The disciplines of anatomy and surgery are not dichotomous since one is dependent on the other. Traditionally, surgeons predominantly taught gross and clinical anatomy. In this review, we examine the context of how human anatomy is taught nowadays. In essence, we discovered that there are certain discernable trends consistently observable between the American and British systems. In Singapore, the British Russell Group first influenced its education landscape but now more so by the American Ivy League. Singapore now has three medical schools all offering differing anatomy curricula, which serves as an opportune time for it to consider if there is a best approach given that the practice of surgery is also evolving in parallel. This review discusses the various pedagogies and issues involved, and will serve as a forum and stimulus for discussion. By tweaking the curriculum correctly and the lessons learnt, future doctors and surgeons in training will receive a better anatomical education, not just in Singapore but the world in general. Key recommendations include the use of body painting, clay, plasticine to facilitate the learning of anatomy, and the implementation of a body donation program. Furthermore, strategic mergers with key stakeholders will also ensure the survival of the discipline.

Key words: gross anatomy education; undergraduate education; surgical practice; medical curriculum; British education; American education; Singapore

INTRODUCTION

The disciplines of anatomy and surgery cannot be separated from one another. In fact, detailed knowledge of the human anatomy is crucial to the work of doctors and certain specialists, especially surgeons and radiologists (Ahmed et al., 2010). Historically, surgeons taught their trainees and students, but as their workload and inclination changed, and with more teachers with postgraduate anatomy qualifications joining the universities, this is clearly no longer the case. However, it is still true that surgeons without sufficient anatomical knowledge cannot perform their role proficiently, lest competently. Today, minimally invasive interventions abound, a laparoscopic cholecystectomy if inadequately performed, for instance, could result in postoperative complications such as biliary injuries that could endanger the patient's life (Nagral, 2005). There are also medico-legal consequences that could jeopardize a practicing surgeon's career, if steps are not taken to avoid such related post-operative complications (Ellis, 2002; Ellis and Crowe, 2009). Nonetheless, before mastering minimally invasive surgery, trainees ought to be competent with gross anatomy before super-specialization (e.g., laparoscopy, robotic-assisted surgeries) in case the need for conversion to open surgery arises (Gogalniceanu et al., 2008; Jiménez and Aguilar, 2009, Yi et al., 2012).

Furthermore, students should be aware of variations in anatomical structures (Strkalj et al., 2011) both in morphology and pathology as a result of trauma, cancer, or inflammation. It is vital for undergraduate and postgraduate trainees to appreciate, recognize, and be familiar with normality. The need to understand the subject becomes even more pressing when one considers the emergence of cutting edge imaging technology.
Fast-forward to the 21st century, the teaching of human anatomy in medical schools has also been transformed remarkably. With some exceptions, the modern institutions are doing away with cadavers altogether (McLachlan et al., 2004) whereas the more traditional institutions such as King's College London (KCL), Imperial College London (ICL) in the United Kingdom, and Duke University in the United States are still persevering with dissection (Guttmann et al., 2004; McLachlan, 2004; McLachlan et al., 2004; Pawlina and Lachman, 2004). In Singapore, we are very much at the crossroads as far as anatomy curriculum is concerned, following the setting up of the two new medical schools. These are (1) Duke University and National University of Singapore (NUS) Graduate Medical School (Duke-NUS GMS; Williams et al., 2008) and (2) Imperial College of London (ICL) and the Nanyang Technological University (NTU)'s Lee Kong Chian School of Medicine (LKCSbM; Ai-Lien, 2011). This nation is unique in being exposed to different educational and health care frameworks before and after it became a sovereign state in 1965. Without going into too much detail, this shall be discussed in the following section.

At the National University of Singapore Yong Loo Lin's School of Medicine (YLLSoM), the oldest institution in the country, there is now less emphasis on “hands-on” learning of human anatomy compared to a decade ago, primarily due to the lack of human cadavers. This is attributed to cultural attitudes, and reluctance to donate one's body for medical sciences. At the Duke-NUS GMS, the curriculum that is largely based on the Duke model (Grochowski et al., 2007) is meant to produce clinician scientists to meet the nation's needs for research and development (Williams et al., 2008). In this new institution, anatomy is taught in a team-based learning manner by specialist doctors (Chow et al., 2009). At the newly established Imperial College of London and the Nanyang Technological University's LKCSbM, administrators are still in the process of formulating the basic science curriculum since formal intake of students will only take place in the year 2013. It suffices to say that the adopted teaching style is likely to be similar to that of the UK (Ai-Lien, 2011). However, it is quite certain that anatomy education will be done without dissection (personal communication).

