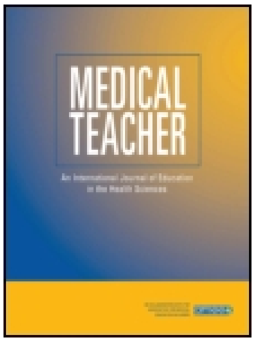

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WEB PAPER

Direct correlation of radiologic and cadaveric structures in a gross anatomy course

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Abstract

Background: Radiologic imaging is increasingly utilized as supplemental material in preclinical gross anatomy courses, but few studies have investigated its utility as a fully integrated instructional tool.

Aims: Establish the benefit of a teaching method that simultaneously correlates cadaveric and radiologic structures for learning human anatomy.

Method: We performed a mixed-methods randomized controlled trial and one-way cross-over study comparing exam grades and subjective student perception in a gross anatomy course. The intervention consisted of daily direct correlation small group sessions in which students simultaneously identified and correlated radiologic and cadaveric structures. The control method utilized identical laboratory and teaching conditions but students did not simultaneously correlate structures. Spatial relationships of structures within each respective media (gross or radiologic) were emphasized in both groups.

Results: No significant differences in radiology, gross, or written exam scores were observed between the intervention and control groups. The cross-over group preferred the intervention and control methods equally. The correlation teaching sessions ranked equally with active dissection as the most important instructional components of the course.

Conclusion: Direct, simultaneous correlation of radiologic and cadaveric structures did not affect exam scores or student preference but helped students understand anatomical concepts in comparison with other course components.

Introduction

The movement to utilize radiologic imaging in anatomy instruction continues to grow internationally. Calls for undergraduate medical students to have deeper anatomical understanding (Miller et al. 2002; Fitzgerald et al. 2008; Mukhtar et al. 2009) and more exposure to radiology (Squire 1969; Subramaniam et al. 2005) have led to a myriad of teaching methods that merge the two fields.

The most commonly reported methods to incorporate radiology with anatomy instruction include concurrent radiology lectures (Sullivan et al. 1987; Squire 1989; Erkonen et al. 1992), small group learning with (Forrester 1971) and without (Tegtmeyer et al. 1974; Whitley 1977) formal instructors, and radiologic images of de-identified patients in the dissection laboratory (Squire et al. 1975; Reidy et al. 1978; Bassett & Squire 1985; Turmezei et al. 2009). Others include problem-based learning (Navsa et al. 2004; Subramaniam et al. 2004; Subramaniam 2006), ultrasound workshops using students and human models (Teichgraber et al. 1996; Wittich et al. 2002), and radiologic imaging of dissection laboratory cadavers (McNiesh et al. 1983; Hisley et al. 2008). Notably, no reported methods to our knowledge formally teach cadaveric and image structures simultaneously – in the same time and space – with an emphasis on relationships between the same structures of different representations.

The ability to mentally toggle between the three- and two-dimensional representations of structures in cadavers and radiologic imaging requires mental rotation skills and conceptual understanding (Squire 1969). Both components have been shown to improve anatomical knowledge. For example, mental rotation activities unrelated to anatomy have been shown to quantitatively improve anatomy exam scores (Hoyek et al. 2009). In addition, studying spatial relationships of structures yields deeper conceptual understanding and improved anatomy exam scores (Mattick & Knight 2007; Pandey & Zimitat 2007).

Thus, we hypothesize that simultaneous formal instruction of cadaveric and gross structures will result in improved anatomical knowledge compared with traditional teaching methods. In particular, we expect improved anatomical

Practice points

- Students reported that radiologic imaging used in direct correlation with gross structures is an important component of comprehending anatomy.
- Direct correlation between cadaveric and radiologic structures did not demonstrate a significant empirical difference in exams.
- The methods by which radiologic imaging is used during a gross anatomy course should be carefully evaluated since not all methods demonstrate empirically significant differences in anatomical comprehension.

