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Do students perceive use of sectional CT/MRI imaging as helpful in teaching of veterinary anatomy, and does it relate to visual spatial ability? A student survey and Mental Rotations Test.

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Abstract

Diagnostic imaging technology is becoming more advanced and widely available to veterinary patients with the growing popularity of veterinary-specific computed tomography (CT) and magnetic resonance imaging (MRI). Veterinary students must, therefore, be familiar with these technologies and understand the importance of sound anatomical knowledge for interpretation of the resultant images. Anatomy teaching relies heavily on visual perception of structures and their function. Additionally, visual spatial ability (VSA), positively correlates with anatomy test scores. We sought to assess the impact of including more diagnostic imaging, particularly CT/MRI, in the teaching of veterinary anatomy on the students' perceived level of usefulness and ease of understanding content. Finally, we investigated survey answers' relationship to the student's inherent baseline VSA, measured by a standard Mental Rotations Test. Inclusion of diagnostic imaging was viewed as quite useful and provided clear links to clinical relevance, thus improving the students' perceived benefits in its use. CT and MRI image use was not viewed as more beneficial, more relevant or more useful than the use of radiographs. Furthermore, students felt that the usefulness of CT/MRI inclusion was mitigated by the lack of prior formal instruction on the basics of CT/MRI image generation and interpretation. To be of significantly greater use, addition of learning resources labelling relevant anatomy in tomographical images used would improve utility of this novel teaching resource. The present study failed to find any correlation between student perceptions of diagnostic imaging in anatomy teaching and their VSA.

Key words: Student survey, learning technologies, anatomy, diagnostic imaging, visual spatial ability.

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Introduction

Veterinary anatomy is, by nature, a visual and tactile discipline, which necessitates an ability to perceive the three-dimensional arrangement of structures to interpret function. Advanced diagnostic imaging, such as computed tomography (CT) and magnetic resonance imaging (MRI), has improved the diagnostic power of veterinary imaging compared to traditional techniques, saving countless lives with its improved diagnostic sensitivity. It also allows presentation of teaching material in an innovative and clinically relevant manner. The detail provided in a CT/MRI scan allows a more comprehensive 3D representation of anatomy. Radiographic imaging is a very commonly employed technique in clinical practice, but a single image can only resolve detail in two dimensions (2D). It is, however, widely available and is still the most commonly used imaging method in veterinary practice. It provides good contrast between bone and soft tissue, but has limitations in its ability to resolve anatomical detail. Radiographic anatomy teaching forms <5% of anatomy teaching in medical schools in the USA, but its importance is becoming more and more evident.[1]

Diagnostic imaging is something that veterinary students in the early years of their study have traditionally found quite challenging, and part of the difficulty stems from the challenges associated with relating and interpreting a 2D image to what is a functional 3D structure. Visual-spatial ability (VSA) is the ability to mentally interpret and rotate 2D and 3D images. Interpreting both anatomical orientation of structures, and also their functional relevance based on an image is something that has caused difficulty for many students. As CT and MRI are able to resolve 3D detail more specifically, it seems logical that it should be easier to appreciate the 3D orientation of structures and interpret their function when compared to plain radiographs, however, CT and MRI images are mostly still viewed as a series of cross-sectional images, which instead presents a different challenge in spatial awareness as the viewer must still mentally generate a 3D image. VSA is important when interpreting any diagnostic image and relating it to existent knowledge of anatomy, and vice versa.

We recently increased the use of diagnostic images, such as radiographs, ultrasound, CT and MRI in teaching of veterinary anatomy. This aimed to improve students' familiarity and comfort with these images when exposed later in the clinical years of the curriculum. In addition to images of normal anatomy, inclusion of examples of imaging of disease and injury are included to help provide even further links to the clinical relevance of what is being taught.

Inclusion of radiology in the teaching and assessment of veterinary anatomy has been demonstrated to improve student engagement, whilst inclusion of a specific series of teaching and a separate examination component based on radiology was also received in a generally positive manner by students. It also encouraged the students to focus on the application of knowledge and clinical skills required for image interpretation, rather than rote learning of facts, thus promoting a deeper approach to learning.[2] Radiology provides a 2D projection through an area of interest so orthogonal projections of the region of interest are essential to help identify the 3D arrangement of anatomical structures. VSA is an important skill related to interpretation of multiple 2D representations of a 3D structure. This skill remains very important for clinicians using radiographs as demonstrated in a study of dental students[3]. CT and MRI both generate contiguous slices of a defined thickness allowing a series of images to be compiled as a matrix to represent a given volume of tissue scanned. These slices can then be digitally reconstructed into a manipulatable 3D image (Figure 1) or as multi-planar reconstructions (MPR) showing manoeuvrable x, y and z planes within a given volume of interest (Figure 2). This allows the user to appreciate the 3D dimensions and orientation of a given structure in any plane within a given volume. These theoretical benefits of CT and MRI theoretically mitigate some of the VSA required to interpret still images.