Given the above background, the aims of this article are to: (1) Outline the changing trend in anatomy pedagogy between United Kingdom (UK), United States (US) and Singapore, and (2) Stimulate debate and exchange of ideas for creating an ideal anatomy curriculum for Singapore and other developing countries.

**LITERATURE REVIEW**

**History of Anatomy Education in UK and the USA**

In 18th century London, anatomy education was shrouded with controversies, as the need for surgical skills improvement and public horror at human dissection went head to head. Gradually, the situation improved with publicized anatomy lecturing with dissection in London and the Anatomy Act of 1832 (Lawrence, 1995). Luminaries like John Hunter (1728–1793) and Henry Gray (1827–1861) laid the foundation for anatomy education in Britain. Back in the United States, before the declaration of independence in 1776 from Great Britain, anatomy education closely resembled that in Europe (Hildebrandt, 2010). Subsequently, things started to change with the development of the American Anatomy Act (Blake, 1955) and throughout the 19th century, American doctors were travelling to either London or Paris for further medical training. These activities cumulated into the transformation of medical education, especially so after the release of the Flexner report (Halperin et al., 2010). In particular, Franklin Paine Mall (1862–1917) chairman of anatomy at Johns Hopkins Medical School, greatly reformed anatomy teaching in the United States (Hildebrandt, 2010). However, over the years, with the dwindling of the British Empire, and the emergences of American economic power, anatomy education in both countries have somewhat reached a stage whereby neither is the clear leader. Both needed on-going educational reforms to stay relevant in this modern era. Numerous issues such as the duration of gross anatomy lectures, embryology teaching, the use of dissections/prosections, and multimedia teaching, et cetera were discussed in recent reviews from both sides of the Atlantic (Drake et al., 2009; Sugand et al., 2010). There appears to be very little uniformity between the different institutions from both continents.

**Early Education and Healthcare Policies in Singapore**

Singapore was once part of the British Empire and got its independence in 1965. Its founding fathers were educated in British universities and hence its education and healthcare policies were largely influenced by the UK (Wong and Tay, 2005). Medicine was largely based on apprenticeship and their previous colonial rulers mentored its early doctors (Tan, 1998; Ong, 2005). All these gradually changed when the United States emerged as a postwar superpower, and policy makers made a strategic move to align itself more with the Americans. Again to the credits of the founding fathers, the system has further evolved to become a hybrid of the two earlier influences, and has developed its unique characteristics peculiar for its own needs (Callick, 2008).

**Teaching Human Anatomy**

In medieval and 18th century Europe, surgeons themselves taught the subject. Obviously, this has changed considerably with the appearance of professionally trained anatomists who are equally qualified to do the teaching. The major issue relating to the subject has not really changed over time; it is still the availability of cadavers for dissection (Bay and Ling, 2007). What has changed is the practice of surgery, and perhaps the in-depth understanding of morphology. Despite this, the teaching and learning of human structures by anatomists, trainee surgeons and students will be a perpetually challenging process (Sugand et al., 2010) in which the content ought to be continuously reviewed and tweaked. As a scientific subject, it has arguably stagnated since everything that needs deciphering and understanding, has been systematically discovered since the days of Herophilus (335 BC–280 BC) and Andreas Vesalius (1514–1564) (Bay and Bay, 2010). However, the way that this information is visualized, instructed and applied clinically is a constantly changing process. In the past and mostly encouraged during the Renaissance, medical students in clusters performed hours of cadaveric dissection, learning from their tutors and each other in the process. This was refined to a few students around one dissection table in contemporary times. However, there is now a de-emphasis on this practice because of a variety of reasons. Such include decreased funding for anatomy education (Lindor et al.,
In terms of teaching pedagogy, at the National University of Singapore YLLSoM, anatomy is taught as a preclinical modular subject with every attempt to integrate with the teaching of biochemistry and physiology. The one year’s endeavor includes weekly didactic lectures (four-six hours), practical classes (two hours) to about 280 students, and tutorials (two hours) for small groups. Lecturers and tutors always attempt to discuss anatomy in a clinically orientated manner so as to prepare the medical students for their clinical studies. From the year 2003–2004, dissection was discontinued in this institution, and prosected cadavers were used instead for teaching and demonstration purposes (Wong and Tay, 2005). Specifically, first year medical students learn their anatomy with prossections supported with computer simulation and imaging modalities (Rajendran et al., 1990; Yip and Rajendran, 2008; Lu et al., 2010; Gopalakrishnakone et al., 2011). Furthermore, there is a state of the art anatomy museum that the students can use for their self-learning ad libitum. This is in line with what most British medical schools are currently offering (McLachlan et al., 2004; Sugand et al., 2010). A review of the literature suggests that such modern practice may be just as effective (Jones et al., 1978), but contrary views remain (Carmichael and Pawlina, 2004; McLachlan et al., 2004; Older, 2004; Pawlina and Lachman, 2004; McLachlan and Patten, 2006).

