excluded for analysis of the question with the missing response.

For survey questions testing content knowledge (questions 7–15), responses to each were recorded as correct or incorrect. Selection of an "I don't know" response was treated as incorrect. We treated non-responses as incorrect if the respondent skipped only a particular question but completed the survey, and we treated them as missing (and excluded from analysis) if the respondent did not answer any additional questions after the question for which there was non-response.

In addition to individual question analyses, we calculated a total "test score" on the nine-question content knowledge section for each respondent based on the number of correct responses. Respondents who skipped questions but completed the survey were included, but respondents who stopped the survey before answering all questions were excluded from this analysis. An independent samples t-test was used to compare control B versus TT2, and a paired samples t-test was used to compare TT2 versus TT1. The distribution of responses for each group was approximately normal, and the data met the assumption of homogeneity of variance for the independent samples t-test (tested with Levene's test, $F = 0.203$, $p = .653$).

For all tests, statistical significance was determined by $p<.05$.

RESULTS

Student response rates ranged from 56.5% to 69.2%. (64.9% ± 5.82%, mean ± SD) for each survey group. Respondent and cohort (entire class) demographics are presented in Table 2. Differences in average ages of TT1 and TT2 are attributable to different students from the class of 2018 participating in the first versus the second survey.

Results from the two survey questions assessing students' prior knowledge of and experience with veterinary radiology (questions 1–2) are presented in Table 3. As expected, a large percentage of pre-matriculation students (control A) indicated that they had "barely been introduced to veterinary radiology" (55.6%). In contrast, control B, TT1 and TT2 students generally indicated that they were "about as familiar with veterinary radiology as any other specialty" (69.4%–91.7%). Also, as expected, over half (55.6%) of control A students indicated they had only "passing experience with veterinary radiology." After 2 years of radiology training, TT2 students indicated that they knew a lot about veterinary radiology (24.2%), and students in control B, TT1, and TT2 frequently indicated having "several lectures, study sessions, or a dedicated veterinary radiology course" (between 66.2% and 85.5%).

There was one statistically significant difference in student attitudes toward and interest in veterinary radiology

Table 2: Demographics for respondents and their respective cohort (entire class)

Student population	Female (%)	% identifying as underrepresented minority	Average age (y) at start of study (May 2015)
Control A	87.3	6.3	22.8
Class of 2019 as a whole	85.3	5.3	23.3
Control B	83.3	8.3	26.3
Class of 2017 as a whole	84.7	8.2	26.6
TT1	89.2	3.1	24.3
Class of 2018 as a whole	82.7	5.1	24.8
TT2	93.5	6.5	25.2
Class of 2018 as a whole	82.7	5.1	24.8

TT1 = treatment time 1;TT2 = treatment time 2

The class of 2019, before matriculation, with no previous radiology training, served as a control population (control A). The class of 2017 followed the traditional curriculum with radiology training starting in their second year and were surveyed 3 months after the final examination of their second-year Diagnostic Imaging course (control B).

Table 3: Summary of student responses to survey questions about background and experience (questions 1–2)

	No. (%) respondents			
	Control A (*n* = 63)	Control B (*n* = 48)	TT1 (*n* = 65)	TT2 (*n* = 62)
1. How much do you know about the specialty of veterinary radiology?				
a. I've never heard of veterinary radiology	0 (0%)	0 (0%)	0 (0%)	0 (0%)
b. I have barely been introduced to veterinary radiology	35 (55.6%)	2 (4.2%)	10 (15.4%)	2 (3.2%)
c. I am about as familiar with veterinary radiology as any other specialty	27 (42.9%)	44 (91.7%)	49 (75.4%)	43 (69.4%)
d. I know a lot about veterinary radiology	1 (1.6%)	2 (4.2%)	1 (1.5%)	15 (24.2%)
e. I know more about veterinary radiology than any other specialty	0 (0%)	0 (0%)	5 (7.7%)	2 (3.2%)
2. Which of the following best describes your prior experience with radiology?				
a. I have only passing experience with veterinary radiology	45 (71.4%)	3 (6.4%)	12 (18.5%)	5 (8.1%)
b. My experience with veterinary radiology is peripheral, as a small part of different course	14 (22.2%)	3 (6.4%)	7 (10.8%)	2 (3.2%)
c. I have had one or two lectures dedicated to radiology	4 (6.3%)	4 (8.5%)	3 (4.6%)	2 (3.2%)
d. I have had several lectures, study sessions or a dedicated veterinary radiology course	0 (0%)	38 (78.7%)	43 (66.2%)	53 (85.5%)

