The additive effect of teaching undergraduate cardiac anatomy using cadavers and ultrasound echocardiography

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SUMMARY

Ultrasound and cadavers are both recognized teaching modalities for the delivery of cardiac anatomy to undergraduate medical students. This study considers the additive effect of the two teaching modalities. We previously reported no significant difference in cardiac anatomy knowledge when taught using either ultrasound echocardiography or cadaveric prosections, both modalities significantly increasing knowledge from baseline. This study considers the cross-over effect with the ultrasound group receiving anatomy teaching with cadavers and vice versa. The results of this study show a small increase in knowledge after experiencing two modalities, but this increase was not significant. Furthermore, the order in which students received their tuition also made no significant difference. These data suggests there is no additive effect of combining cadaveric prosections with ultrasound. This has implications for curriculum design. However, these findings do not consider the hidden learning and learning experiences students will receive by two vastly different teaching modalities.

INTRODUCTION

There are multiple ways by which cardiac anatomy teaching can be delivered. Each lecturer will have preferred teaching methods, with evidence for and against each modality. As with all aspects of medical education, there is no one 'correct' teaching modality.

Within anatomical teaching much debate exists between the advantages and disadvantages of cadaveric and prosection-based teaching (Alexander, 1970; Biasutto et al., 2006; Granger, 2004; Granger and Calleson, 2007; Gunderman and Wilson, 2005; McLachlan et al., 2004; McLachlan and Patten, 2006; Parker, 2002; Patel and Moxham, 2008; Winkelmann, 2007). For example, teaching anatomy using cadavers gives the student an

overview of spatial orientation (Parker 2002; Granger 2004; Granger and Calleson 2007) and a three-dimensional view of human anatomy (McLachlan 2004; McLachlan and Regan de Bere, 2004). However, cadavers do not allow observation of living anatomy, the condition which qualified doctors are most likely to encounter.

Newer modalities of anatomy teaching such as the Virtual Human DissectorTM (Touch of Life Technologies Inc, Aurora, CO), plastic models, cross sectional radiological images, living (surface) anatomy and ultrasound are becoming increasingly popular (Collett et al., 2009; Donnelly et al., 2009; Erkonen et al., 1992; Finn et al., 2011; Lufler et al., 2010; McLachlan et al., 2004; McLachlan and Patten, 2006; Gunderman and Wilson, 2005; Shaffer, 2004; Sugand et al., 2010). Many studies have demonstrated that ultrasound is beneficial in teaching anatomy in a clinically orientated method (Heilo et al, 1997; Ivanusic et al., 2010; Patten et al., 2010; Tshibwabwa and Groves, 2005; Wittich et al., 2002), thus allowing the students to learn using a modality they will encounter often in clinical practice.

We have previously demonstrated that teaching gross cardiac anatomy with either echocardiography ultrasound or cardiac prosections is equally effective at significantly improving medical students' anatomical knowledge (Griksaitis et al., 2012). However to our knowledge, there is no work considering the additive effect of these two modalities.

The primary aim of this study was to consider the additive effect of two teaching modalities for teaching cardiac anatomy; echocardiography ultrasound along with cadaveric prosections. The secondary aim was to assess if the order of students' exposure to each modality altered their increase in knowledge. It is often presumed that you need to understand the gross anatomy prior to learning the interpretation skills of ultrasound. Therefore anecdotally you taught it after teaching using ultrasound (echocardiography).

Methods

Setting

This study took place within Durham University Phase One Undergraduate medical program within the United Kingdom, in the first year medical student cohort. The cardiac anatomy is taught within the first semester of the first year program.

Study Recruitment

All first-year medical students from the academic year 2010-11 (potential of 114 students) were invited to participate in this research study via email, the Virtual Learning Environment, and posters on departmental notice boards. Invitations outlined the project, and included a copy of the consent form and a participant information sheet. An introductory presentation was held to explain the procedure and to provide students with an opportunity to ask questions. All students were provided with the opportunity to discuss the study with the researchers should they have any concerns.

Ethics & Consent

This study was approved by the Durham University School of Medicine and Health Ethics Sub-committee, along with additional ethical approval from the Durham University Ethics Committee for Teaching Work and Practicals, to allow the ultrasound to be performed on a volunteer in front of the class.

Individual consent forms were signed by all participating students. Students were reassured that non-participation or withdrawal from the study would not incur any negative consequences. Data collection was anonymous.

Consent for using the data was collected at the start of each test, using the KEEpad™ audience response device (KEEpad, London, UK), as detailed in the data collection section.

Data Collection

We have previously reported in detail the following aspects of the methodology and statistical analysis of the pre-intervention test and immediate cross over scores of ultrasound to cadaver and vice versa (Griksaitis et al., 2012).

Students were randomly assigned to one of eight anatomy teaching groups at the start of the academic year. These groups were maintained during this study, due to their randomization prior to the study commencing.

