Sabina R.S. Ku
Matriculation Number: 2125756
Date: 07/04/2016
MSc Medical Visualisation and Human Anatomy
School of Life Sciences, University of Glasgow and
Digital Design Studio, Glasgow School of Art

Modern Anatomy Education: A Case for a Multimodal Approach

Introduction

Anatomy is considered one of the most important subjects in medical study. The primary goal of anatomy is to study the functions and structures of the human body and the spatial relationships of different body parts. The teaching of anatomy encourages students to learn and understand meaningful anatomy for clinical purposes so they can develop their logic and interpretation skills and provide solutions when they face patients. Time and staffing levels for anatomy teaching has been reduced in the last two decades and this trend has been seen across the world. The reduction in time spent learning anatomy is due to the importance of other topics and subjects(Collins, 2008).

Dissection of cadavers is regarded as the most powerful approach to learn anatomy. Learning anatomy by cadaver dissection can be traced back to the 16th and 17th centuries (Collins, 2008; McLACHLAN and Patten, 2006; Evans and Watt, 2005). Today's anatomy curriculum faces the challenges of time constraints, availability of cadavers, innovations, and advances in 3D imaging technology. These challenges have stimulated debate and discussion about the role of dissection in anatomy teaching (Elizondo-Omaña et al., 2005). The curriculum must be modified to response to these challenges. The change in anatomy curriculum must focus on making teaching and learning more effective in terms of time and cost (Collins, 2008).

The advantages and disadvantages of cadaver based anatomy, dissection and procession, will be discussed in next section.

Cadaver based anatomy-traditional approaches

Dissection and prosection are the two primary methods of learning anatomy. Several studies have demonstrated that prosection is as effective as dissection in teaching gross anatomy (Nnodim, 1990; Nnodim et al., 1996; Yeager, 1996; Ashdown et al., 2013). It is widely accepted that dissection and working with cadavers provides students with hands on experience and brings the following benefits to students(Granger, 2004; Topp, 2004),

1. Understand the multiple dimensions of the human body.
2. Practice several useful skills including the observation of spatial relationships between anatomical structures, the use of instruments, and hand-eye coordination.
3. Be more involved with anatomy through the visual, auditory, and haptic feedback of dissection.
4. Be aware of the variability and uniqueness of the human body.
5. Learn the basic language of medicine which is essential and fundamental in the medical professions.
6. Learn how to work in a team.
7. The experience of working with a cadaver could help to establish the link to living patients and make them aware of their responsibility of treating patients.
8. Learn how to deal with their emotions and express their attitudes towards death.

On the other hand, it is also accepted that dissection has disadvantages in terms of time, cost, emotional impact and health and safety hazard. The disadvantages include (Aziz et al., 2002; McLachlan et al., 2004; McLACHLAN and Patten, 2006; Elizondo-Omaña et al., 2005),

1. Time consuming and labour intensive.
2. Students have to memorize and learn excessive clinically irrelevant facts.
3. Availability of cadavers.
4. Cost of Cadavers: cadavers are expensive throughout the entire process from obtaining them to properly disposing of them. The preservation and storage of cadavers is also costly. Furthermore, it needs extra care to handle human remains. Improper disposal or handling of human remains can damage public confidence in the medical profession.
5. Emotional impact: It has been reported that some students have encountered mental and physical symptoms of stress in the dissection laboratory. This could be due to the un-aesthetic appearance and smell of cadavers.
6. Health and safety hazard: students and teaching staff might be exposed to embalming fluid and infectious diseases.

It is argued that Learning anatomy from the dissection and prosection of cadavers might restrict the experience to chemically preserved cadavers which are different from what is encountered in practice(McLACHLAN and Patten, 2006), where doctors face and deal with living patients. The debate arises then, of how students should learn anatomy, cadaver based anatomy or living anatomy. To date, it is clear that there is no one approach for learning anatomy which is objectively superior to all others (Brenton et al., 2007). However, some medical schools have reduced the dissection/prosection in anatomy and increased the study of living anatomy.

Living anatomy and recent advances in medical imaging will be reviewed in the following section.