TT1 = treatment time 1; TT2 = treatment time 2

The class of 2019, before matriculation, with no previous radiology training, served as a control population (control A). The class of 2017 followed the traditional curriculum with radiology training starting in their second year and were surveyed 3 months after the final examination of their second-year Diagnostic Imaging course (control B).

(Table 4). When asked "How interesting is the subject matter in veterinary radiology?," a statistical difference in responses was noted between control B versus TT2 students (p = .011), with more control B students responding responded that radiology was "interesting in its own right" (61.7% versus 35.5% TT2) but more TT2 students responding that radiology was "more interesting than other specialties" (56.5% vs. 31.9% control B). We found no other significant differences when comparing control B versus TT2 or TT2 versus TT1 for responses to questions regarding attitude toward, and interest in, veterinary radiology. Despite this absence of statistical significance, there were some interesting trends. For example, TT2 students more frequently responded that radiology "often changes patient care" than control B students, nearly reaching statistical significance (96.8% vs. 87.2%, respectively, p = .077). In general, students with early exposure to radiology (TT2 and TT1) more often responded that they were at least considering a career in veterinary

Table 4: Summary of student responses to survey questions about attitudes to radiology (questions 3–6)

	No. (%) respondents			
	Control A (n = 63)	Control B (n = 48)	TT1 (n = 65)	TT2 (n = 62)
3. How interesting is the subject matter in veterinary radiology?				
a. It is a dull subject	0 (0%)	1 (2.1%)	1 (1.5%)	0 (0%)
b. Occasionally I find it interesting	4 (6.3%)	2 (4.3%)	3 (4.6%)	5 (8.1%)
c. It is interesting in its own right	36 (57.1%)	30 (61.7%)	32 (49.2%)	22 (35.5%)
d. It is more interesting than other specialties	8 (12.7%)	15 (31.9%)	29 (44.6%)	35 (56.5%)
e. I do not know if I find veterinary radiology interesting or not	15 (23.8%)	0 (0%)	0 (0%)	0 (0%)
p (control B vs. TT2)				.011*
p (TT2 vs. TT1)				.222
4. How likely are you to consider a career as a board-certified veterinary radiologist?				
a. Highly unlikely – I am not interested in a career as a veterinary radiologist	8 (12.7%)	15 (31.9%)	10 (15.4%)	15 (24.2%)
b. Unlikely but it is possible	28 (44.4%)	22 (46.8%)	27 (41.5%)	24 (38.7%)
c. I am considering specializing in veterinary radiology	5 (7.9%)	4 (8.5%)	18 (27.7%)	17 (27.4%)
d. Veterinary radiology is my top choice for a career	0 (0%)	0 (0%)	1 (1.5%)	1 (1.6%)
e. I haven't made a decision about my career at this time	22 (34.9%)	6 (12.8%)	9 (13.8%)	5 (8.1%)
p (control B vs. TT2)				.091
p (TT2 vs TT1)				.692
5. Will you take additional radiology electives during your fourth year?				
a. No, I will just take the required rotation	2 (3.2%)	0 (0%)	3 (4.6%)	4 (6.5%)
b. I am not sure if I will take additional radiology electives	39 (61.9%)	25 (51.1%)	28 (43.1%)	23 (37.1%)
c. I will likely take at least one radiology elective	17 (27%)	20 (42.6%)	27 (41.5%)	28 (45.2%)
d. I plan to take at least one, possibly more radiology electives	5 (7.9%)	3 (6.4%)	7 (10.8%)	7 (11.3%)
p (control B vs. TT2)				.175
p (TT2 vs. TT1)				.888
6. What type of impact does the specialty of veterinary radiology have on patient care?				
a. Veterinary radiology has minimal impact on patient care	0 (0%)	0 (0%)	0 (0%)	0 (0%)
b. Veterinary radiology occasionally changes patient care	16 (25.4%)	6 (12.8%)	6 (9.2%)	2 (3.2%)
c. Veterinary radiology often changes patient care	47 (74.6%)	42 (87.2%)	59 (90.8%)	60 (96.8%)
d. I don't know what impact veterinary radiology has on patient care	0 (0%)	0 (0%)	0 (0%)	0 (0%)
p (control B vs. TT2)				.077
p (TT2 vs. TT1)				.274