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knowledge will be reflected by higher exam scores and enhanced student preference for this method.

Methods

Study setting and participants

All protocols for this study were granted exemption status by the institutional review board, and written informed consent was obtained from all participants. All study participation was voluntary, blinded to instructors, and had no relationship with course grades.

Participants were recruited from the 102-member 2008 first-year class of a university medical school during the human anatomy course. The anatomy course and our study spanned two academic quarters. The gross laboratory component of the course lasted 3 hours each day. Five Medical Scientist Training Program students and one PhD student who began the course early were excluded from analysis.

Study design

Mixed methods comprised a prospective, single-blinded, randomized controlled trial, a one-way cross-over design, and a survey were utilized. Students were randomized into two groups: cross-over and intervention. The cross-over group experienced the traditional teaching method for the first half of the course and the intervention method for the second half. The intervention group experienced only the intervention method for the entire course. Thus, the first half of the study was a randomized controlled design and was followed in the second half by a one-way cross-over design with the control group (Figure 1). A randomized trial with a control group for the entire course was considered but rejected by the authors out of ethical concern for completely withholding a presumed beneficial intervention from students. A full cross-over design in which the intervention group experienced the control teaching method during the second half of the course was also considered. However, we anticipated that students may carry concepts of the intervention method into the control method phase, thus providing additional confounders to the data set.

Students were informed that various teaching methods would be utilized and studied during the course, but they were blinded to which components were being studied and which method they were experiencing. Control and cross-over groups were separated into two different sections of the dissection laboratory, divided by a wall, to maintain the integrity of the assigned teaching method. Four students were assigned to each cadaver table, and all students actively dissected.

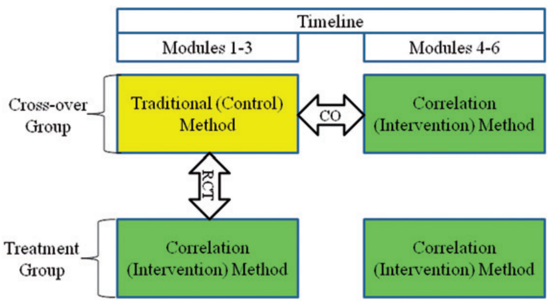

Figure 1. Study design diagram. CO, cross-over; RCT, randomized controlled trial.

Instruction methods

For the intervention teaching method, second- and fourth-year medical student teaching assistants (TA's) reviewed 15–20 pre-specified structures in both radiographic images and cadavers every day for 20 minutes during dissection in groups of approximately 10 students. Image structures were labeled and displayed on LCD panels within viewing distance of each cadaver, and cadaveric structures were dissected in the laboratory by students just before the image/cadaver correlation sessions.

During the correlation sessions, students *simultaneously* identified structures on both an image and a cadaver during TA instruction, making note of the three-dimensional spatial relationships and tissue densities in both. Correlation between visualizing structures in the cadaver and in the images was emphasized (Figure 2). For example, students were often asked to match an axial image to its approximate location in a cadaver, then describe how the image would appear differently as image slices were taken superiorly or inferiorly to the aforementioned image.

The traditional method was identical to the intervention method with respect to images, structures identified, length of instruction, day and time, and instructors. However, no reference or correlation to cadavers was made. References to models were permitted in both intervention and

Figure 2. Demonstration of direct correlation of radiologic and cadaveric structures during daily teaching assistant small group teaching sessions.

traditional groups. Image structures were chosen for clinical relevance and image clarity by radiology faculty. Image modalities included computed tomography, magnetic resonance imaging, magnetic resonance angiography, X-ray imaging, angiography, sonography, and echocardiography. TA's rotated table assignments weekly and were monitored daily for adherence to the appropriate teaching method.

Data analysis

Multiple quantitative and qualitative measurements were used to best characterize various component impacts on learning, defined as exam scores, participant perception of integration and understanding of anatomy, and participant instructional method preference. Comparisons of demographic data between intervention and traditional groups utilized chi-square, Fisher's exact test, and *t*-tests, as appropriate.

