The Translucent Cadaver: An Evaluation of the Use of Full Body Digital X-Ray Images and Drawings in Surface Anatomy Education

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It has been noted by staff at the Faculty of Health Sciences, Stellenbosch University that medical students neglect the study of surface anatomy during dissection. This study reports on the novel use of Lodox® Statscan® images in anatomical education, particularly the teaching of surface anatomy. Full body digital X-ray images (Lodox Statscan) of each cadaver ($n = 40$) were provided to second year medical students. During dissection students were asked to visualize landmarks, organs, and structures on the digital X-ray and their cadaver, as well as palpate these landmarks and structures on themselves, their colleagues, and the cadaver. To stimulate student engagement with surface anatomy, dissection groups were required to draw both the normal and actual position of organs on a laminated image provided. The accuracy of the drawings was subsequently assessed and students were further assessed by means of practical identification tests. In addition, students were asked to complete an anonymous questionnaire. A response rate of 79% was obtained for the student questionnaire. From the questionnaire it was gathered that students found the digital X-ray images beneficial for viewing most systems' organs, except for the pelvic organs. Although it appears that students still struggle with the study of surface anatomy, most students believed that the digital X-rays were beneficial to their studies and supported their continued use in the future. Anat Sci Educ 5: 287–294. © 2012 American Association of Anatomists.

Key words: gross anatomy education; medical education; surface anatomy; Lodox Statscan; medical imaging; digital X-rays; full cadaver X-ray; radiology education; cadaver dissection

INTRODUCTION

Medical students and healthcare professionals alike, feel that the study of gross anatomy is clinically relevant to their careers (Pabst and Rothkötter, 1996, 1997; Arráez-Aybar et al., 2010). It is therefore fundamental that it is taught in the best possible manner (Sugand et al., 2010). Although dissection and didactic lectures are the traditional approaches to teach anatomy, many medical schools have reconsidered the way in which they teach anatomy to medical students (Korf et al., 2008). Studies have shown that the best approach to teaching anatomy is the design of a multimodal curriculum that incorporates a combination of one or more pedagogical modalities, such as dissection, prosection, and imaging (Gunderman and Wilson, 2005; Miles, 2005; Rizzolo et al., 2006, 2010; Drake, 2007; Collins, 2008; Louw et al., 2009; Sugand et al., 2010).

It has been shown that students differ in the way they study (Lujan and DiCarlo, 2006). The acronym VARK represents the major sensory modalities used for learning, namely: visual, aural, read/write, and kinesthetic (Fleming, 1995). Very few students use only one of these sensory modes when studying, and it has been demonstrated that Millennial generation students prefer to use a combination of all four given

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modes for learning (Lujan and DiCarlo, 2006; DiLullo et al., 2011). It was further demonstrated by Lufler et al. (2010) that the majority (61%) of learners in their cohort of first year medical students were multimodal learners, able to process all forms of information. Therefore, by providing students with materials to use multiple sensory modes while studying, they will be more adequately prepared for life-long learning (DiLullo et al., 2011).

The discovery of the X-ray in 1895 and the wide range of imaging modalities in use today, such as MRI and CT scans, have given us a clearer understanding of the internal anatomy of the human body. Most medical students will not become surgeons and will therefore be unlikely to ever perform major operative treatment. As such, these students will only ever see the internal anatomy of their patients through the use of radiology (Gunderman and Wilson, 2005). They will therefore need to have the skills to identify structures on radiographs and the ability to correlate this with surface anatomy in the living patient (Brenton et al., 2007).

The incorporation of radiology into gross anatomy education is however, not a new idea (Pabst et al., 1986; Erkonen et al., 1990; Boon et al., 2002; Reidenberg and Laitman, 2002; Gunderman and Wilson, 2005; Miles, 2005; Turmezei et al., 2009; Lufler et al., 2010; Marker et al., 2010; Zumwalt et al., 2010). Clinical radiographs showing normal and pathological anatomy are often placed in dissection halls (Pabst et al., 1986), and suggestions have been made for greater interaction between anatomy and radiology departments (Chowdhury et al., 2008). Zumwalt et al. (2010) describe a course where radiology has been used to enhance the clinical context of anatomy.