TT1 = treatment time 1; TT2 = treatment time 2

The class of 2019, before matriculation, with no previous radiology training, served as a control population (control A). The class of 2017 followed the traditional curriculum with radiology training starting in their second year and were surveyed 3 months after the final examination of their second-year Diagnostic Imaging course (control B).

* $p \leq .05$ statistically significant between compared groups when analyzed using Fisher's exact test

radiology (27.4% TT2 and 27.7% TT1) compared to students with only late exposure (8.5% control B). Similarly, although a large number of students in all groups with exposure to radiology planned to take "at least one radiology elective" during the clinical year (41.5%–45.2%), students with early exposure to radiology (TT2 and TT1) more often indicated that they would take "at least one, possibly more electives" (11.3% TT2 and 10.8% TT1) compared to students with late exposure (6.4% control B).

Responses for the nine questions about content knowledge are presented in Table 5. There was one statistically significant difference between control B and TT2 and several between

Table 5: Summary of student responses to survey questions about knowledge of radiology and radioanatomy and ability to interpret radiographic abnormalities (questions 7–15)

	No. (%) respondents			
	Control A	Control B	TT1	TT2
7. Which of the following modalities does not involve ionizing radiation?				
n	58	47	65	62
Correct answer: ultrasound	38 (65.5%)	42 (89.4%)	62 (95.4%)	62 (100%)
Incorrect answers	20 (34.5%)	5 (10.6%)	3 (4.6%)	0 (0%)
p (control B vs. TT2)				.013*
p (TT2 vs. TT1)				.244
8. Which of the following diagnostic imaging tests is typically the most expensive?				
n	58	47	65	62
Correct answer: magnetic resonance imaging (MRI)	47 (81%)	43 (91.5%)	60 (92.3%)	58 (93.5%)
Incorrect answers	11 (19%)	4 (8.5%)	5 (7.7%)	4 (6.5%)
p (control B vs. TT2)				.724
p (TT2 vs. TT1)				1.000
9. Which of the following has the least radiation exposure for a patient and a technician holding or monitoring a patient?				
n	57	46	65	60
Correct answer: magnetic resonance imaging (MRI)	19 (33.3%)	23 (50%)	40 (61.5%)	28 (46.7%)
Incorrect answers	38 (66.7%)	23 (50%)	25 (38.5%)	32 (53.3%)
p (control B vs. TT2)				.845
p (TT2 vs. TT1)				.108
10. All of the following procedures are often done by a board-certified radiologist except:				
n	57	46	65	61
Correct answer: using endoscopy to remove an esophageal foreign body	29 (50.9%)	31 (67.4%)	47 (72.3%)	42 (68.9%)
Incorrect answers	28 (49.1%)	15 (32.6%)	18 (27.7%)	19 (31.2%)
p (control B vs. TT2)				1.000
p (TT2 vs. TT1)				.699
11. All of the following procedures can be done on an awake or sedated patient (e.g., they do not require general anesthesia) except:				
n	57	46	65	61
Correct answer: magnetic resonance imaging (MRI)	33 (57.9%)	38 (82.6%)	58 (89.2%)	57 (93.4%)
Incorrect answers	24 (42.1%)	8 (17.4%)	7 (10.8%)	4 (6.5%)
p (control B vs. TT2)				.120
p (TT2 vs. TT1)				.532
12. Based on the radiographs below, what is your primary differential for the radiographic lesion in this panting Labrador retriever?				
n	59	44	65	61
Correct answer: pericardial effusion	7 (11.9%)	25 (56.8%)	10 (15.4%)	25 (41.0%)
Incorrect answers	52 (88.1%)	19 (43.2%)	55 (84.6%)	36 (59.0%)
p (control B vs. TT2)				.118
p (TT2 vs. TT1)				.002*