The use of tomographical imaging has been reported in relation to medical anatomy teaching. One study evaluated the use of CT images of the cadavers being dissected and reported strongly positive student perspectives and improved clinical radiology skills in later clinical years [4]. Lufler and others [5] showed that students who used a CT scan of the dissected cadaver were more likely to score higher in the practical examinations, end of unit score and, in particular, on spatial anatomy questions than those who did not use the CT scans. Other studies have demonstrated that a wider increase in computer-aided teaching material, in which CT/MRI imaging was included, in curricula, was evaluated as helpful in promoting student engagement, understanding and improving student understanding of complex anatomical systems [6-9]. Regarding imaging technique, CT and MRI were rated by medical students as best imaging modality used for one human anatomy course [8]. Increased inclusion of technological supplementary material (including CT/MRI images) also improved performance over dissection alone [10]. Reporting of use of CT/MRI in veterinary anatomy teaching is limited and has not included evaluation of use of tomographical/sectional image series' which are the form most commonly used for interpretation in clinical work.

Interpretation of complex diagnostic images is associated with VSA.[3] VSA has also been correlated positively with performance in human anatomy subjects[11,12] and conversely, completion of anatomy courses has also been reported to improve students' VSA.[11,13]

There is some evidence in the literature to suggest that inclusion of CT/MRI imaging in teaching of veterinary anatomy to students is more beneficial than use of radiographs alone. CT imaging was viewed by 75% of surgeons as the most important adjunct technology which should be used with cadaveric dissection for teaching of anatomy [14]. Lee et al [15] demonstrated that veterinary students taught with only 2D radiographs found identification of normal and abnormal anatomical structures on a thoracic radiograph more difficult to understand than those taught using 3D CT reconstruction images as well. This highlighted the fact that many veterinary students find interpretation of radiographs alone difficult, and inclusion of 3D reconstructed imaging, like in Figure 1, proved useful in improving understanding and test scores. Unlike in most human medical general practice, primary practice veterinary clinicians are expected to perform and interpret many diagnostic images themselves, rather than refer to a radiology specialist, as in human medicine. Interpretation of clinical CT/MRI imaging still remains, for the most part, the purview of veterinary specialists. Nevertheless, one might argue that ability to accurately interpret diagnostic images is a more important skill for veterinary general practitioners (GPs) than it is for human GPs.

The present study aimed to assess if inclusion of more diagnostic imaging, and in particular, advanced sectional imaging in the veterinary anatomy curriculum improved students' perceived usefulness of the content and also if they felt it changed their understanding of the anatomical detail taught. Furthermore, we aimed to determine if the students' responses related to their visual spatial ability. The study therefore had two main aims: (1) to survey 2nd year undergraduate veterinary students to establish their opinions/perceptions on the relative usefulness of different types of imaging in the teaching of veterinary anatomy; (2) to assess each student's Visual Spatial Ability using a Mental Rotations Test (MRT) and correlate this with their perceptions according to survey responses. We hypothesised that students would feel that the inclusion of tomographical imaging (CT/MRI) was more helpful than radiographs in the learning of anatomical detail by demonstrating better spatial arrangement of structures and also that students would feel the teaching demonstrated more clear relevance to their later clinical careers.

Methods

Students enrolled in the veterinary anatomy course in year 2 of the BVSc degree at the University of Bristol were surveyed using a Likert-Scale questionnaire with either 5 or 7 options to evaluate their perceptions of the effect of the inclusion of more diagnostic imaging in the revised veterinary anatomy curriculum. The full survey is shown in table 1. Topics specifically covered in the involved part of the course were musculoskeletal and neuro-anatomy. The survey was administered following the completion of all teaching pertaining to these two elements.