Exams for each of six total body regions were composed of a radiology section, a gross anatomy section, and a written section. Radiology exams were composed entirely of new images that had never been previously seen by the students. Participant grades for each section type were compared between the traditional and intervention methods experienced during the randomized controlled phase of the study (first half of the course). To control for confounders, a mixed three-way ANOVA was performed. The randomization group (intervention vs. control) served as the between-subjects variable, and exam-type (radiology, gross, and written exams) and body region (thorax, abdomen, and pelvis.) served as the within-subjects variables, completed by all students. A power analysis assuming a moderate effect size (Murphy & Myors 2004) of $f = 0.25$, $\alpha \leq 0.05$, and $1\text{-}\beta = 0.80$ demonstrated a necessary sample $N = 98$ (Faul et al. 2007). Thus, variation in exam characteristics was accounted.

In a course conclusion survey, all participants were asked to rank (1 through 6, 1 = highest) the course's laboratory components with respect to influence on anatomical integration and understanding. Components included gross dissection, image/cadaver correlation, small group anatomy reviews, small group radiology reviews, a novel radiology study guide (Phillips et al. 2012), and guest physician clinical presentations. Average ranks were analyzed with a one-way ANOVA and compared with *Tukey's post hoc* test to account for multiple comparisons. During the same survey, participants in the cross-over group, which experienced both the traditional and intervention methods, were asked their preferences of the methods with regard to their personal definitions of learning and course goals. A power analysis for a two-tailed exact binomial goodness of fit test for a large effect size ($g = 0.25$, $\alpha \leq 0.05$, $1 - \beta = 0.80$) demonstrated a required minimum sample size, $N = 30$ (Faul et al. 2007). Class size limited the ability to detect a smaller effect size, but the comparison was deemed to be nonetheless worthwhile to observe the extent of impact of the intervention.

All data was entered into Excel 2007 (Microsoft Corporation, Seattle, WA) and calculated with SPSS version 18 (Statistical Package for the Social Sciences Corporation, Chicago, IL).

Results

Of the 96 students in the 2008 first-year class of medical students who met inclusion criteria, 89 students responded to the survey, yielding a 93% response rate and all consented for analysis of their exams. The cross-over group was composed of 48 respondents (54% of total) and the intervention group of 41 respondents. No significant demographic differences were observed between groups (Table 1).

There was not a significant main effect of intervention vs. traditional teaching method on exam scores, $F(1, 94) = 0.211$, $p = 0.647$. Significant main effects on exam grades were observed for exam type, $F(2, 188) = 195.38$, $p < 0.001$, and for body region, $F(2, 188) = 4.59$, $p < 0.001$. Assumptions of sphericity were not met for the interaction effect of exam type and body region, Mauchly's test $\chi^2(9) = 41.16$, $p < 0.001$. A Greenhouse-Geisser correction ($\epsilon = 0.84$) demonstrated a significant interaction effect, $F(3.36, 315.89) = 57.60$, $p < 0.001$.

Table 1. Demographics of cross-over and intervention group participants.

Characteristics	Cross-over* $N = 48$	Intervention† $N = 41$	All participants	*p* value
Age, years ± SD	23.2 ± 2.6	23.9 ± 3.1	23.5 ± 2.9	0.23
Male sex, no. (%)	22 (46)	19 (48)	41 (47)	0.88‡
Bachelor's degree completed within 3 months of beginning medical degree, no. (%)	23 (48)	19 (46)	42 (47)	0.88§
Bachelor's degree in a basic science, no. (%)	34 (71)	24 (59)	58 (65)	0.23§
Previously attained advanced science degree, no. (%)	5 (10)	4 (10)	9 (10)	1.00¶
Parent(s) trained as physician, no. (%)	9 (19)	8 (20)	17 (19)	0.97§
Ethnicity, no. (%)				0.72§
African American	7 (15)	3 (8)	10 (12)	
Asian American	14 (30)	9 (24)	23 (27)	
Caucasian	22 (47)	21 (55)	43 (51)	
Native American	1 (2)	2 (5)	3 (4)	
Other	3 (6)	3 (8)	6 (7)	