However, relatively few studies exist on the inclusion of cadaver radiographs in anatomy dissection halls. The use of cadaver radiographs in anatomical education was first proposed by McNiesh et al. (1983) who found it an expensive and time-consuming process. The authors did however conclude that these cadaver X-rays helped students in the understanding of complex three-dimensional positional relationships of many organs. Subsequent studies used premortem clinical radiographs of cadavers (Pantoja et al., 1984, 1985) and postmortem computed tomography scans (Chew et al., 2006; Jacobson et al., 2009; Lufler et al., 2010; Bohl et al., 2011).

Furthermore, radiography has been found to illustrate the clinical importance of anatomy (Gunderman and Wilson, 2005; Chew et al., 2006), stimulate discussion between students (Rizzolo et al., 2006), and spark interest in both anatomy and dissection (Pabst et al., 1986; Rengier et al., 2009; Marker et al., 2010; Bohl et al., 2011). Erkonen et al. (1990, 1992) also found the combination of dissection and radiography to result in long-term memory retention.

Anatomy is mostly seen by the general practitioner in the form of surface anatomy, and the ability to know the positions of organs and important structures is fundamental to the study of medicine (McLachlan, 2004; Aggarwal et al., 2006). The study of surface anatomy allows students to gain valuable knowledge, which forms the basis for clinical examinations (Boon et al., 2002). Surface anatomy is therefore of primary importance to the students' future as medical practitioners and should form a substantial part of the anatomy curriculum. Yet, surface anatomy is often neglected as a category in reviews on student learning of anatomy (McLachlan and Patten, 2006).

Previous studies have attempted to get students to engage with surface anatomy through the use of body painting (Op Den Akker et al., 2002; McMenamin, 2008, Finn and McLachlan, 2010), body drawing (Aggarwal et al., 2006), and image projection (Patten, 2007). However, no studies have reported the use of radiography to stimulate students to engage with surface anatomy.

Full body digital X-rays were chosen for this study as it has previously been shown that they are less costly than other imaging modalities (such as CT and MRI) and the quality of the images produced are comparable to conventional X-rays (Beningfield et al., 2003; Deyle et al., 2009; Chen et al., 2010), making them ideal for incorporation into anatomy education.

This report describes the incorporation of a "see-through" or "translucent cadaver" in the form of a full body digital cadaver X-ray in conjunction with drawings, into the dissection program, primarily assessing if such a tool is beneficial to the study of surface anatomy.

METHODS

Stellenbosch University uses an integrated systems-based approach to teaching medicine. Cadaver dissections are conducted throughout the year coinciding with each system's module. Second year medical students start dissection on the respiratory system, followed by the cardiovascular, gastrointestinal (GI) tract, and urogenital systems. The remaining systems are dissected by third year medical students and did not form part of this study.

Beginning in 2011, each embalmed cadaver ($n = 40$) was scanned using the Lodox® Statscan® system (Lodox Systems Pty., Sandton, South Africa) housed at the Western Cape Forensic Pathology Service Medico-Legal Mortuary. The images were obtained free of charge. The DICOM (Digital Imaging and Communications in Medicine) images produced were viewed and converted to (.jpeg) format using ImageJ, version 1.45 freely available online (ImageJ, 2012). Printouts of the jpeg images (~2/3 life size) of the full body scans were placed on the walls of the dissection hall near each respective cadaver (Fig. 1). To gain an understanding of normal anatomical variation, students were encouraged to look at the cadavers and digital X-rays of other groups as well.