Teaching for these elements included a combination of didactic lectures and practical sessions. Lectures (33 x 1hr – 19 for musculoskeletal (appendicular, axial and skull) and 14 x 1hr for neuroanatomy (brain, peripheral nerves and special senses)) included interactive elements such as multiple-choice quiz questions using audience response handsets. Dissection/prosection-based cadaver practical classes (23 x 2-3hr sessions) generally involved students rotating through several stations examining separate defined regions of the anatomy related to that day's content. Some practicals involved student dissections. Lectures typically included diagnostic images on an *ad hoc* basis and practical classes generally devoted one (out of four or five) of the rotating stations to diagnostic imaging of the region of interest for the given practical session. The balance of radiographs to CT/MRI varied dependent on the region of study. For example neuroanatomy relied more heavily on MRI imaging, whereas limb anatomy relied more heavily of radiographic anatomy. This balance was based primarily on the clinical experiences of the primary author as a European Veterinary Specialist in Small Animal Surgery and also clinical availability of diagnostic imaging. For example radiographs are most commonly performed of the limbs, with a slowly increasing frequency of CT scanning of limb anatomy and disease, whereas MRI and CT are most commonly performed for problems of the brain, spine and thorax/abdomen. Radiographs were more commonly used in the course than CT, which was more commonly used than MRI. Ultrasound received the most limited use in the musculoskeletal and neuroanatomy elements as its sole use was to explore tendons and ligaments, however real time ultrasound was available to students within the practicals. Additional self-directed learning "Live" anatomy classes with use of barn animals for examination and palpation/manipulation and inclusion of further clinical diagnostic imaging were also provided to help students integrate the anatomical information learnt in lectures and cadaver sessions to the living animal and clinical case relevance (6 x 1hr sessions). Students are also provided one lecture on radiography fundamentals and one on ultrasound fundamentals in their first year of the BVSc programme, but only passing mention of CT/MRI fundamentals is given.

Students completed a summative examination based on the musculoskeletal anatomy element two months prior to completing this survey. Unfortunately application for Institutional ethical approval for use of anonymised examination scores to directly compare with the survey results and MRT scores was declined. The questionnaire was conducted using audience response handsets within an existing teaching session. Concurrently, a mental rotations test (MRT) was conducted on students[16]. The test was originally designed by Vandenberg and Kuse[17] and has subsequently been digitally rendered [18] for more accurate repeated reproduction. The test used in this experiment was the MRT-A version. Respondents are asked to match a given block figure to a selection of four other images. Two of which are true rotated representations, and two of which are incorrect representations of the original shape. Figure 3 demonstrates an example question used in the MRT. There are 24 test items, and candidates have a limited time to record their answers. The MRT tests a person's speed and ability to mentally rotate an image and match it to the possible options. Full details are described in the study by Peters et al[18].

For the survey, respondents were asked in question 4-7 to rate from 1-5 how useful they felt a given diagnostic imaging modality was for understanding the content of the unit involved. Question 8-18 involved rating level of agreement with a series of statements (ranked 1-7). A higher score represents a more positive response. See Table 1 for the survey questions/possible answers. As these answers presented a categorical data set, the median and inter-quartile range (IQR) are reported in Table 2. Where >2 questions were compared for similarity, (eg Q4-7) a Kruskal Wallis Test was performed. Where paired comparisons of responses related to radiographs vs responses related to CT/MRI were compared (Q8 vs 11, Q9 vs 12 and Q10 vs 13), a Wilcoxon matched-pairs signed rank test was performed.

Students were additionally encouraged to provide any free-text feedback they wanted regarding issues raised by the survey and any additional thoughts they felt were pertinent to the use of imaging in veterinary anatomy teaching.

MRT scores collected from the same student cohort from a concurrent study [16] were used. The whole cohort was used to calculate mean scores. Scores from the MRT are reported as mean ± standard deviation (Mean±SD). Data was tested for normality using the D'Agostino and Pearson Omnibus normality test. Scores between male and female respondents were compared using an independent-samples t-test. The data from respondents who had completed both the MRT and survey were used to perform Spearman's Rank test to determine if MRT score demonstrated any significant correlation with the answers reported for self-perceived VSA (Q3), usefulness of each modality for learning material (Q4-7), importance for learning clinical anatomy (Q8, 11), ease of interpreting images (Q9, 12) and usefulness for appreciating 3D relationships of structures (Q10, 13). Spearman's Rho (r_s) coefficient and p-value is reported for any that demonstrated a significant correlation. All statistical analyses were performed using GraphPad Prism v5.03 (La Jolla, CA, USA).

The study design was evaluated and approved by the Research Governance and Ethics Panel of the Faculty of Health Sciences for the University of Bristol (Study ID: 31501)

Results and analysis

A total of 108 students (of a total of 149 enrolled in the entire course) completed the survey (18 male, 84 female and 6 preferred not to answer), although not all respondents answered all questions. Sixty-nine students completed the Mental Rotations Test (MRT) as part of a concurrent study [16]. Of the students who completed the MRT, 50 also completed the survey (10 males, 40 female) allowing correlation of their survey answers with their MRT scores.

Table 1 lists the number of respondents, mean score, maximum possible score and SD for the MRT scores and also for all Likert Scale questions from the survey (Q3-18). Mean MRT score was 11.13 ± 4.17. This data was normally distributed (p=0.21). When divided by gender, males (n=10) scored significantly higher than females (n=39) (13.9±1.1 vs 10.33±0.67, p=0.016). Students perceived their VSA as average to good (Median 4 (out of 5) IQR 3-4). This demonstrated a moderate correlation with the scores achieved on the MRT (r_s=.54, p<.0001). Male students were also more likely to perceive their VSA as better than females (Males 4.11±0.58 vs Females 3.41±0.84, p<0.001). The variance remains still quite high, so it also highlights the fact that many students do not have a good understanding of their actual visual spatial ability, as measured by the MRT.