Prior to any Durham University teaching on cardiac anatomy, a pre-intervention multiple choice test was delivered to the students

using the KEEpad™ audience response system, allowing us to establish a baseline of their existing understanding of cardiac anatomy. The data collected served to establish that the randomly assigned groups mentioned above had equal level of knowledge prior to the teaching intervention. The students were not given the answers to these questions at this point.

All students were issued with a KEEpad™ audience response device (KEEpad, London, UK). The KEEpad™ system uses Turning Point (Turning Technologies LLC, Youngstown, multiple choice questions. KEEpads™ were chosen for data collection as they enable anonymity to be preserved and are a rapid, efficient method of collecting data within the classroom.

Test Structure

All tests delivered in this study consisted of the same 10 multiple-choice questions (MCQs); five containing cadaveric prosection images and five echocardiogram images. The images and questions considered the cardiac chambers and septal walls, interior of the heart and the great vessels. The cadaveric prosections were dissected in a manner to mirror the echocardiographic ultrasound images. Each MCQ had five possible answers. A 'don't know' option was not provided to ensure consistency with the format of the summative examinations. The authors wrote the questions, based on the learning outcomes of the session. The questions were scrutinized by fellow colleagues blinded to the study for content validity, difficulty of question and test wiseness.

Intervention

Figure one outlines the study design utilizing a cross-over design.

Following the pre-test, the randomly allocated anatomy groups were assigned to an initial teaching intervention. For randomization purposes odd-numbered groups received cadaveric teaching first, and even-numbered groups received echocardiography teaching first. Both teaching sessions ran simultaneously for 30 minutes, covering the same learning
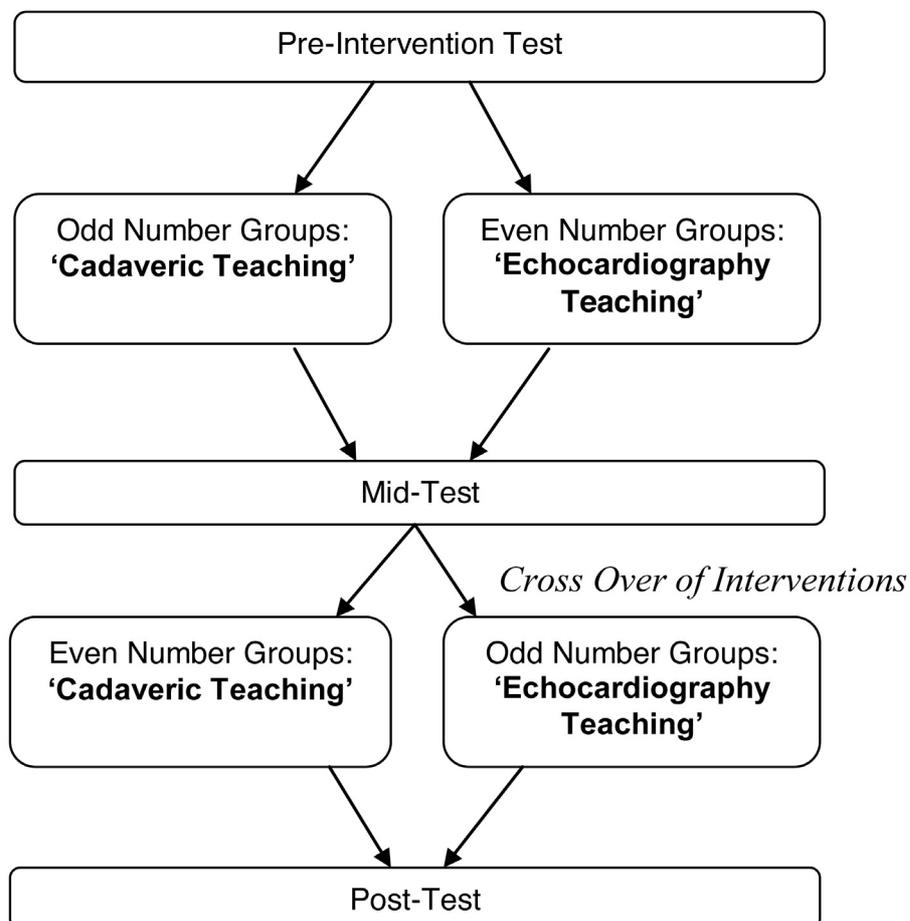

Fig 1: Design of the Study

outcomes, with identical content as far as possible, but with different teaching modalities. The same two facilitators with similar clinical backgrounds and teaching experience were used throughout the study, both teachers having extensive undergraduate teaching experience. The teachers standardized the content to be delivered between themselves prior to the teaching session in order to ensure teaching to be as uniform as possible between the two groups.