(Continued)

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	No. (%) respondents			
	Control A	Control B	TT1	TT2
13. Based on the images below, what is the primary differential for the radiographic lesion in this vomiting cat?				
n	59	43	65	*60*
Correct answer: linear foreign body	4 (6.8%)	25 (58.1%)	7 (10.8%)	33 (55.0%)
Incorrect answers	55 (93.2%)	18 (41.9%)	58 (89.2%)	27 (45.0%)
p (control B vs. TT2)				.841
p (TT2 vs. TT1)				<.001*
14. In the radiograph of a horse below, what is the structure marked with an asterisk (*)?				
n	59	43	65	60
Correct answer: fourth tarsal bone	1 (1.7%)	27 (62.8%)	59 (90.8%)	44 (73.3%)
Incorrect answers	58 (98.3%)	16 (37.2%)	6 (9.2%)	16 (26.7%)
p (control B vs. TT2)				.285
p (TT2 vs. TT1)				.017*
15. In the radiograph below, at which of the numbered positions would you look to evaluate the left atrium?				
n	59	43	65	60
Correct answer: 5	0 (0%)	22 (51.2%)	28 (43.1%)	42 (70.0%)
Incorrect answers	59 (100%)	21 (48.8%)	37 (56.9%)	18 (30.0%)
p (control B vs. TT2)				.065
p (TT2 vs. TT1)				.004*
Mean score (of all 9 knowledge questions)				
n	59	43	65	60
Average score (*SD*)	33.0% (16.0)	68.2% (15.0)	63.4% (13.0)	71.5% (15.0)
p (control B vs. TT2)				.273
p (TT2 vs. TT1)				.001*

TT2 and TT1. When comparing control B versus TT2, 89.4% of control B students correctly responded that ultrasound was the modality that did not use ionizing radiation (question 7) versus 100% of TT2 students (p = .013). There were no other significant differences between control B and TT2.

In both radiograph interpretation questions (questions 12–13), TT2 students performed better than TT1 students, with 41.0% of TT2 students correctly diagnosing pericardial effusion (vs. 15.4% TT1, p = .002) and 55.0% correctly diagnosing a linear foreign body (vs. 10.8% TT1, p <.001). TT2 students also more often correctly identified the left atrium of a dog than TT1 students (70.0% and 43.1%, respectively, p = .004). In contrast, TT1 students more often correctly identified the fourth tarsal bone of a horse than TT2 students (90.8% and 73.3%, respectively, p = .017). There were no statistically significant differences in responses between TT2 versus TT1 for the remaining content knowledge questions.

As with the attitude questions, we noted some additional interesting findings despite a lack of statistical significance; for example, a high percentage of all three groups of students with exposure to radiology correctly responded that magnetic resonance imaging (MRI) was usually the most expensive modality (91.5%–93.5% of students) and that MRI typically requires anesthesia (82.6%–93.4% of students), but fewer remembered that it did not involve ionizing radiation exposure to patients or technicians (46.7%–61.5%).

For comparisons of the average score for the nine content knowledge questions, there was no statistically significant difference between control B versus TT2 (68.2% vs. 71.5%, respectively). However, TT2 did have a significantly higher average score (71.5%) than TT1 (63.4%, p = .001).

DISCUSSION

The primary goal of this study was to identify any short-term benefit following the addition of a novel, first-year radioanatomy course to a curriculum that already contained a second-year Diagnostic Imaging course. As expected, students with early and early and increased exposure to radiology found radiology more interesting than other specialties. Unexpectedly, students with early and increased exposure to radiology only outperformed students with late and less exposure to radiology on one content knowledge question. Students with early and increased exposure to radiology outperformed students with only early exposure on questions of radiograph interpretation. Unexpectedly, students with the early radioanatomy-focused exposure to radiology did not always outperform students with early and increased radiology exposure on questions of radioanatomy.