Using a Kruskal Wallis test, the perceived usefulness reported for each type of diagnostic imaging (Table 1, Q4-7) was not significantly different between differing imaging modalities. MRT score did not show any correlation with reported usefulness for any imaging modality (p>0.05).

When comparing responses (median (IQR)), between questions pertaining to radiographs and questions pertaining to CT/MRI for use during teaching for veterinary anatomy using Wilcoxon matched pairs signed rank test (Q 8, 11), radiographs were viewed as more important than CT/MRI for learning clinical anatomy (7 (6-7) vs 6 (5-7) respectively, p<0.0001). Furthermore, radiographs were perceived by students to be easier to interpret than CT/MRI (Q9, 12) (5 (3-5) vs 4 (3-5) respectively p=0.0033). Importantly, the level of agreement with statements regarding ease of interpreting for both radiographs and CT/MRI was much lower compared to the perceived importance of each modality. This suggests that although students are able to appreciate that diagnostic imaging is very important in terms of clinical relevance, they still continue to find all imaging somewhat difficult to interpret. When examining the usefulness for appreciating 3D arrangement of structures in anatomy practicals (Q 10, 13), there was no significant difference between reported radiograph vs CT/MRI scores (p=0.3102). In this vein, students also did not seem to agree or disagree that CT/MRI was superior to radiographs for 3D spatial interpretation (Q14)(4.5 (4-6). MRT score did not correlate with any of the reported answers for radiographs or CT/MRI (p>0.05).

Students agreed that imaging added value to the practical sessions (Q15)(5 (5-6), and they also had a slight preference for inclusion of more diagnostic imaging anatomy in the anatomy course (Q16)(5 (4-6). Students agreed that better grounding in the basics of diagnostic imaging interpretation would be beneficial when approaching the content for veterinary anatomy (Q17)(6 (5-7). Interestingly, CT/MRI imaging was only viewed to be slightly beneficial at helping appreciate clinical relevance (Q18)(5 (4-6).

Finally, whilst very few students completed feedback comments (8/108), the most recurrent comments from respondents to the survey focused on improving supporting information for the diagnostic images used with labelled images to help students confirm the identity of the structures they were viewing, especially while undertaking content revision. Additionally, students wanted us to include teaching on the fundamentals of image interpretation to improve their understanding of the images themselves.

Discussion

This study has demonstrated that the use of diagnostic imaging during the teaching of veterinary anatomy is perceived by veterinary students as highly relevant to clinical veterinary practice. All types of diagnostic images were viewed as very useful, particularly for identifying and appreciating 3D orientation of anatomical structures. Intriguingly, students reported a greater importance for radiographs than they did for CT/MRI scans. This is understandable, as most veterinary GPs will have access to, and regular use of radiographs, but limited exposure to CT or MRI scans. The most frequent clinical exposure that veterinary students will have at the early part of the course is with their local primary care veterinary practice whilst doing work-experience/extramural studies, so this experience forms their clinical “frame of reference” and thus visualising radiographs probably promotes a greater feeling of clinical relevance for these students.

The type of diagnostic imaging did not appear to influence students’ opinions of usefulness to learning of anatomy. All imaging types were rated between moderately and quite useful (mean 3.52 – 3.83). Radiographs did score the highest usefulness rating, although this was not significantly different to the other types of imaging (CT, MRI and ultrasound). This indicates that students are very aware of the clinical relevance of these technologies for their future careers and are invested in engaging with them to improve their understanding of both the anatomy and imaging.

The perceived importance of radiographs for learning clinical anatomy was rated higher than for CT/MRI scans, indicating students felt that learning radiographic anatomy is probably more relevant to their learning and future careers than learning CT/MRI anatomy. This is unlike a similar study performed of medical students, where CT and MRI were both rated very highly [8]. Additionally, more students in the present study agreed that interpreting radiographs was easier than those that felt interpreting CT/MRI images was easy. Radiographs provide a more holistic view of the region being imaged, whilst CT and MRI slices only provide a single section of the anatomy in question. To appreciate the anatomy fully in a CT or MRI scan, one must view the entire series together, cycling through the contiguous images to help generate the 3D image in their mind. Some of the methods of image presentation used during the course did not allow for easy display of the images in this manner, mostly due to technological limitations (e.g. single images presented on a lecture slide). This may have influenced the slightly lower rating of importance for the CT/MRI over radiographs as occasionally they could not be displayed optimally.