The cadaveric groups used a selection of pre-dissected isolated hearts (prosections), designed to demonstrate key structures. The echocardiographic ultrasound group considered the cardiac anatomy using real-time imaging of the heart viewed from traditional apical four chamber, parasternal, subcostal and suprasternal views with a portable ultrasound (SonoSite Micro Maxx, Sonosite Inc, Bothell, WA), projected onto a screen for all the cohort to observe. The scanning was performed by a clinician on a student from within the group, who had a diagnostic echocardiogram performed prior to the session. Due to difficulties with time constraints, students did not have the opportunity to carry out the scans themselves. The volunteers for the scans (n=8) had additional consent obtained, and did not complete the study, as their learning experience was different from the rest of their cohort.

Immediately following the teaching intervention all students sat a test which was identical to the pre-test (mid-test). Once again, students were not given the answers to the questions at this point. Once the mid-test was completed, the groups changed to the opposite intervention so that those taught with cadavers were now taught with echocardiography and vice versa. The facilitators delivered the same session as they had previously taught; ensuring that each session was structured in an identical fashion.

Following this cross over teaching, all students then sat the test again (post-test). It was only after the last test (the post-test) was completed that the students were given the answers to these questions to aid their learning of cardiac anatomy and give them feedback on their understanding. Timings were such that the sessions ran for one full day, to prevent the effect of students undertaking self-directed learning based on the test questions, and learning outcomes.

All the data from this study were analyzed using SPSS version 15.0 for Windows (SPSS Inc. Chicago, IL). The statistical analytical test used at each stage of the study is described within the results below. For all tests a value of $p < 0.05$ was considered statistically significant.

RESULTS

Sample demographics

One hundred and eight students consented to take part (n=108), excluding the eight peer students who had the ultrasound performed on them. Participants were excluded if they had not been able to complete all tests and all teaching sessions (n=6). These exclusions were made using a registry of attendance to the teaching sessions. After these exclusions the overall participation rate was 108/114 (94.7%).

Statistical analysis (one way ANOVA) demonstrated that there was no significant difference for the pre-test scores between each randomly assigned anatomy group (53.6±17.4% vs. 53.8±16.9%; $F = 0.312$, $p = 0.947$, see Table 1), showing that the baseline level of knowledge of each group on cardiac anatomy was equal.

Further analysis (independent t-test) demonstrated no significant difference between the scores obtained from the ultrasound questions and those from the cadaveric questions (within the pre-test), and thus we could assume that the standard of questions was equal between the two question types ($t = 1.121$, $p = 0.295$).

Mid-Intervention Test

We have previously demonstrated (Griksaitis et al., 2012) that the scores on the immediate mid-test showed no significant difference between the scores for those taught cardiac anatomy with ultrasound or those taught using cadaveric prosections (independent t test, $t = 0.065$, $p = 0.948$) and those taught using ultrasound did not score higher in the ultrasound questions than in the cadaveric questions; $t = 2.124$, $p = 0.66$ and *vice versa*, for the cadaveric group $t = 1.828$, $p = 0.133$.

We found that there was a significant improvement in test scores following both teaching interventions (see Table 1); the ultrasound group improved their mean score by

31.63% (t = 73.79, p = 0.026) and the cadaveric group increased their mean score by 31.66% (t = 78.37, p = 0.023). This led to the conclusion that there was no significant difference between understanding gained from teaching cardiac anatomy with ultrasound or prosections.

Post-Cross Over Test

All students that participated in the first part of the study (n=108) took part in the cross over study test, resulting in a 100% participation rate for the cross over study.
Overall we found that after cross over both groups of students increased their test scores further.

Table 1: Mean test scores before and after teaching interventions

Intervention Condition	Mean Pre-Intervention Test Score (% ± SD)	Mean Mid-Intervention Test Intervention Test Score (% ± SD)	Mean Post-Cross-over Test Score (cross over) (% ± SD)
Ultrasound then Cadaver Group (n = 53)	53.6±17.4	85.1±13.9	87.4±10.8
Cadaver then Ultrasound Group (n = 55)	53.8±16.9	85.0±12.6	86.2±10.4

Those taught with ultrasound first and then with cadavers increased their scores from a mean mid-test score of 85.1±13.9% after ultrasound teaching alone to 87.4±10.8% after the additional teaching with cadavers. This increase mean score of 2.3% was not found to be statistically significant (paired t test, t =-0.38, p = 0.712).

Those taught with cadavers first and then with ultrasound increased their scores from a mean mid-test score of 85.0±12.6% after cadaveric teaching alone to 86.2±10.4% after the additional teaching with ultrasound. This increase mean score of 1.2% was not found to be statistically significant (paired t test, t = -0.229, p = 0.824).

The difference in percentage of post-test scores from the 'ultrasound then cadaver' group and the 'cadaver then ultrasound' group was not found to be statistically significant between the two groups (independent t test, t = 0.133, p = 0.895).