For all three groups of students with some radiology exposure, a high number reported that the specialty was at least "interesting in its own right," but students with early exposure were more likely to respond that it was "more interesting than other specialties." The statistical significance between control B versus TT2 but not between TT2 and TT1 for this question supports early interactions between students and specialists, particularly in the first year. Although not statistically significant, students with early (TT1) and early and increased (TT2) exposure to radiology did more often respond that they were at least considering a career in veterinary radiology, a finding which is supported by results in medical research looking at early integration of specialist-facilitated learning in pre-clinical training.[3,6] As with the previously noted interest in radiology compared to other specialties, the lack of difference between TT2 versus TT1 supports the role of specialists as educators in the first year of the curriculum.

For the content knowledge questions, there were several statistically significant differences; however, these were not always in the directions we expected. Despite the addition of a novel first-year course radiology course and an overall increase in total hours of radiology content within the first 2 years of the preclinical veterinary curriculum, only one content knowledge question showed statistical significance between control B versus TT2 (question 7 regarding modalities that utilize ionizing radiation). We feel this is an important area of difference, as ionizing radiation is an occupational safety hazard; however, the lack of other differences between control B and TT2 was an unexpected finding as a study in the medical field showed statistically significant improvement in student scores on tests of basic radiology knowledge following a redesigned preclinical curriculum with radiology training in the first year.[3]

Some study limitations may have prevented the identification of student group differences in academic performance. Many of the nine knowledge questions about medical imaging principles were developed using another study as a guideline.[3] Questions 7–9 and 11 related to medical imaging physics and radiation safety, material that was covered in the first-year course during an introduction to alternative imaging modalities; however, it is possible students did not retain this information as they may have been more focused on the larger learning objectives for the course related to normal radioanatomy. Question 10 addressing the role of a board-certified radiologist was not specifically covered in the learning objectives of either the first or the second-year course.

The statistically significant differences between TT2 versus TT1 for the interpretation and radioanatomy knowledge questions are interesting, but as expected based on the curriculum at the authors' institution. The second-year Diagnostic Imaging course largely focuses on the interpretation of abnormal findings on thoracic, abdominal, and musculoskeletal radiographs, while the first-year course focuses on normal radiographic anatomy. Thus, we expected that TT2 students would outperform TT1 students for interpretation questions. Perhaps more interesting is that TT1 students outperformed TT2 for the identification of the fourth tarsal bone in a horse radiograph, but did worse than TT2 on identification of the left atrium in a dog radiograph. This difference in retention of large versus small animal radioanatomy may be multifactorial. Though the first-year radioanatomy course is approximately 75% small animal and 25% large animal anatomy, the first-year Gross Anatomy course, which the radioanatomy course is designed to follow, is more evenly divided with nearly an entire semester devoted to both small and large animal anatomy. In the second-year Diagnostic Imaging course, approximately 2 lecture hours are devoted to equine musculoskeletal radiograph interpretation in the early part of the course, while 7 hours are devoted to small animal thoracic radiograph interpretation in the later part of the course. TT1 students would have more recent and even division of material and may, therefore, be more likely to retain equal amounts of large and small anatomy compared to TT2, leading to better performance on the large animal anatomy question. TT2 students would have had a more recent exposure to thoracic radiographs and may, therefore, be more likely to retain knowledge of where structures are located. Another possibility is that by second year, many TT2 students may have decided an area of interest (e.g., small animal practice vs. large animal practice) and may have decided to selectively retain the material they feel is relevant to their area of interest.

Another study limitation that may have limited the ability to identify statistically significant results was that the authors were unable to use each class as their own control, as the curriculum changes had already been in place for a year before the start of this study. It is possible that the three different veterinary classes simply had inherently different interests in the field of veterinary radiology.

Based on studies in the medical literature, we believe there may also be long-term positive effects of early integration of specialists in the pre-clinical veterinary curriculum that are not tested here. To address a concern for a shortage of human surgery applicants matching to residencies, one medical school found that even brief interactions with surgeons during the first year of medical school increased interest in pursuing surgery as a first- or second- choice career path.[7] Another study found that 59% of medical students made career choices before clinical-year clerkships,[8] further suggesting that early exposure to veterinary specialists could have a direct impact on student career choice. Long-term effects of adding radiology content to the first-year curriculum could be investigated by comparing student performance during the required senior year clinical radiology rotation with the total number of radiology curriculum hours. In addition, veterinary school graduate attitudes toward veterinary radiologists and career choices related to the specialty could be compared to the timing and total hours of radiology training both within the authors' institution and across multiple veterinary schools.