The reported slight (non-significant) student preference for radiographs over CT/MRI for importance and ease of interpreting is at odds with surgeons, who viewed CT as most valuable for teaching of surgical anatomy.[14] Furthermore, as highlighted by studies in medical programmes, inclusion of CT/MRI images in the teaching for anatomy improved performance and engagement and provided long-term benefits in clinical skills compared to teaching with radiographs alone [6-10]. This probably links with the improved ability for students to appreciate the 3D orientation of the anatomy using these advanced modalities.

The slight preference for radiographs over CT/MRI evident in this study may also relate to the relative exposure of students to the respective imaging modalities. Whilst sectional imaging is becoming much more prevalent and popular within veterinary practice, radiographs are still the predominant form of diagnostic imaging, and as such, still constitute the majority of the images used in the teaching of the course associated with this study and the majority of the images taken and viewed by students in clinical practice. Further studies more precisely defining the relative contributions of sectional imaging versus the contributions of radiographic imaging in veterinary anatomy courses are necessary to better delineate the respective benefits of each type of imaging modality. The data from this preliminary survey of student perceptions should be used to help guide further experimental design of prospective interventional studies.

VSA was only tested in a sub-population of the survey cohort, but in those who participated in both, VSA was better in male students than in female students. VSA has been repeatedly demonstrated as one of the few sex-linked cognitive skills [3,12,19-21]. This study supports these prior findings. The reported mean MRT score (11.13±4.17) for the standardized Vandenberg and Kuse MRT-A test of this cohort of veterinary students was within the reported ranges for medical students tested with the same test (range 8.13 to 14.6) [3,12,20,22,23]. Peters et al [24], in a large, international collaborative study testing 3367 people, demonstrated a significant effect of the subject's academic programme on the relative MRT scores achieved so comparison between students from medical courses and veterinary courses may actually be invalid.

Perceived VSA was correlated with the actual MRT score, but only a moderate correlation ($R^2 = 0.309$) shows that students are not very good at self-assessing their actual visual spatial ability. However, the perceived VSA was, like actual MRT score, also affected by gender – males were more likely to report a greater VSA than females. It is fairly widely stated that men generally have a better VSA, so this gender-dependant difference in self-reporting of VSA may be partly societally inherent bias, with men feeling they are likely to have a better VSA.

Interestingly, MRT scores did not correlate to students' agreement with any statement in the survey. It seems logical that students with a higher MRT would agree more with statements about the ease of interpreting diagnostic images, however this does not appear to be the case for this cohort. The reported usefulness of the images for learning, doesn't necessarily need to correlate with MRT scores, as perceived usefulness isn't just based on VSA. Use of imaging improved interest and perceived importance and thus encourages a deeper approach to learning, regardless of a given student's VSA.

Alternately, the lack of correlation and agreement with the hypothesis could be explained by relatively small sample size, however, almost half of the survey cohort (50/108) also completed the MRT, which should be able to detect at least moderate correlations with adequate statistical power (evident by the significant correlation detected between perceived VSA and MRT scores). Statistical power calculation revealed that to determine a similar effect size as seen with the correlation seen between MRT and self-reported VSA, a sample size of 31 would be required to have $\alpha<0.05$ and $\beta<0.05$ (indicating the chances of either a Type I or Type II statistical error are less than 5%). Our sample size of n=50 appears to be a sufficient sample to detect a moderate effect. This power calculation was performed post-hoc based on the results achieved in this study. This power calculation should be kept in mind when designing future studies of similar nature.

Lack of familiarity with CT/MRI images and the methods with which to interpret them is likely a major cause of the findings seen in this study. Introduction to CT/MRI scanning is currently given at a very rudimentary level in a small part of one lecture in Year 1 of the veterinary programme. Failure to introduce the fundamental aspects of how CT or MRI images are generated prior to, or during, the anatomy lectures is likely to have led to a general reduction in confidence when interpreting this type of image. This could also easily explain the preference for radiographs as these are far more familiar to the students, having had more instruction in interpreting them and wider exposure to these in the Year 1 anatomy course and during their visits to veterinary clinics during work-experience. A specific subject element based on radiographic anatomy in an anatomy course described in one report received positive feedback from students and also improved examination performance, encouraging a deeper approach to learning [2]. Significantly, the lack of specific teaching related to diagnostic image interpretation was viewed as a limitation by students completing the current survey.