Living anatomy: alternative approaches

Cadaver based anatomy can only provide static post-mortem anatomy which is highly dependent on the pre-morbid state of the cadaver. The subjects in living anatomy, on the contrary, are living people. It is suggested that there are three approaches in learning living anatomy which are surface anatomy, medical imaging and surgical procedures (Gunderman and Wilson, 2005; Ganguly and Chan, 2008; McLachlan et al., 2004).

Surface anatomy

Surface anatomy can be learned by hiring professional models or peer examination (McLachlan et al., 2004; Ganguly and Chan, 2008). This is not a new approach and has been recommended for many years. Students can interact with the living models and observe the movements and functions of anatomical structures from them. This can also be more intuitive than dissection and prosection for learning mobile regions of the body such as the upper and lower limbs since muscles and joints in cadavers are stiff and therefore harder to observe in dynamic motion. This method is particular useful in learning the musculoskeletal system and the important landmarks of the human body(Collins, 2008).

Surgical procedure

As a real world application of anatomical knowledge, surgical procedures can act as a link between anatomy teaching and clinical practice (Allen and Roberts, 2002). Although teaching anatomy to students is not the main purpose of surgery and students can only learn the regions of anatomy in a surgical procedure, it can still be used in teaching as it does not affect the procedure (Ganguly and Chan, 2008). Recent advances in technology also allow students to experience procedures in a virtual reality environment.

Medical imaging

The advances in imaging technologies such as computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET) and ultrasound can provide

3D images of anatomical details and show students the spatial relationship of anatomical structures.

Radiography has been used in skeletal anatomy for years but is limited to images in single plane. However, recent progress in cross-sectional imaging makes it possible to visualize the soft tissues in two dimensions and even in three dimensions. These imaging technologies can reconstruct the internal anatomy in high resolution images at the sub-millimetre level. Moreover, these imaging technologies allow students to visualize the changes of organs over time. For example, changes of the heart in chamber size, thickness of chamber walls and movement of the valves, corresponding to the different stages of the cardiac cycle can be visualized through cinegraphic techniques. Functional images from PET and MRI technologies allow regional changes in anatomical structures due to the body's metabolism to be observed(Gunderman and Wilson, 2005). Recently, real-time intraoperative magnetic resonance imaging (IMRI) has been used in neurosurgery. This technology can improve the visualization of soft tissues and its change in real time and it can also be applied to anatomy teaching (McLACHLAN and Patten, 2006).These imaging techniques are therefore much better for learning about organs and tissues in the body such as the heart where observing dynamic changes in the organ are important for understanding its function, normal operation, and how it interacts with other organs in the body. This cannot be observed in dissection or prosection since the state of such an organ in a preserved cadaver is fixed and cannot be observed while in motion. Another advantage for students is that these imaging technologies are the tools they are going to use in their careers. These technologies are the most straightforward means of knowing the internal anatomy of patients(Gunderman and Wilson, 2005).

These images are digitized, stored and available to exchange between different institutes for teaching and researching purpose. Thereby, these images present a wider range of pathologies than dissection/prosection. (Gunderman and Wilson, 2005).Furthermore, these digitalized and stored images can be used to build the computer assisted learning (CAL) system. Compared to dissection/prosection, CAL can be customised according to individual requirements and allow learning by self-pace and is always-available. CAL can also provide interactive teaching and real-time feedback.

The recent advance of 3D printing technology has also make it possible to create high quality productions of prosection material based on the images provided by surface scans and CT. This approach can reproduce specimens quickly and with good anatomical accuracy. Moreover, this method can also avoid several cultural and ethical issues found in anatomy teaching in some countries (McMenamin et al., 2014)

The recent development and progress using imaging technologies and its effectiveness in teaching anatomy will be discussed in next two sections.

Applications of digital images in human anatomy

For visualizing and learning anatomy using digital images, there are several 'Visible Human Projects' (VHP) which collect the digital images of cadavers and aim to serve as the image libraries for the study of anatomy and research. These projects include the National Library of Medicine's Visible Human Project, Visible Korean Human and Chinese Visible Human Project. The datasets of these projects consist of images of MRI and CT scans of the cadavers (Spitzer et al., 1996; Park et al., 2006; Zhang et al., 2006). Several programs based on VHP were developed for teaching different regions of the human anatomy.