Each dissection group consisted of four to seven members chosen by the students. There were 40 groups with a mean of 219 students per module. During each module, students were provided with lists of structures and landmarks relevant to the surface anatomy of that particular system. Students were asked to visualize the listed items on the cadaver and the digital X-rays as well as palpate the listed items on themselves, their colleagues, and the cadaver (Fig. 2). Palpation between students was encouraged but not enforced and was conducted in the dissection hall, with clothes on. Furthermore, each dissection group was provided with a laminated A3 sketch of a skeleton (adapted from Wikimedia, 2012), upon which they were asked to draw an additional list of organs and structures of each system. All students were asked to give input into this group sketch.

Three colored pens were provided for the purpose of drawing:

- Blue pen: to plot the normal position of organs (as seen in text books and lecture notes).
- Red pen: To plot the actual position of organs (as seen in the cadaver and on the digital X-ray).

Figure 1.

Full body digital X-ray images of a female and male cadaver used during the dissection program.

- Black pen: To plot the actual position of any visible pathology or abnormality that may have been present.

A separate smaller image was provided for students to draw the listed organs from the posterior view. Smaller images were also provided for students to draw the planes of the body during the GI module and for drawing the reproductive organs of the sex opposite to the cadaver being dissected during the urogenital system module. The accuracy of the drawings (Fig. 3) was assessed by first marking the normal positions of organs and landmarks. Second, each cadaver sketch was compared with the actual size and position of the organs of the cadaver. The pathology drawn by students was however, not directly assessed. Instead, if a cadaver presented with an obvious pathology that was not drawn, the group would lose a mark. An example of the marking scheme used can be found in Table 1.

In our department, in addition to written tests, students are normally assessed by means of a practical identification test once the dissection of a system is completed. These practical tests typically consisted of 50–60 marks. During the present study, 10% of the marks in each practical test were dedicated to questions on surface anatomy and the digital X-rays. Practical tests involved students moving between stations where they had 45 seconds to answer a question before moving on to the next station. Each station had only one question that generally involved identifying a labeled structure.

Toward the end of the dissection program, students were given an anonymous questionnaire to complete. Completion of the questionnaire was optional, however in order to optimize the response rate, students were given an opportunity to complete a questionnaire during a dissection period. The questionnaires were used to assess the perceptions of the students toward the incorporation of the digital X-rays into the dissection program and contained 19 questions, 17 of which were Yes/No questions. Two open ended questions required comments from the students. To assess these comments, all comments of a similar theme were grouped together, counted and expressed as a percentage of the total group of comments.

This study was granted ethical clearance by the Health Research Ethics Committee of Stellenbosch University (ref no: N10/10/333).

RESULTS

Drawing

A summary of the results for the drawings can be found in Figure 4. In general, the drawings were assessed as to the size, relating to landmarks, and accuracy of the structures drawn. Students were allowed to use any resource (textbooks, lecture notes) to draw the normal position of the organs. The results of the accuracy of the drawings were fairly high. The average results for all the groups' drawings per system were as follows: respiratory system 93%, cardiovascular system 85%, GI 81%, and urogenital system 84%.

Practical Identification Tests

Students were assessed by means of practical identification tests at the end of each dissection module. Ten percent of the questions in the practical identification tests were dedicated to questions on surface anatomy. A summary of the test results can be found in Figure 4. The average results for the

Figure 2.

Students visualize structures on the digital X-rays, the cadaver and mounted skeletons during the dissection of each system.