The data in this report is limited by the nature of the data collection. Likert scale questionnaires have inherent weaknesses. Lozano et al [25] demonstrated using experimentally modelled data that Likert scale questions should have between 4 and 7 items. Less than 4 items reduces content validity and reliability, and more than 7 items does not demonstrate any further increase in psychometric properties. There is further disagreement as to whether Likert scales should have an even or uneven number of responses. Having a neutral response option may encourage respondents to select this rather than make a decision. Increasing the number of response options reduces the number of respondents selecting the neutral option [26]. The effect of removal of a neutral point from Likert questions appears to be content specific with different studies finding both positive scoring effects [27] and negative scoring effects[28] We felt that our questions did not need to force respondents into a positive or negative opinion, so included 5-point (Q4-7) and 7-point (Q8-18) questions. Furthermore, as with all survey-based questions, a respondent's answer relies on their personal interpretation of both the inciting question and also the wording of the possible answers. Although there is inevitably some variability between survey participants,

Additionally, our study could have done more to specifically separate student's opinions on the benefits of radiographs specifically relative to CT/MRI. Only one of the questions in the survey specifically asked respondents about the relative merits of CT/MRI over radiographs, and this question returned an equivocal response. Furthermore, surveying students' opinions does not evaluate the actual effect of the intervention on students' behaviour and approach to learning. Further research into the effects of inclusion of diagnostic images into the subject curriculum should include objective outcomes, such as examination scores, which could also be correlated with VSA scores. This type of intervention poses several experimental ethical dilemmas which would require careful consideration when planning experimental design. Similarly a cohort-control study where some students receive the CT/MRI imaging with teaching and others do not to provide a more controlled comparison also poses ethical dilemmas and would require careful consideration and forward planning with full and informed consent of all participants.

Conclusions

Students perceived the inclusion of diagnostic imaging to be useful, important and to add value to the teaching provided in a veterinary anatomy course, suggesting that its inclusion improves student interest and encourages a deeper approach to learning, although objective outcome measures need to be pursued to confirm this preliminary inference. Contrary to our hypothesis, the specific use of CT and MRI images was not viewed by students as more beneficial, more relevant or more useful than the use of radiographs, despite the fact that majority of clinical surgeons feel CT imaging is the most beneficial modality for teaching anatomy. This disparity should be considered in future when developing further research and potential changes to curriculum. Students felt that the usefulness of CT/MRI inclusion was mitigated by the lack of formal instruction on the basics of CT/MRI image generation and interpretation suggesting that introduction of a defined element early in the veterinary course dedicated to the fundamentals of CT and MRI image creation and interpretation would assist students in being better prepared for the inclusion of sectional imaging in veterinary anatomy courses. VSA did not correlate to any of the student survey responses regarding perceived usefulness or ease of interpretation, however, this study reports only the perceptions of students rather than objective outcome measures, such as examination scores. Further work should build on this preliminary data to focus on better differentiating the respective effects of radiographs and CT/MRI on student perceptions and learning within an anatomy course and examining objective outcome measures following these interventions such as MRT scores before and after inclusion of the CT/MRI images. Despite the inherent limitations of a student perceptions survey, we still feel this survey of veterinary students' perceptions of diagnostic imaging use in anatomy teaching illustrates some important and useful information that can be used to help guide curriculum design and development in future.

Figure legends

Figure 1 - 3D reconstruction of the bones of a dog's forearm. These images can be manipulated in any plane to view any aspect of the structure of interest.

Figure 2 - Multiplanar reconstruction (MPR) of the same canine forearm as in Figure 1. The raw axial/transverse images, seen in the bottom left corner of the image, are digitally reformatted to generate images in the two other planes (saggital and frontal). The coloured lines represent the location of the images for the other corresponding images.

Figure 3 - Example question for the MRT-A test. 24 similar questions are used in the actual test and students have a total of 6 minutes to complete the test. The time limit is an important part of the assessment as those with better VSA can identify the correct answers more quickly[18].