Over at the Duke-NUS GMS, a specially designed curriculum (Normal Body Course) involving specialist doctors, teaches anatomy in an integrated manner, together with a clinical system (e.g. alimentary anatomy with gastroenterology). Interestingly, it begins with a module quiz and ends with another to allow faculty and students to identify and rectify knowledge gaps (Chow et al., 2009). Furthermore, having a smaller enrollment of about 50 students, team based learning (TBL) called TeamLEAD is carried out as a form of active teaching (Vasan et al., 2008, Vasan et al., 2011). Briefly, TBL entails three phases which are (1) Pre-class preparation (students are given materials to read and then expected to discuss the key concepts in class), (2) Readiness assurance (multiple-choice questions about the preparation work), and finally (3) Application (to apply concepts to laboratory and clinical scenarios; Chow et al., 2009). The TBL is based on the following assumptions; that medical students are a motivated group of learners (Misch, 2002), and that more learner-to-learner interaction in a group will lead to active learning (Haidet et al., 2004). At the Duke-NUS GMS, successful outcomes have been reported but not without issues which have to be further streamlined (Cook et al., 2008; Krishnan, 2011).

On the basis of the above two examples alone, it is clear that anatomy lessons can generally be conducted in a didactic or active learning manner, both with clinical relevance to medical practice. However, the question remains as to which of the above two pedagogies will lead to better critical thinking and instill abilities to be a life long learner.

Separately, over the last 20 years, the subject is increasingly taught in a technology-driven manner (e.g., imaging and commercial software). One of the new educational aids that we have come to depend on is the application of computer and multi-media for anatomy teaching (Bay, 2007; Bay and Ling, 2007; Abrams, 2011). Such include Primal Pictures 3D (Primal, 2007), A.D.A.M. Interactive Anatomy (A.D.A.M, 2011), and Bracco’s volumetric interactive 3D (Bracco, 2012) representing several commercially available programs. The availability of such programs to aid the teaching of human anatomy is challenging traditional methodology of teaching and learning which is, to perform dissection on cadavers, coupled with encouraging the students to learn and appreciate various procedures (embalmed cadaveric and pot specimens). While it would be an understatement to say that multimedia has been a valuable assistant for teaching anatomy, it has revolutionized the way knowledge can be reinforced. However, in a recent report, medical students and trainees did not find these programs to be especially enticing compared to other established pedagogies but this will need further validation (Ahmed et al., 2010).

The Practice of Surgery

Surgical practice has also evolved considerably since those days when open procedures were the norm. Back then, one has to touch and see the structures that are operated on before proceeding with either excision, ablation or reconstruction (Mack, 2001). In a recent review done in the United States, there is a significant trend towards the use of percutaneous interventions, angiographic embolization, and endovascular surgery, with corresponding sharp declines in major open biliary, aortic, colon, and trauma cases recorded in logs of surgeons and residents from 1993 to 2007 (Eckert et al., 2010). Their aspiration was to get the job done efficiently with minimally invasive interventions, so as to reduce inpatient stay, and return the patient to functional status as soon as possible (Mack, 2001). Moreover, open procedures that are labor intensive, are gradually replaced by robotic intervention in multiple disciplines such as biliary, urological, vascular, and colorectal surgery (Mack, 2001; Antonioiu et al., 2011; Giulianotti et al., 2011; Patel et al., 2011). The idea is for the surgeon to work from a remote site away from the patient, using state of the art computer assisted technology to reduce hand tremor and to enhance dexterity, haptic feedback, and motion scaling (Mack, 2001). However, the benefits of using robotics to enhance laparoscopic procedures are still contentious since there are reports suggesting advantages between different platforms used (Garcia-Ruiz et al., 1998; Nguan et al., 2007).