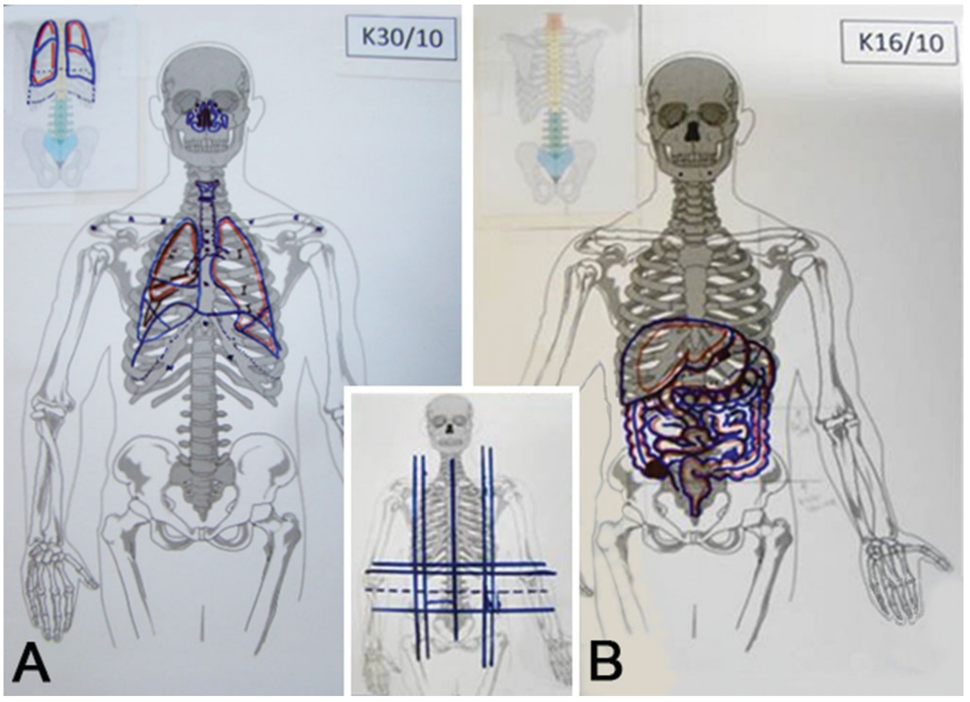

Figure 3.

Examples of student surface anatomy drawings. **A**, Respiratory system; **B**, Gastrointestinal tract; Inset, Subdivisions of the abdomen.

surface anatomy questions in the practical tests were as follows: respiratory system 60%, cardiovascular system 61%, gastrointestinal system 54%, and urogenital system 84%.

Table 1.

Example of the Marking Scheme Used for the Drawings of the Cardiovascular System Module

Aspect	Marks
Normal position of the heart	2
Normal position of the heart valves	4
Normal position of auscultation points	4
Normal position of aorta	0.5
Normal position of tracheal bifurcation	0.5
Normal position of domes of diaphragm (anterior view)	1
Normal position of domes of diaphragm (posterior view)	1
Actual position of the heart	2
Pathology	−1 (if not shown)
Total	**15**

Questionnaire

A response rate of 79% (195/247) was obtained for the student questionnaire. A summary of these results can be found in Table 2.

The majority of the second year students (53%) utilized the digital X-rays when they saw pathologies or abnormalities in

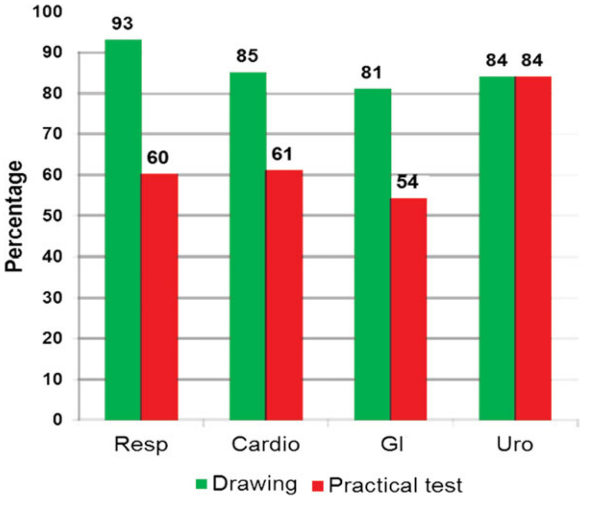

Figure 4.

Average drawing and test results per module; Resp, respiratory system; Cardio, cardiovascular system; GI, gastrointestinal tract; Uro, urogenital system.

Table 2.