1. Inner Organs:3D inner organs of human body based on the images of male VHP were created in this study(Pommert et al., 2001). This system consists of more than 650 3D anatomical elements and more than 2000 relations between these elements. In addition

to the graphical presentation of the inner organs of the human body, this system is also integrated with a knowledge based database which provides not only the knowledge and information of the parts found in the system but also their hierarchy. The 'self-explaining body' image of this system allows users to learn complex anatomical facts

2. Female Pelvis: The pelvis anatomy is difficult to learn due to its complicated, multi-layered 3D structures. A 3D dimensional female pelvis was created based on VHP images. This model allows students to explore the pelvis structures stereoscopically. The model includes the pelvic girdle, organs inside the pelvic cavity, surrounding musculature, the perineum, the peritoneum, and neurovascular structures. The model allows individual structures to be added, removed and made transparent to observe the spatial relationships between different structures. The structures and spatial relationships can be viewed in different angles in 3D(Sergovich et al., 2010).
3. Head and Neck: A dynamic head and neck model in virtual reality was developed based on CT scans of a cadaver. This model can display images of the head and neck in 2D, 3D and stereoscopic 3D. This model offers more benefits than traditional anatomy teaching. For example, users can visualize small and hidden anatomical structures by changing the scale of the displayed images and the feature of endoscopic view can be used to explore the hollow structures. The spatial relationship between different structures can be observed by adding or removing the structure of the interest. The transparency of tissues/structures can be altered to visualize spatial relationship of tissues and structures (Nguyen and Wilson, 2009) .
4. Brain: The brain is one of the most complex organs in human body. Understanding its anatomical structure remains a challenge in learning human anatomy. Cadaveric dissection might not be a suitable approach. Traditional 2D images and 3D models are

insufficient at presenting the brain in 3D. There are several computerised virtual brain systems which have been developed.

To overcome these problems encountered in learning brain anatomy, a 3D virtual brain system based on MRI scans of the brain from a Korean cadaver was created. The 3D brain image in this system was made by stacking 2D brain images which allows the virtual dissection to be operated on this 3D brain. The virtual dissection program allows the 3D brain in the program to be sectioned orthogonally or at free angles. This virtual dissection program could help the medical profession to understand the brain better in 3D(Chung and Kim, 2000).

Another virtual human cerebral ventricular system has been created based on MRI scans of a male cadaver. The system allows users to learn the spatial relationships within the ventricular system and its adjacent neural and skeletal structures by adding, removing and altering the transparency of these anatomical structures. The model can be projected in 3D to enhance the users' appreciation of the spatial relationships between anatomical structures(Adams and Wilson, 2011).

5. Temporal bone dissection simulator: The images of this virtual dissection program are based on CT scans of a cadaver. The haptic interface allows the user to feel and touch the cadaver's bones. The aural interface synthesises sound effects, such as drilling sounds, when users dissect bones. The system also integrates a virtual interactive tutor which can imitate a real instructor to help students learn anatomy and acquire surgical skills (Wiet et al., 2002).

Evaluation of the effectiveness of computer images in learning anatomy

The efficacy of learning cardiac anatomy by prosection and ultrasound imaging were evaluated (Griksaitis et al., 2012). Before teaching started, students had a pre-test to assess their knowledge of cardiac anatomy. After teaching finished, students had a post-test to assess the impact of the different teaching approaches. The results showed that both approaches improved the students' understanding of the heart. The test scores of both groups were increased but the difference was not statistically different, suggesting that cadaver prosection teaching and imaging technology teaching can achieve a similar outcome for students learning cardiac anatomy.

The performance of learning anatomy across three universities using dissection alone (group A), using computer assisted resource alone (group B) and the combination of both (group C) was evaluated (Biasutto et al., 2006). The examination results showed that, overall, Group A was significantly better than group B and that Group C was significantly better than Group A and B. Interpreting these results, the authors suggested that innovations in technology cannot outweigh the value and importance of dissection in learning anatomy. The best method of learning anatomy might be the combination of traditional dissection with the additional support of newer technologies.