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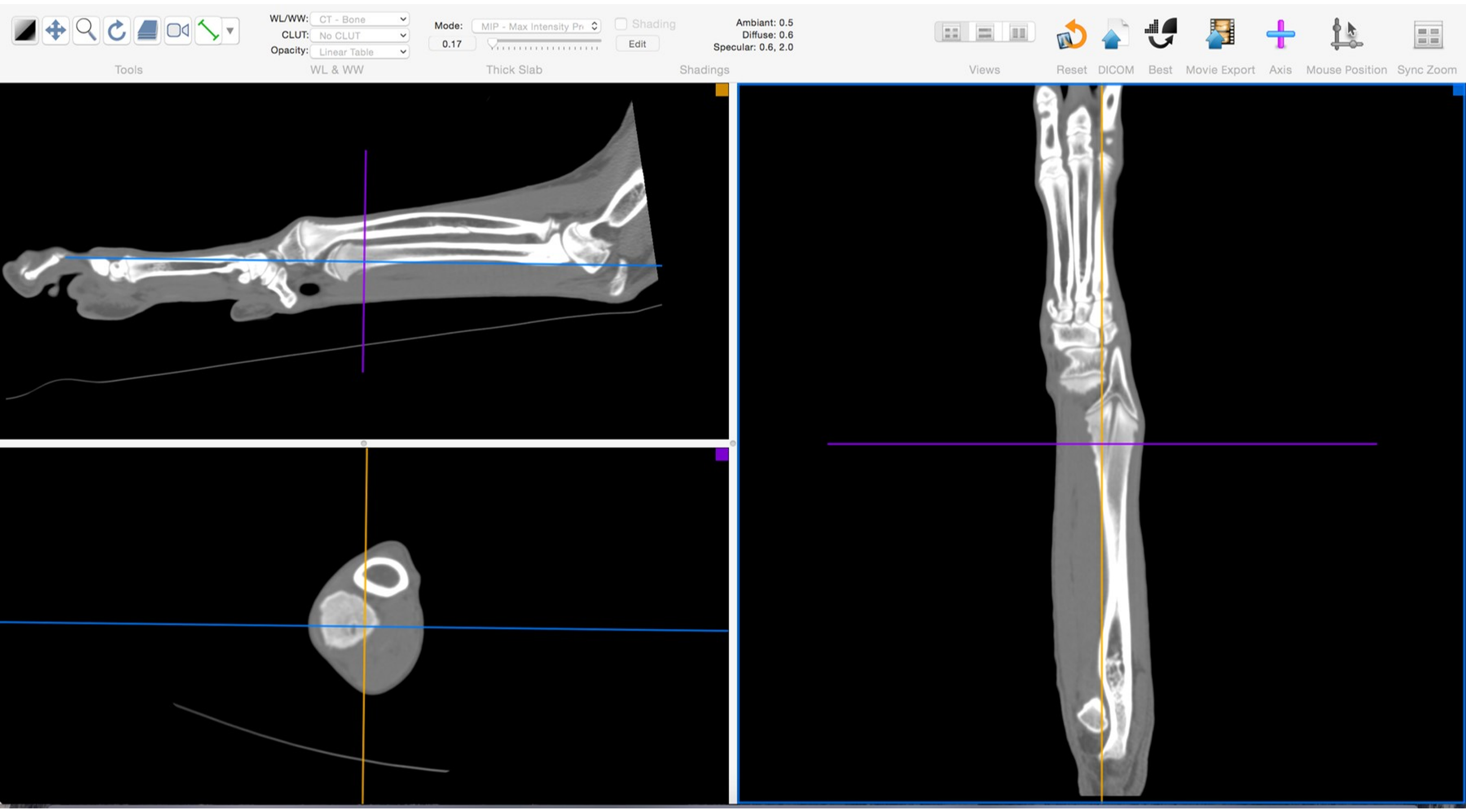
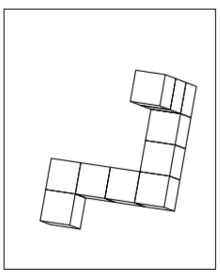
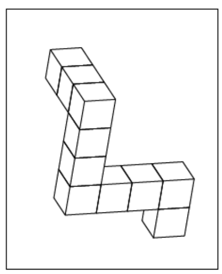


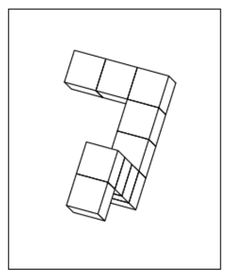
WL/WW:
CT - Bone
CLUT:
No CLUT
Opacity:
Linear Table
Mode:
MIP - Max Intensity Pr
0.17
Shading
Edit
Ambiant: 0.5
Diffuse: 0.6
Specular: 0.6, 2.0
Tools
WL & WW
Thick Slab
Shadings
Views
Reset
DICOM
Best
Movie Export
Axis
Mouse Position
Sync Zoom

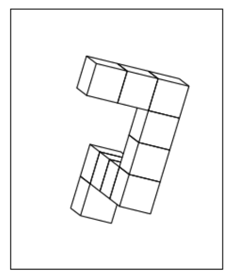
Now look at
this object:
1.

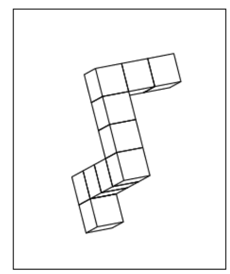


Two of these four drawings show the same object.
Can you find those two? Put a big X across them.









If you marked the first and third drawings, you made the correct choice.