Results of the Second Year Medical Student Questionnaire

Question	Yes, *N* (%)	No, *N* (%)	No response, *N* (%)
Q1. To what extent did you use the image: choose one from a to c.		5 (3)	1(<1)
a. Only at the beginning of each module.	61 (31)		
b. Only when I saw pathologies and abnormalities.	103 (53)		
c. Regularly during the dissection of a particular organ system including observing pathologies.	25 (13)		
Q2. Did the image help you to visualize and find the position and extent of the thoracic cavity in the living person?	141 (72)	54 (28)	0
Q3. Did the image help you to visualize and find the lungs in the living person?	119 (61)	76 (39)	0
Q4. Did the image help you to visualize and find the exact position of the heart in the living person?	96 (49)	99 (51)	0
Q5. Did the image help you to visualize and find the exact position of the diaphragm in the living person?	142 (73)	53 (27)	0
Q6. Did the image help you to visualize and find the position and extent of the abdominal cavity in the living person?	105 (54)	90 (46)	0
Q7. Did the image help you to visualize and find the nine different regions of the abdominal cavity in the living person?	60 (31)	135 (69)	0
Q8. Did the image help you to visualize and find in the living person the position of the abdominal organs relating to each of the nine regions?	61 (31)	134 (69)	0
Q9. Did the image help you to visualize and find the exact position of the urogenital tract (pelvic organs) in the living person?	52 (27)	143 (73)	1 (<1)
Q10. Did the exposure to the image arouse your interest in imaging or radiographic anatomy?	91 (47)	104 (53)	0
Q11. Did the exposure to the image help you to be better prepared for your radiological lectures?	84 (43)	107 (55)	4 (2)
Q12. Did the exposure to the image arouse your interest in anatomical pathology?	82 (42)	113 (58)	0
Q13. In your opinion, do you think that adding the images to the dissection experience has enhanced your overall learning of anatomy?	114 (58)	81 (42)	0
Q14. In your opinion, is it worth our while to make these cadaver images available to students during dissection in future years?	128 (66)	59 (30)	8 (4)
Q15. Did you find that the pathologies you saw on the image before dissection of an organ system could relate to what you saw during dissection (was the image accurate in terms of what you saw during dissection)?	113 (68)	61 (31)	1 (<1)
Q16. Did having the image give you a better understanding of the importance of an anatomical basis for clinical examination?	135 (69)	56 (29)	4 (2)
Q17. Did exposure to the image while dissecting reinforce the fact that you are studying appropriate material for your future as a medical practitioner?	133 (68)	60 (31)	2 (1)

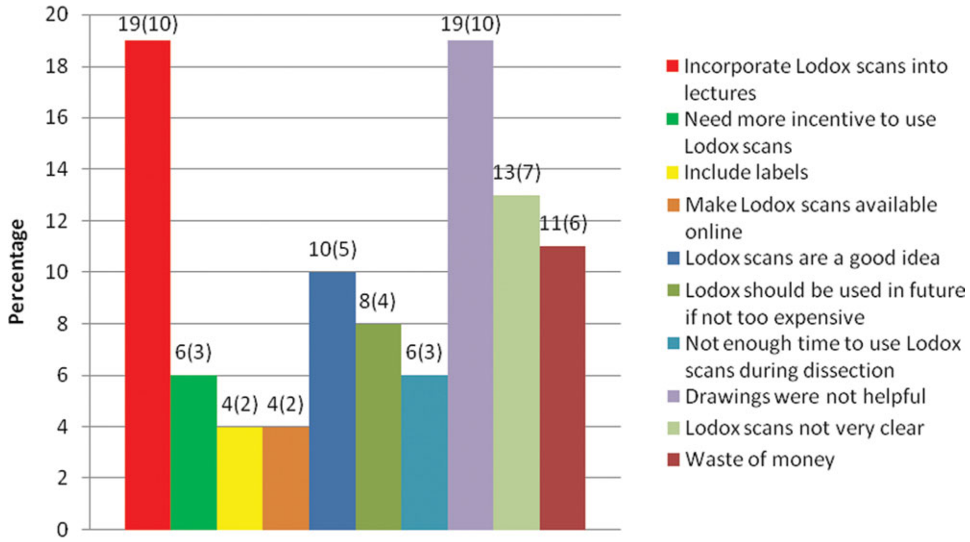

Figure 5.