The impact of web based teaching tools in learning anatomical landmarks was inspected (Hallgren et al., 2002). The teaching tools could provide interactive teaching, real time feedback and self assessment exercise. The students in the study were divided into three groups. Group 1 received the introductory material and activate their web account to access and use the web based tool. Group 2 received the introductory material but didn't activate the web based account, i.e. they could not use this teaching tool. Group 3 neither received the introductory material nor activated the accounts. The graphs in the introductory material were used in the test. The examination performance in group 1 was significantly better than the other two groups in two tests. This demonstrated the usefulness of the web-based computer learning environment in learning anatomical landmarks.

The usefulness of MRI images in learning anatomy was also evaluated (Nicholson et al., 2006).An interactive model of the middle and inner ears was created based on MRI images. The control group learned the ear anatomy from the web-based tutorial without the use of the interactive model. The intervention group used the interactive ear model in addition to the web-based tutorial. At the completion of the tutorial, the participants were tested on their understanding of the spatial structures inside the ear. The results showed that the intervention group outperformed the control group in this test. The difference was significant and demonstrated the usefulness of 3D imaging in learning ear anatomy.

A similar study inspected the effectiveness of a computer assisted learning environment for learning anatomy. The traditional group learnt anatomy through the textbook, supplementary material and dissection, while the modified traditional group could use the virtual classroom in addition to the resources the traditional group had. The effectiveness of the virtual classroom was evaluated by examination performance. The modified traditional group had a significantly better result compared to the traditional group(Elizondo-Omaña et al., 2004).

The usefulness of virtual reality surgical stimulators has also been inspected(Hariri et al., 2004). In their study, the control group studied shoulder joint anatomy by the text book, while the intervention group studied using the virtual reality surgical stimulator. The intervention group performed better in the assessment than the control group but the difference was not significant. However, the surgical stimulator was rated as the more effective learning tool compared to the text book by the students in this study. The result indicated that the surgical stimulator could be as effective as the text book in learning shoulder joint anatomy.

Most of these studies were also restricted to certain regions of human anatomy. These studies did not assess the benefits in terms of the clinical application of spatial, visual, and procedural skills which come with dissection practice.

Discussion and conclusion

The importance of the imaging technologies is increasing in teaching anatomy. For example, Peninsula Medical School is the first UK medical school taking the radical step of not teaching human anatomy based on cadavers (McLachlan, 2004; McLachlan et al., 2004). In Peninsula, students learn surface anatomy and living anatomy through imaging technologies (McLachlan et al., 2004).

Evidence supporting the superiority of cadaver based teaching in learning anatomy over other approaches and the long term effects in recall and retention of anatomical knowledge and clinical practice is insufficient(McLachlan, 2004; Collins, 2008).The effectiveness of new approaches takes time to evaluate. Any new approach takes time to develop before it become solid and complete. It is particularly difficult to measure the benefits of different approaches on the outcomes in medicine education.

The variability of anatomy is dependent on age, gender, race, genetics and environment. For medical professionals, facing living patients, i.e. living anatomy, daily is a fundamental part of their work. Therefore, it makes sense that they should be taught anatomy by the means which they are going to use in their future career(McLACHLAN and Patten, 2006). From this point of view, living anatomy is more relevant than cadaver based anatomy.

Living anatomy is an option for teaching anatomy if it is integrated well with existing approaches. Computer generated images might be useful when used with other teaching methods. Imaging technologies alone cannot give students the experience of 3D spatial relationships in human anatomy. However, some of the attributes of computer assisted learning have the potential to be applied to the application of virtual dissections. They can also demonstrate complicated topics in textbooks and regions difficult to access in cadavers(Tam et al., 2009; Rizzolo and Stewart, 2006).

Although living anatomy has demonstrated its usefulness in teaching anatomy, cadaver based anatomy cannot be replaced. Some believe that students should learn cadaver based anatomy (dissection/prosection) and gain sound knowledge of 3D anatomy before they can benefit from living anatomy (Ganguly and Chan, 2008; McLACHLAN and Patten, 2006). Some medical schools who adopt different approaches other than dissection re-embrace dissection again when they find that students are lacking in anatomical knowledge after learning anatomy without dissection, and many students still regard dissection courses as more rewarding and challenging. In some schools where the dissection course was optional, it was found that almost all students enrolled in the course leading to it being made compulsory course(Rizzolo and Stewart, 2006; Ganguly and Chan, 2008).