DISCUSSION

Main Findings

We have previously demonstrated that there is no difference in efficacy of teaching gross cardiac anatomy between ultrasound and cadaveric prosections (Griksaitis et al., 2012). This study adds to these findings; with the addition of a second teaching modality, students will increase their overall score, but this increase in score is limited and not statistically significant (p = 0.895). Furthermore the order of teaching delivery with each modality (i.e. ultrasound or cadaver first) does not improve the students understanding of cardiac anatomy significantly.

Application of Findings

Our data suggest no significant improvement in knowledge with the use of two modalities of anatomy teaching compared to either one alone. Therefore, in terms of factual knowledge recall there is no significant additive effect of the two methods of ultrasound or cadaveric cardiac anatomy teaching. Despite this, our experience is that ultrasound and cadavers offer very different learning experiences, yet can deliver a similar anatomical content to meet gross anatomy learning outcomes.

Our findings have implications when planning a curriculum and selecting teaching modalities. Multiple teaching modalities are available to teach anatomy; this study suggests that either teaching tool could be used successfully. More does not necessarily equate to better. Time and resources might be better spent perfecting one teaching tool. Factors such as how the university would like the students to use the knowledge in the future, facilities available, student numbers, learning outcomes, previous teaching, and staff experience need to be considered. (Davies and Harden, 2003; Prideaux, 2003).

Furthermore, if two teaching modalities are to be used, our data would seem to support that it is irrelevant as to the order in which the students attend these sessions. Despite no significant additive effects of the two modalities (ultrasound echocardiography and cadaveric cardiac prosections), at our institution we frequently combine these two methods. The rationale for this is discussed below.

Teaching with Ultrasound

Using ultrasound for cardiac anatomy teaching has great potential benefits. It allows students to identify with the dynamic nature

of anatomy (opening and closing of heart valves, direction of blood flow around the heart using colour doppler), and to integrate some key physiology with the anatomy (for instance, ejection fraction and cardiac output). It also provides a clinical context in which to learn anatomy. The concept of clinical contextualization is important: students can appreciate why the anatomy is important to learn and hopefully this facilitates longer term retention of knowledge. (Finn et al., 2010) One of the main arguments against using cadavers is that students are exposed to anatomy in clinical practice via imaging and surface anatomy; not in a cadaveric or prosection form (McLachlan et al., 2004). Cardiac ultrasound (echocardiography) is a frequently performed clinical investigation, which students can relate back to their anatomical teaching.

Teaching with cardiac ultrasound requires a member of staff that is able to successfully demonstrate the key anatomy using this tool to the students, but also to identify and suitably counsel the student should any potential underlying cardiac defect be discovered. We perform a diagnostic echocardiogram on all students participating as volunteers prior to the teaching session. This can be time-consuming, and requires additional levels of consent plus the availability of a suitably trained clinician.

Teaching with cadavers is heavily discussed in many papers with authors expressing many views for and against (Alexander, 1970; Biasutto et al., 2006; Granger, 2004; Granger and Calleson, 2007; Griksaitis et al., 2012; Gunderman and Wilson, 2005; McLachlan et al., 2004; McLachlan and Patten, 2006; Parker, 2002; Patel and Moxham, 2008; Winkelmann, 2007). As with any teaching modality, it is important that it is delivered well and meets the learning objectives, as well as the ethos of the university in question.

Learning Experiences

It is important to remember that the modalities of cadaveric cardiac anatomy and ultrasound echocardiography anatomy will offer a different learning experience to each student. Whilst this may not be represented in the test scores, it does not mean that students did not learn different core skills, such as dealing with a 'patient' (with the ultrasound volunteer) and seeing anatomy in use by a clinician using the ultrasound, or equally

learning to appreciate the process of death and respect for the cadavers (Bertman and Marks, 1989; Finn et al., 2010; Marks et al., 1997). Outside this study, we routinely use cadavers and prosections to teach all aspects of anatomy at Durham University, with the additional use of ultrasound to complement the cadaveric anatomy, thus emphasizing the importance of living anatomy within the curriculum.

Study Limitations

Like all studies, we acknowledge limitations. This study was only conducted in one institution and there is the possibility that it was underpowered. However, the sample size was determined by the power calculation based on previous data from a homogenous cohort (Finn et al., 2010, 2011).

Conclusions

Ultrasound and cadavers have been shown to be valid methods of teaching cardiac anatomy to undergraduate medical students. Our data demonstrate that there appears to be no additive effect when combining these two methods, when considering the increase in students' knowledge base. However, the hidden learning by combining the two methods is difficult to demonstrate, and we feel students benefit in other ways by receiving teaching with two different modalities. A qualitative follow-up study to explore students' thoughts around this may be an intuitive next step.

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