Student comments about the incorporation of full body digital X-rays into the dissection curriculum. Values are in percentages and number of students who made comments is in parenthesis (N).

the cadaver. Only 3% of students did not use the digital X-rays at all, while 13% of students regularly used the digital X-rays. The remaining 31% of students only used the digital X-rays at the beginning of each module.

The majority of students found the digital X-rays beneficial in visualizing all of the body systems studied except for the urogenital/ pelvic organs, as only 27% of students were able to visualize these organs on the digital X-rays. A number of students (69%) also had difficulty visualizing the abdominal organs in relation to the nine abdominal regions.

The digital X-rays were found to stimulate interest in anatomical pathology and radiographic anatomy of 42 and 47% of students, respectively.

The incorporation of the digital X-ray images into the dissection curriculum was believed to enhance the overall learning of anatomy by 58% of students, with 66% of students stating that the full body digital X-ray images should continue to be used in the future.

One of the questions asked if the students could relate the pathologies they saw on the digital X-rays to what they found during the cadaver dissection. For 61 students (31%) who answered "No" to that question, the next question gave these students the opportunity to explain specific reasons for their negative answer. Explanations offered by 32/61 (52%) of the students were as follows: 3/61 (5%) said they did not use the images; 2/61 (3%) preferred to use a textbook, which they felt was more accurate; 5/61 (8%) said that pathologies were not visible on the images; 7/61 (11%) felt they were not yet experienced enough to identify pathologies, or what they thought were pathologies on the image turned out not to be a pathology; 6/61 (10%) said there were no pathologies seen on the image or the cadaver; and 7/61 (11%) felt that the images were not clear enough to identify any pathologies.

The final open ended question was answered by 52 (27%) students. The comments made by the students were grouped into common themes, counted and expressed as a percentage of the total comments. These comments can be seen in Figure 5.

DISCUSSION

In the present study, the full body digital X-rays provided the students with a translucent cadaver allowing them to visualize the internal structures of the entire cadaver at a glance. This allowed students the ability to visualize in two dimensions, the relationships of internal organs and skeletal components before dissection began. Subsequently, dissection then gave students a three-dimensional understanding of the positional relationships of these organs (McLachlan and Patten, 2006; Collins, 2008), thereby reinforcing what the students have seen on the digital X-ray and enhancing the concept of clinical surface anatomy.

The drawings were used as a means to further encourage the students to engage with surface anatomy; following this, practical identification tests were used to gauge the students learning of surface anatomy. The results for the accuracy of the drawings were as expected relatively high. This is because students were allowed to utilize any resource to find the normal position of the organs. These results demonstrate that the students actively engaged with surface anatomy. In contrast, the results for the practical identification tests are average to low, suggesting that although students are engaging with surface anatomy they still struggle with its implementation. It has previously been shown that active drawing or painting of normal organ positions by students on each other's bodies is beneficial to the study of surface anatomy (Op Den Akker et al., 2002; Aggarwal et al., 2006; McMenamin, 2008; Finn and McLachlan, 2010). Most recently, Finn et al. (2011) demonstrated that students found body painting useful because the visual stimulus and color aided in their ability to recall the positional information of organs. Similarly, we believe that the drawing of the position of organs on the laminated sketch of a skeleton helps to engage students in the study of surface anatomy. The act of drawing the positions of organs on the laminated sketch is not hampered by the ethical considerations of body painting, yet still provides students with a kinesthetic and visual stimulus for learning.