CONCLUSIONS

Despite providing early and increased radiology exposure to pre-clinical veterinary students and efforts to closely integrate a novel first-year Clinical Radioanatomy course with the existing course material, we found few statistically significant differences when comparing students following a traditional curriculum with radiology only in the second year and students following a modified curriculum with radiology training in first and second year. Although students with early and increased exposure to radiology reported significantly increased interest in the specialty, study limitations may have prevented the identification of statistical significance on other outcomes of interest. The study does suggest that there is a benefit to early and increased exposure to veterinary specialties in terms of increasing student interest in those fields and some short-term retention of knowledge. As the ACVR faces a shortage of radiologists, particularly in academia, it may be beneficial to increase student interest in and appreciation for the specialty of veterinary radiology.

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NOTES

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APPENDIX 1

Survey Questions Administered to Four Preclinical Veterinary Student Populations

Correct answers for questions of knowledge and radiographic interpretation abilities (questions 7–15) are marked in bold.

1. How much do you know about the specialty of veterinary radiology? If you answer "a," you will skip question 2 and be directed to question 3.
   a. I've never heard of veterinary radiology
   b. I have barely been introduced to veterinary radiology
   c. I am about as familiar with veterinary radiology as any other specialty
   d. I know a lot about veterinary radiology
   e. I know more about veterinary radiology than any other specialty

2. Which of the following best describes your prior experience with radiology?
   a. I have only passing experience with veterinary radiology
   b. My experience with veterinary radiology is peripheral, as a small part of different course
   c. I have had one or two lectures dedicated to radiology
   d. I have had several lectures, study sessions or a dedicated veterinary radiology course

3. How interesting is the subject matter in veterinary radiology?
   a. It is a dull subject
   b. Occasionally I find it interesting
   c. It is interesting in its own right
   d. It is more interesting than other specialties
   e. I do not know if I find veterinary radiology interesting or not

4. How likely are you to consider a career as a board-certified veterinary radiologist?
   a. Highly unlikely – I am not interested in a career as a veterinary radiologist
   b. Unlikely but it is possible
   c. I am considering specializing in veterinary radiology
   d. Veterinary radiology is my top choice for a career
   e. I haven't made a decision about my career at this time

5. Radiology is a required rotation in the fourth year. Will you take additional radiology electives (e.g., radiology, ultrasound, CT/MRI) during your fourth year?
   a. No, I will just take the required rotation
   b. I am not sure if I will take additional radiology electives
   c. I will likely take at least one radiology elective
   d. I plan to take at least one, possibly more radiology electives

6. What type of impact does the specialty of veterinary radiology have on patient care?
   a. Veterinary radiology has minimal impact on patient care
   b. Veterinary radiology occasionally changes patient care
   c. Veterinary radiology often changes patient care
   d. I don't know what impact veterinary radiology has on patient care

7. Which of the following modalities does not involve ionizing radiation?
   a. <u>Ultrasound</u>
   b. Computed tomography (CT)
   c. Digital radiography
   d. Nuclear scintigraphy
   e. Fluoroscopy
   f. I do not know

8. Which of the following diagnostic imaging test is typically the most expensive?
   a. <u>Magnetic resonance imaging (MRI)</u>
   b. Computed tomography (CT)
   c. Ultrasound
   d. Film screen radiography
   e. Digital radiography
   f. I do not know

9. Which of the following has the least radiation exposure for a patient and a technician holding or monitoring a patient?
   a. <u>Magnetic resonance imaging (MRI)</u>
   b. Computed tomography (CT)
   c. Digital radiography
   d. Film screen radiography
   e. I do not know