The ultimate goal of the changing how anatomy learning is approached is to improve the learning experience and learning outcomes of students. A multimodal curriculum may be the solution. A multimodal curriculum can be achieved by supplementing traditional dissection with living models, imaging technologies, computer assisted learning, problem-based learning through clinical cases, surface anatomy, clinical correlation lectures, peer teaching, and team-based learning(Johnson et al., 2012; Brenton et al., 2007). Dissection/prosection should remain but the number of the hours spent using it can be reduced.

Word count: 3305

References:

Adams, C. M. & Wilson, T. D. 2011. Virtual cerebral ventricular system: An MR-based three-dimensional computer model. *Anatomical sciences education,* 4(6)**,** pp 340-347.

Allen, S. S. & Roberts, K. 2002. An integrated structure-function module for first year medical students: correlating anatomy, clinical medicine and radiology. *Medical education,* 36(11)**,** pp 1106-1107.

Ashdown, L., Lewis, E., Hincke, M. & Jalali, A. 2013. Learning Anatomy: Can Dissection and Peer-Mediated Teaching Offer Added Benefits over Prosection Alone? *ISRN anatomy,* 2013

Aziz, M. A., Mckenzie, J. C., Wilson, J. S., Cowie, R. J., Ayeni, S. A. & Dunn, B. K. 2002. The human cadaver in the age of biomedical informatics. *The Anatomical Record,* 269(1)**,** pp 20-32.

Biasutto, S. N., Caussa, L. I. & del Río, L. E. C. 2006. Teaching anatomy: cadavers vs. computers? *Annals of Anatomy-Anatomischer Anzeiger,* 188(2)**,** pp 187-190.

Brenton, H., Hernandez, J., Bello, F., Strutton, P., Purkayastha, S., Firth, T. & Darzi, A. 2007. Using multimedia and Web3D to enhance anatomy teaching. *Computers & Education,* 49(1)**,** pp 32-53.

Chung, M. S. & Kim, S. Y. 2000. Three-Dimensional Image and Virtual Dissection Program of the 'Brain. *Yonsei medical journal,* 41(5)**,** pp 299-303.

Collins, J. P. 2008. Modern approaches to teaching and learning anatomy. *Bmj,* 337(a1310.

Elizondo-Omaña, R. E., Guzmán-López, S. & De Los Angeles García-Rodríguez, M. 2005. Dissection as a teaching tool: past, present, and future. *The Anatomical Record Part B: The New Anatomist,* 285(1)**,** pp 11-15.

Elizondo-Omaña, R. E., Morales-Gómez, J. A., Guzmán, S. L., Hernández, I. L., Ibarra, R. P. & Vilchez, F. C. 2004. Traditional teaching supported by computer-assisted learning for macroscopic anatomy. *The Anatomical Record Part B: The New Anatomist,* 278(1)**,** pp 18-22.

Evans, D. J. & Watt, D. J. 2005. Provision of anatomical teaching in a new British medical school: getting the right mix. *The Anatomical Record Part B: The New Anatomist,* 284(1)**,** pp 22-27.

Ganguly, P. K. & Chan, L. K. 2008. Living anatomy in the 21st century: how far can we go? *South-East Asian Journal of Medical Education,* 2(2)**,** pp 52-57.

Granger, N. A. 2004. Dissection laboratory is vital to medical gross anatomy education. *The Anatomical Record Part B: The New Anatomist,* 281(1)**,** pp 6-8.

Griksaitis, M. J., Sawdon, M. A. & Finn, G. M. 2012. Ultrasound and cadaveric prosections as methods for teaching cardiac anatomy: A comparative study. *Anatomical sciences education,* 5(1)**,** pp 20-26.

Gunderman, R. B. & Wilson, P. K. 2005. Exploring the human interior: The roles of cadaver dissection and radiologic imaging in teaching anatomy. *Academic Medicine,* 80(8)**,** pp 745-749.

Hallgren, R. C., Parkhurst, P. E., Monson, C. L. & Crewe, N. M. 2002. An Interactive, Web-based Tool for Learning Anatomic Landmarks. *Academic Medicine,* 77(3)**,** pp 263-265.