Table 1 – Tabulated version of survey given to undergraduate BVSc students enrolled in a veterinary anatomy course. *The survey was conducted anonymously with students using electronic audience response handsets which automatically recorded their responses. 108/149 students enrolled in the course completed the survey.*

<table>
<tr><td>Q1 Are you:</td><td>A. Male?
B. Female?
C. Prefer not to answer?</td></tr>
<tr><td>Q2 Did you complete the Mental Rotation Test for the concurrent study?</td><td>A. Yes
B. No</td></tr>
<tr><td>Q3 Visual spatial ability is defined as the ability to mentally manipulate two-dimensional (2D) and three-dimensional (3D) figures. How would you rate your Visual Spatial Ability?</td><td>1. Very Poor
2. Poor
3. Average
4. Good
5. Very Good</td></tr>
<tr><td colspan="2">When trying to understand the material delivered in AHS2 anatomy lectures, how useful did you find inclusion of:</td></tr>
<tr><td>Q4 Radiographs?</td><td rowspan="4">1. Not at all useful
2. Slightly useful
3. Moderately useful
4. Quite useful
5. Extremely useful</td></tr>
<tr><td>Q5 CT scans?</td></tr>
<tr><td>Q6 MRI scans?</td></tr>
<tr><td>Q7 Ultrasound?</td></tr>
<tr><td colspan="2">Please rate your level of agreement with the statements using the following options:</td></tr>
<tr><td>Q8 Radiographs are an important part of learning clinical anatomy needed for a veterinarian.</td><td rowspan="11">1. Strongly disagree
2. Disagree
3. Slightly disagree
4. Neither Agree nor Disagree
5. Slightly agree
6. Agree
7. Strongly Agree</td></tr>
<tr><td>Q9 I find radiographs easy to interpret.</td></tr>
<tr><td>Q10 Radiographs were useful in the practicals to help appreciate the 3D relationship of certain structures with others.</td></tr>
<tr><td>Q11 CT/MRI scans are an important part of learning clinical anatomy needed for a veterinarian.</td></tr>
<tr><td>Q12 I find CT/MRI scans easy to interpret.</td></tr>
<tr><td>Q13 CT/MRI scans were useful in the practicals to help appreciate the 3D relationship of certain structures with others.</td></tr>
<tr><td>Q14 CT/MRI imaging is better than radiography to allow me to appreciate the 3D orientation of structures.</td></tr>
<tr><td>Q15 Diagnostic imaging adds value to dissection/ prosection based teaching.</td></tr>
<tr><td>Q16 Greater emphasis should be placed on teaching basics of diagnostic imaging anatomy in anatomy units.</td></tr>
<tr><td>Q17 Diagnostic imaging would be more useful when learning anatomy if I were better grounded in the basics of reading radiographs and CT/MRI images before starting.</td></tr>
<tr><td>Q18 Use of CT/MRI imaging helped me to better appreciate the clinical relevance of what we were covering.</td></tr>
</table>

Table 2 ***Response data from Mental Rotations testing and student survey.*** *Students completed a survey using audience response handsets asking for their perceptions of various aspects of inclusion of diagnostic imaging in veterinary anatomy course and/or a Mental Rotations Test. Number of respondents, median scores, maximum possible score and Interquartile Range (IQR) of responses is reported. A higher median score indicates a more positive response. The full text of the questions asked of students is included in Table 1. There were a total of 108 respondents, although not every question was answered by every student. ** = p>0.01, *** = p<0.001 CT/MRI vs Radiographs (Q8 vs 11, Q9 vs 12 and Q10 vs 13) using Wilcoxon matched pairs signed rank test.*

Q #	Summarised statement (Full phrasing from survey is in table 1)	N	Median	Max. possible score	IQR
3	How do you rate your Visual Spatial Ability?	102	4	5	3-4
4	For understanding anatomy, how useful were Radiographs?	103	4	5	3-5
5	For understanding anatomy, how useful were CT scans?	100	4	5	3-4
6	For understanding anatomy, how useful were MRI scans?	100	4	5	3-4.75
7	For understanding anatomy, how useful was ultrasound?	93	4	5	3-5
8	Radiographs are important for clinical anatomy for vets	102	**7 *** **	7	6-7
9	Radiographs are easy to interpret	92	**5 ** **	7	3-5
10	Radiographs are useful to appreciate 3D relationship of certain structures with others	92	5	7	4-6
11	CT/MRI is important for clinical anatomy for vets	95	6	7	5-7
12	CT/MRI is easy to interpret	91	4	7	3-5
13	CT/MRI is useful to appreciate 3D relationship of certain structures with others	84	5	7	4-6
14	CT/MRI is easier than Radiographs for appreciating 3D orientation of structures	86	4.5	7	4-6
15	Diagnostic imaging adds value to dissection/prosection-based practicals.	81	5	7	5-6
16	Greater emphasis should be placed on basics of diagnostic imaging anatomy in anatomy units	88	5	7	4-6
17	Diagnostic imaging would be more useful when learning anatomy if I were better grounded in the basics of reading radiographs and CT/MRI images before starting	74	6	7	5-7
18	CT/MRI helps me better appreciate clinical relevance	73	5	7	4-6