Anatomical variation is a clinically important concept of human anatomy, especially when it comes to invasive surgery (Ellis, 2001). Drawing organs both in their normal position and as seen in the cadaver, allows students to effectively "compare" the position of the organs in their cadaver with that of the standard model human being, classically presented in textbooks, atlases, and lectures. The act of drawing the actual position of the organs as seen in the cadaver is believed to allow students to better understand the normal anatomical variation seen in humans. This is further reinforced by also looking at the cadavers and digital X-rays of other groups. Students asked for the digital X-rays to be incorporated into their gross anatomy lectures. The demonstration of the position of organs and other structures on the digital X-rays during lectures should allow students to overcome difficulties experienced with visualizing certain organs on the images, as well as giving students insight into what they can expect to see during dissection. This will help the few students who felt that the digital X-rays were unclear to have a better understanding of how to read radiographs. The pointing out of possible pathology on the digital X-rays during a lecture may also cause an increase in the number of students whose interest in anatomical pathology is stimulated.

A number of medical schools have created online imaging libraries (Reidenberg and Laitman, 2002; Miles, 2005; Turmezei et al., 2009; Marker et al., 2010). These online libraries give students access to a wide range of medical imaging modalities that can demonstrate both normal and pathological anatomy. Some students requested the digital X-rays be placed online, as students are unable to access the images outside of class time. In a study done at the Johns Hopkins University, Baltimore, MD, it was found that the majority of students accessed such online libraries from home over the weekend, demonstrating that students want the ability to access resources at their own time and convenience (Marker et al., 2010). Placing the digital X-rays online would allow for this, however further ethical clearance needs to be granted before this can occur.

The issue of labeling of images is a frequent comment made by students in similar pedagogical studies. Students either ask for the inclusion of labels or for more labels to be added to the images (Turmezei et al., 2009; Bohl et al., 2011). Similarly, our students asked for the inclusion of labels to be added on the digital X-ray images. Although the inclusion of labels might be beneficial to some students, a balance needs to be found between the extent to which structures are labeled (Bohl et al., 2011). Issues with labeling images need to be carefully considered, since it may affect the process of active learning. Strategically placed labels should guide students in their learning of anatomy, in contrast to a completely labeled image that may lead to passive learning by recreating another textbook image.

Limitations

In the present study, practical tests were used as a means to gauge the students' learning of surface anatomy. However, in previous years, students were not formally tested in practical tests on surface anatomy in the same manner as described here. There are therefore no results available with which a comparison can be made.

The comments made by the students gave valuable insight into some of the limitations of this study. One such comment is that a number of students believed that the drawings were not very beneficial to them. A possible reason for this is that within a group, the task of drawing was often delegated to a single student who was subsequently tasked to do the drawing for each system. This may have resulted in the other students not benefiting as much from the drawings. Therefore in the future, it may be necessary to ask each student to complete a drawing of their own, thereby eliminating the possibility of one student being singled out as the "drawer" of a group.

Future Directions

In future, this study will be improved in numerous ways. Labels will be included on six to eight of the digital X-rays used during 2011, which will then be placed in the dissection halls along with the digital X-rays of the new cadavers. Furthermore, explanations of the digital X-rays and the highlighting of possible pathologies on the images will be incorporated into gross anatomy lectures. Each student will be asked to complete a drawing of their own to be added to their study portfolios, in addition to contributing to the making of the group sketch that will still be marked for accuracy. As students asked for more incentive to use the images, time will be allocated for an oral test during each system module dissection. Electronic copies of the digital X-rays of all cadavers will be made available, so that students can access the images of their own and other cadavers at any time they choose. The results from these future studies can then be compared to the results from the current study to determine if the proposed adaptations are successful.

Cost Implications in the Future

The scans are performed free of charge and the cost of the printing of the posters can be easily covered from student note fees in future years.

CONCLUSION

To our knowledge, the use of full body digital X-ray cadaver images in anatomical education has not previously been reported in the literature. This study suggests that full body digital X-ray images could be an effective tool in improving surface anatomy education in medical schools. The majority of students supported the future use of this method of surface anatomy study. Suggestions made by staff and the students during the present study will be incorporated in the future, which will further increase the students' learning of surface anatomy using the present method.

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