10. All of the following procedures are often done by a board-certified radiologist except:
    a. Filling the urinary bladder with a positive contrast agent to assess for rupture
    b. Biopsying a liver mass with ultrasound guidance
    c. Performing an esophagram under fluoroscopy to evaluate esophageal motility
    d. <u>Using endoscopy to remove an esophageal foreign body</u>
    e. I do not know

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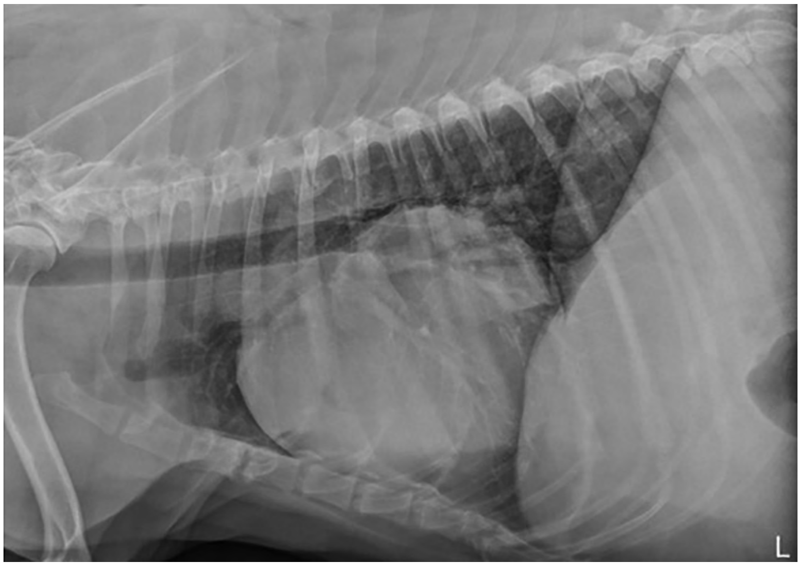
11. All of the following procedures can be done on an awake or sedated patient (e.g. they do not require general anesthesia) except
    a. Digital/film screen radiography
    b. Computed tomography
    c. Ultrasound
    d. Magnetic resonance imaging (MRI)
    e. I do not know

12. Based on the radiographs below, what is your primary differential for the radiographic lesion in this panting Labrador retriever?



    a. Nothing, this is a normal radiograph
    b. Right sided cardiomegaly
    c. Left sided congestive heart failure
    d. Pericardial effusion
    e. I'm not sure what this dog has

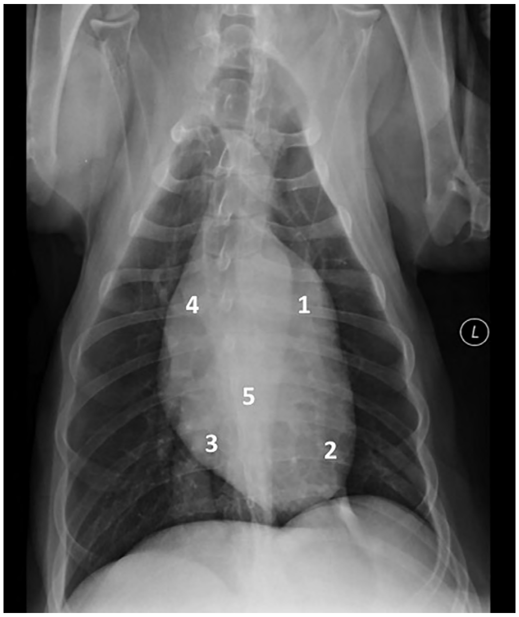
13. Based on the images below, what is your primary differential for the radiographic lesion in this vomiting cat?


    a. Nothing, this is a normal radiograph
    b. Severe enteritis
    c. Severe pancreatitis
    d. Linear foreign body
    e. I'm not sure what is wrong with this cat

14. In the radiograph of a horse below, what is the structure marked with an asterisk (*)?

a. Central tarsal bone
b. Fourth tarsal bone
c. Third tarsal bone
d. Second tarsal bone
e. I do not know/remember what the structure is

15. In the radiograph below, at which of the numbered positions would you look to evaluate the left atrium?



a. 1
b. 2
c. 3
d. 4
e. 5
f. I do not know/remember where the left atrium is

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