Given the above technological advancements and the lack of thorough anatomy education, it is not inconceivable that it will take longer to train surgeons. This is especially so in Europe, with the European Working Time Directive (EWTD; DOH, 2009; Goddard, 2011; Kelly et al., 2011; Simpson et al., 2011), which puts legal time restrictions on work. In Singapore, with the practice of medicine and surgery now subjected to the review of the Accreditation Council for Graduate Medical Education (ACGME) of the United States, trainees are required to abide to work-hour limits as well (Willis et al., 2009).
Perspectives for the Future of Anatomy Education

Other educational competencies such as communication skills, medical ethics and law, genetics, and the biomedical research agenda have gained more attention and significance over time. These are now vying for more time from medical students and residents (Rieger-Johnson et al., 2004; Kanna et al., 2006; Bay and Ling, 2007). Furthermore, disciplines such as surgery and radiology, which are dearly married to anatomy have also evolved considerably, with the emergence of “key-hole” interventions and the ever sophistication of imaging techniques (Epstein, 2002; Goh et al., 2005; Charalampaki et al., 2006). Against this background, is the current method of teaching anatomy still relevant? More pertinent to surgical practice, is there still a need for surgeons to know “gross anatomy” to the expected standard in the past? Since there is now minimal manual handling of organs, is there really a need for them to use cadavers to understand the gross morphology of organs? Yes, to the latter two points, as the trainees are still expected to deal with either distorted view, or inferred feel of the operated site via the minimally invasive approach. Instead of the previous rigors of descriptive anatomy, there is now an increasing need to appreciate practical spatial awareness instead, to have a sense of depth perception, and the ability to see things from different angles as seen on a monitor. The challenge for the students and trainees is to try to make that connection between what they see in two-dimension (2D) to what is happening in three-dimension (3D). Failing to do so will result in post-op complications such as cases of unnoticed perforations (Dozois, 2008; Gogalniceanu et al., 2008). This is important because the take-up rate for minimally invasive procedures is likely to go up since there is evidence to suggest that it is less dangerous (Mamidanna et al., 2011). This is perhaps where medical simulation will have a bigger role to play in future. In robotic surgery at least, no longer does the surgeon need to handle the organs to be operated on, hence the question if the present way of teaching the subject is still relevant? Perhaps, it should be done in a simulation laboratory whereby procedures can be practiced on animal carcasses and cadavers instead. It is therefore recommended that anatomists work more closely with professionals from the arts or computing departments to produce high quality educational visual aids to relate anatomical structures with their function.

At present, the suspicion is not many younger surgeons will have the experience and courage to open up the abdomen or any part of the patient if the need arises. This is because they lack the training and the opportunity as an undergraduate to do dissection. In a recent review, due to a lack of anatomy training in undergraduate years, surgical trainees are disadvantaged in their early phase of training, and hence there should be focus on core clinical anatomy (Standring, 2009). It is therefore imperative that the teaching of anatomy should involve input, ideas, and perspectives from clinicians (surgeons and radiologists) to stay relevant to clinical practice (Purkayastha et al., 2007; Ahmed et al., 2010). Dissection is also now used far more often by the trainees and specialists in their later studies compared to medical students (Ahmed et al., 2010). This highlights the preferential method of dissection over prosections (Ahmed et al., 2010; Kerby et al., 2011), especially for post-graduate surgical study where dissection rooms using fresh frozen cadavers is now becoming more common (Cleveland Clinic Lerner College of Medicine, Bristol, Newcastle and Warwick Medical Schools and Royal College of Surgeons, England; Drake, 2007; Ahmed et al., 2010; Kerby et al., 2011). That being said, the “open “ method of teaching anatomy using prosections should not be discarded entirely, but with adjuncts such as ultrasound, trocars insertion with laparoscopic procedures and learning to orientate monitors. Whatever the future holds, it suffices to say at this stage that all trainees should be encouraged to take up the role of demonstrators in anatomy education, as is happening at KCL, UK as part of the curriculum for core surgical trainees (Older, 2004; Abdalla, 2011).

Body painting to teach clinical anatomy as pointed out by studies (Op Den Akker et al., 2002; McMenemy, 2008; Finn and McLachlan, 2010) can also be useful in developing spatial awareness. In addition, other methodologies such as the use of clay modeling alone (Myers et al., 2001; Motoike et al., 2009; Oh et al., 2009) or in conjunction with animal carcass dissection (DeHoff et al., 2011), plasticine (Naug et al., 2011), and low fidelity simulation (Chan, 2010; Chan and Cheng, 2011) could all be harnessed to help with anatomy education. There should also be clinically orientated training for the students to identify of surface markings as this forms the basis of thorough physical examinations, and appropriate clinical skills (Rizzolo et al., 2011). If medical students are unwilling to partake in the above exercise due to cultural or religious reasons, it is also recommended that professional models and simulated patients be invited to facilitate the learning process.

In summary, it is important to realize that anatomy teaching is a human activity and as such no amount of technology would be able to take over this role completely. It is also important to note that one size will never fit all and surgical trainees will need to have a deeper understanding of the anatomy in their own specialty. This will also be different from the needs of a professional career anatomist.