Notes: *In the cross-over group, data were missing for one participant for age and one participant for ethnicity.
†In the intervention group, data were missing for one participant for age, one participant for sex, and three participants for ethnicity.
‡*p* value was calculated with the use of an independent *t* test.
§*p* value was calculated with the use of the chi-square test.
¶*p* value was calculated with the use of a two-sided Fisher's exact test.

Table 2. Ranked comparison by students of the human morphology laboratory course components with respect to influence on integration and understanding of anatomy.

Course component	Mean rank*	Ordinal rank	*p* value for ordinal rank comparisons† 1	2	3	4	5	6
Gross cadaver dissection	2.37	1	1.00	0.865	0.036	< 0.001	< 0.001	< 0.001
Gross and radiologic structure correlation	2.62	2		1.00	0.440	< 0.001	< 0.001	< 0.001
Classroom small group anatomy reviews	3.04	3			1.00	0.017	0.002	< 0.001
Self-guided radiology atlas tutorials	3.77	4				1.00	0.994	< 0.001
Classroom small group radiology reviews	3.89	5					1.00	< 0.001
Guest physician clinical presentations	5.01	6						1.00

Notes: *1 = Highest rank.
†*p* values calculated by *Tukey's post hoc* test.

Ranked course components differed significantly in their contributions to anatomy integration and understanding, F (5,484) = 37.7, $p < 0.001$. Students reported that cadaver dissection and cadaver/image correlation (intervention method) were equally the most helpful laboratory components (mean rank 2.37 vs. 2.62, respectively, $p = 0.865$). Small group anatomy review sessions in classrooms without cadavers led by staff members were equally as helpful as the image/cadaver correlations (3.04 vs. 2.62, respectively, $p = 0.440$), but not dissection (3.04 vs. 2.37, respectively, $p = 0.036$). The remaining laboratory components and their rankings are described in Table 2.

Participants in the cross-over group, who experienced both intervention and traditional teaching methods, were asked their personal preferences regarding the use of radiology in the anatomy course. Of 43 total responses, 21 participants (49%) preferred the approach that 'emphasizes gross anatomy correlations with radiological images'. The remaining 22 participants (51%) preferred the approach that 'emphasizes anatomy and includes radiology instruction as supplemental material'. The approaches were preferred equally (exact binomial test, $p = 1.000$).

Discussion

An instructional method that simultaneously and directly correlated radiographic and cadaveric structures was found to be generally equivalent to the traditional method as measured by exams and student preference, in contrast to our initial hypothesis. Notably, the correlation instructional method was also reported by students to be one of the most influential components of the course with respect to integration and understanding of anatomy, equivalent to dissection.

Exam performance

In a previous study that provided passive access to radiographic imaging during dissection, students reported that direct instruction and additional labeling would further potentiate the use of radiographic imaging in the anatomy laboratory (Turmezei et al. 2009). In addition, there is a long-held belief and evidence that mental rotation ability and spatial reasoning are necessary for both radiologic and gross anatomical comprehension (Squire 1969; Squire et al. 1975; Folan & de Montfort Supple 1986; Terrell 2006; Khalil et al. 2008). Moreover, a series of self-guided radiology atlas study modules that emphasized spatial relationships found a significant improvement in radiology and gross practical exam scores (Phillips et al. 2012). All suggest that direct, simultaneous instruction should enhance anatomical comprehension. The similar exam scores we observed between the control and intervention groups may provide clarity to the current concepts of instructional methods for the complex spatial relationships of human anatomy.