Hariri, S., Rawn, C., Srivastava, S., Youngblood, P. & Ladd, A. 2004. Evaluation of a surgical simulator for learning clinical anatomy. *Medical education,* 38(8)**,** pp 896-902.

Johnson, E. O., Charchanti, A. V. & Troupis, T. G. 2012. Modernization of an anatomy class: From conceptualization to implementation. A case for integrated multimodal–multidisciplinary teaching. *Anatomical sciences education,* 5(6)**,** pp 354-366.

McLachlan, J. C. 2004. New path for teaching anatomy: living anatomy and medical imaging vs. dissection. *The Anatomical Record Part B: The New Anatomist,* 281(1)**,** pp 4-5.

McLachlan, J. C., Bligh, J., Bradley, P. & Searle, J. 2004. Teaching anatomy without cadavers. *Medical education,* 38(4)**,** pp 418-424.

McLACHLAN, J. C. & Patten, D. 2006. Anatomy teaching: ghosts of the past, present and future. *Medical Education,* 40(3)**,** pp 243-253.

McMenamin, P. G., Quayle, M. R., McHenry, C. R. & Adams, J. W. 2014. The production of anatomical teaching resources using three-dimensional (3D) printing technology. *Anatomical sciences education,* 7(6)**,** pp 479-486.

Nicholson, D. T., Chalk, C., Funnell, W. R. J. & Daniel, S. J. 2006. Can virtual reality improve anatomy education? A randomised controlled study of a computer-generated three-dimensional anatomical ear model. *Medical education,* 40(11)**,** pp 1081-1087.

Nnodim, J. 1990. Learning human anatomy: by dissection or from prosections? *Medical education,* 24(4)**,** pp 389-395.

Nnodim, J., Ohanaka, E. & Osuji, C. 1996. A follow-up comparative study of two modes of learning human anatomy: By dissection and from prosections. *Clinical Anatomy,* 9(4)**,** pp 258-262.

Park, J. S., Chung, M. S., Hwang, S. B., Shin, B. S. & Park, H. S. 2006. Visible Korean Human: its techniques and applications. *Clinical Anatomy,* 19(3)**,** pp 216-224.

Pommert, A., Höhne, K. H., Pflesser, B., Richter, E., Riemer, M., Schiemann, T., Schubert, R., Schumacher, U. & Tiede, U. 2001. Creating a high-resolution spatial/symbolic model of the inner organs based on the Visible Human. *Medical Image Analysis,* 5(3)**,** pp 221-228.

Rizzolo, L. J. & Stewart, W. B. 2006. Should we continue teaching anatomy by dissection when…? *The Anatomical Record Part B: The New Anatomist,* 289(6)**,** pp 215-218.

Sergovich, A., Johnson, M. & Wilson, T. D. 2010. Explorable three-dimensional digital model of the female pelvis, pelvic contents, and perineum for anatomical education. *Anatomical sciences education,* 3(3)**,** pp 127-133.

Spitzer, V., Ackerman, M. J., Scherzinger, A. L. & Whitlock, D. 1996. The visible human male: a technical report. *Journal of the American Medical Informatics Association,* 3(2)**,** pp 118-130.

Tam, M., Hart, A., Williams, S., Heylings, D. & Leinster, S. 2009. Is learning anatomy facilitated by computer-aided learning? A review of the literature. *Medical Teacher,* 31(9)**,** pp e393-e396.

Topp, K. S. 2004. Prosection vs. dissection, the debate continues: rebuttal to Granger. *The Anatomical Record Part B: The New Anatomist,* 281(1)**,** pp 12-14.

Wiet, G. J., Stredney, D., Sessanna, D., Bryan, J. A., Welling, D. B. & Schmalbrock, P. 2002. Virtual temporal bone dissection: an interactive surgical simulator. *Otolaryngology--Head and Neck Surgery,* 127(1)**,** pp 79-83.

Yeager, V. L. 1996. Learning gross anatomy: dissection and prosection. *Clinical Anatomy,* 9(1)**,** pp 57-59.

Zhang, S. X., Heng, P. A. & Liu, Z. J. 2006. Chinese visible human project. *Clinical Anatomy,* 19(3)**,** pp 204-215.