Body Donation Program

The greatest hurdle for the medical students and trainees to learn their anatomy via cadaveric dissection is the acute lack of cadavers. Here at National University of Singapore YLL-SoM, we are in the process of instituting a body donation program, but there are numerous contentious and challenging issues to overcome linked to religion and society. There is therefore a need to engage all faiths and to ensure donors’ wishes are fulfilled. This will come at considerable cost if all logistical needs are to be met. Furthermore, Singaporeans are conservative and not many are accustomed to donating their bodies for medical sciences and research. At the moment, the Ministry of Health (Singapore) releases unclaimed bodies for medical and educational purposes, and NUS YLLSoM is one of the recipients (Abu Baker, 2011). In the United States, body donation programs have already been well implemented (Pawlina et al., 2011) and the Duke-NUS GMS is in fact importing cadavers into Singapore to fulfill their needs for education. In summary, this is an issue that is not peculiar to Singapore and is faced by other developing countries as well (Anyanwu et al., 2011). We draw inspiration from other Asian cultures that have conducted the programs well (e.g., Korea, Thailand, and Taiwan) and believe that these issues are not insurmountable (Kao and Ha, 1999; Winkelmann and Gildner, 2004; Lin et al., 2009; Park et al., 2011).
Mergers and Strategic Collaboration

Anatomy education worldwide is undergoing major transformation due to an array of issues including professional, ethical, and financial (Drake et al., 2009). All these are happening in the midst of further integration with other basic science and clinical disciplines (e.g., cellular biology, surgery, and oncology) into larger departments (Collins, 2008). It has been proposed that a merger with a clinical department (surgery) would better ensure survival for anatomy (Fasel et al., 2005). Departmental mergers or downgrade aside, it is imperative that anatomy professors remain active advocates and champions for thorough anatomy education in the medical schools. The society as a whole will benefit from it when institutions produce competent doctors and surgeons.

CONCLUSIONS

We do not know if there will be a shift back to dissection rooms in Singapore (and other countries). A review of this nature has been attempted in the past in the United Kingdom (Older, 2004) but has not been done in this part of the world. What is peculiar of Singapore is the fact that we now are straddled between two contrasting educational cultures, that of the British and the Americans. The national education framework was first aligned to the British but is now increasingly leaning towards the numerous lucrative benefits of American standards. More resources and financial incentives are attracting more students to the latter than British competing universities.

In addition, competition from computer-based learning (multimedia programs and the Internet) has become increasingly popular, and will inevitably affect the future of anatomy education. The teachers of the subject should also aim to inspire the students and trainees to keep up lifelong learning and not attempt to overload the students in a limited time frame. Despite all the arguments, what is certain is the fact that good knowledge of anatomy is essential for good clinical practice (Older, 2004; Ahmed et al., 2010).

NOTES ON CONTRIBUTORS

ENG-TAT ANG, B.Sc, P.T., Ph.D. is a lecturer in the Department of Anatomy at Yong Loo Lin School of Medicine, National University of Singapore, Singapore. He teaches gross anatomy and histology to first year medical and life science students. He is also involved in elementary bedside teaching at the hospital.

KAPIL SUGAND, B.Sc. M.B.B.S., is an Academic Foundation Doctor, researcher, author and Board Representative for South Thames Deanery and is currently a surgical trainee at Kingston Hospital and St. George’s London NHS Healthcare Trust, London, UK.

MIKAEL HARTMAN, M.D., Ph.D., is an assistant professor in the Saw Swee Hock School of Public Health and the Department of Surgery at the National University of Singapore, Singapore. He teaches general surgery and epidemiology to medical students.

CHOON-SHEONG SEOW, M.B.Ch.B., M.D., F.R.C.S., is a consultant surgeon at the Department of Surgery at the Alexandra Hospital, Jurong Health Service and a visiting consultant to the Department of Surgery, National University Health System (NUHS) in Singapore. He teaches anatomy to first year medical students at the National University of Singapore.

BOON-HUAT BAY, M.B.B.S., Ph.D., is a professor of anatomy and Chair of the Department of Anatomy at the Yong Loo Lin School of Medicine, National University of Singapore, Singapore. He teaches gross anatomy to first year medical students and has research interest in cancer biology.

PETER ABRAMS, M.B.B.S., F.R.C.S., F.R.C.R., D.O., is a professor of clinical anatomy at Warwick Medical School, University of Warwick, Coventry, West Midlands, United Kingdom. He is currently leading an active career within postgraduate teaching and research.

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