First, the equivalent exam scores may suggest that inanimate models are as effective as cadavers for image and physical structure correlation instruction since both the control and intervention groups were permitted to correlate image structures directly with models in the laboratory. It is plausible that the metacognitive lessons from the visualization process are more important than the specific type of three- and two-dimensional structures used to learn the process. This possibility is supported by the finding of Hoyek et al. (2009) that students who utilized mental rotation exercises that were unrelated to anatomy performed better on anatomy exams.

Alternatively, the equivalent scores may reflect an abundance of anatomy course components so that a single part contributed relatively little that was unique to the overall learning experience. The spatial reasoning objectives may have been sufficiently addressed in other course components. This possibility has important implications since contemporary gross anatomy courses are often composed of a multitude of components that have not only the potential to be mutually reinforcing but also distracting (Sugand et al. 2010).

It is additionally possible that the students who were motivated to grasp the deeper anatomical understanding offered by the intervention would have grasped the information without direct instruction. Smith and Mathias demonstrated that individual students choose different levels of learning approaches: deep, strategic, and superficial (Smith & Mathias 2007). Thus, it is plausible that students in both control and intervention groups who implicitly chose deep approaches gained the conceptual understanding by their own course of study, regardless of the intervention. Those students who chose superficial or strategic approaches may have limited their ability to benefit from the intervention.

Perceived influence of the teaching method on learning anatomy

The equal ranking of active dissection and post-dissection cadaver/image correlation contributes to the extensive debate around the value of dissection versus prosection. Our findings support the mixed literature that suggests the two environments are essentially equal in their instructional potential and that students learn from both (McLachlan & Patten 2006; Winkelmann 2007; Winkelmann et al. 2007). It is notable that the image/cadaver correlation instruction was only 20 minutes each day, considerably less than the remaining 2 hours 40 minutes of the dissection laboratory. The nonetheless equivalent ranking may be due to the timing of the correlation method at the end of the dissection laboratory during which students had been reviewing identities and locations of gross structures. There are no reported studies to our knowledge that assess the timing efficacies of radiologic interventions in gross anatomy (before, during, or after introduction to gross structures), and our observations suggest the need exists. These conjectures must be taken in the context that our study did not address why the shorter correlation instruction was as valuable to students as the extensive process of dissection, nor did it delineate physical dissection and study of completed dissections. Nonetheless, the observation is quite remarkable and suggests that direct correlation instruction on previously dissected cadavers promotes more focused instruction and learning than active dissection.

Additional influence

Direct correlation instruction of radiologic and cadaveric structures may bear merit beyond our end-points. The full extent of the correlation method's impact may yet to be observed because it cannot be realized until students begin clinical work. For example, the transfer gap between preclinical knowledge and clinical use is growing in recognition, and preclinical laboratories that incorporate clinical applications may help reduce the gap (Wilson et al. 2009). Direct correlation between cadavers of the preclinical laboratory with the corresponding radiology that will be used by the majority of students on a daily basis in their clinical practices may buffer the knowledge gap in ways that are difficult to measure.

Limitations

Our study is subject to several limitations. Of particular practical significance, the anatomy TA's were not openly supportive of the study concept nor the additional work to prepare for daily radiology instruction. Multiple studies have shown that the success of an educational intervention is heavily dependent on the behavior of the instructors (Kearney et al. 1991; Burroughs 2007; Gorzelsky 2009; Gunn 2010). This in itself could also explain some equivocal findings. A second limitation was the study's attenuated power for small effect sizes. However, we consider a medium effect size to be the minimum of practical significance in this setting.

Conclusion

In conclusion, our study demonstrated that direct correlation of radiologic and cadaveric structures to teach anatomy results in similar exam scores and student preference but plays an essential role in students' understanding and integration of anatomy with respect to other course components. Future studies may be directed at the underlying reasons for student preference and the high importance students placed on the direct correlation sessions.

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CALLUM ROSS, PhD, and CHRISTOPHER STRAUS, MD, co-direct the medical gross anatomy course at the University of Chicago.

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