Anatomy: the future teaching of undergraduates

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The time devoted to the teaching of anatomy to medical students has long been under pressure. Much work has been devoted to how best to teach anatomy in both a time-efficient and cost-effective manner. This article discusses the main methods of teaching anatomy and their respective advantages and disadvantages as evidenced in the literature. Suggestions are made as to how best to teach anatomy to medical students in the future.

INTRODUCTION

The education of a clinician begins with medical school and continues throughout a doctor's career. Throughout this process, the goals to which the trainee aspires will alter. For example medical students focus on gaining a grasp of the basic medical sciences and acquiring clinical skills of history taking and examination, and combining these to formulate a diagnosis.

The training of a junior doctor shares common educational goals. However, once qualified, goals correspond to the medical specialty to which the individual aspires – the knowledge a doctor needs for a career in orthopaedic surgery will differ greatly from that of a dermatologist.

Anatomy is the science of the structure of the human body. It can be divided into cellular anatomy and gross anatomy. Cellular anatomy is the microscopic study of cells and cell structure. Gross anatomy can be further divided into systematic anatomy (e.g. osteology, angiology, neurology) and topographic anatomy (the positions of organs and their relation to each other and their surroundings).

The change of priorities throughout medical training can be applied to the teaching of anatomy. Anatomy teaching can be aimed at several levels:

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- Undergraduate anatomical teaching – providing a basic pre-clinical knowledge
- Applied anatomy for clinical examination, diagnosis and basic procedures
- Applied anatomy for specialist training, e.g. surgery or radiology.

The teaching of anatomy to a medical student will be different to the teaching of anatomy to a trainee surgeon. Ellis (2001) commented that at first it is necessary to demonstrate normal anatomy (and physiology) before teaching complex pathology, implying that at first, medical students need to learn a basic knowledge of topographical anatomy. The same work suggests that the teaching of anatomy to students should be clinically relevant and this can be achieved by means of clinical demonstrations of patients with the relevant pathology affecting the region that students are being instructed on.

The training systems of the undergraduate anatomy curriculum should aim to produce junior doctors with a sound anatomical knowledge, enabling them to perform clinical examinations and procedures expected of them, but at the same time having sufficient anatomical knowledge to progress into whichever specialty they chose. However, less and less time is devoted to the teaching of anatomy in the undergraduate medical curriculum (Marks and Cahill, 1988). This means that much work has been carried out as the most efficient means to teach anatomy.

This article outlines methods used in the teaching of anatomy and suggests how it may be taught and examined in the future.

TRADITIONAL METHODS OF TEACHING ANATOMY

Cadaveric teaching

Cadaveric teaching involves the use of donated dead bodies in the teaching of anatomy (*Table 1*). It can be broadly divided into dissection and prosection. Dissection involves the student exploring the body him-/herself and studying the structures as they arise. Prosection is the examination of pre-dissected specimens.

Dissection has long been the mainstay in the teaching of anatomy and many believe it to be essential not just for the learning of anatomy but in the medical student's development as a doctor (Ellis, 2001; Ashraf Aziz et al, 2002). Ellis (2001) lists six reasons why dissection is important:

1. To teach the basic language of medicine
2. To aid development of manual dexterity

TABLE 1.
Methods of teaching anatomy

Traditional methods	Cadaveric teaching
	Live models/living anatomy
	Literature
	Lecturing
	Problem-based learning
	Regional anatomy
Modern methods	Systems
	Radiology
	Intraoperative
	Website advances
	Software
	Multimedia
	Personal digital assistants (PDAs)

3. To introduce the concept of biological variability between different people and to demonstrate pathological changes in the human body
4. To teach the student how to communicate
5. To teach the student how to access information.
6. To acclimatize students to the reality of death.

Weeks et al (1995) suggested that dissection (if performed in an appropriate manner) can reduce dehumanization of the doctor–patient relationship, enabling the integration of 'the scientific view of the human body as an object with a more holistic view of the patient as a person'. They also suggest how to achieve this, for example giving personal and medical details of the cadaver and holding a memorial service at the end of the course.

However, much of this evidence is based on professional opinion and it may not be the best or most efficient means of teaching anatomy. Cadaveric dissection is also associated with some drawbacks and hazards (*Table 2*) such as expense, danger of embalming fluids and potential exposure to infectious diseases (Ashraf Aziz et al, 2002).

The work of Nnodim (1990, 1997) and Nnodim et al (1996) in Nigeria focused on the comparison between prosection and dissection. He also addresses the student response to dissection (Nnodim, 1996). The power of this questionnaire study is reduced by a 54.1% response rate, but it does show that students had strong reactions to dissection. These were negative at first but neutral and positive attitudes later supervened. It is difficult to extrapolate these data to Western medical schools because of cultural differences and also the nature of cadaver acquisition. In Nigeria, the only bodies used are those of executed criminals or those abandoned by their families. This leads to a shortage of bodies making the need to identify alternatives to dissection more real. This may introduce an element of bias into these studies, which is weighted against dissection. However, similar studies have demonstrated that dissection is a significant stressor but ultimately a positive experience (McGarvey et al, 2001).

TABLE 2.
Negative aspects of dissection

Time consuming	
Labour intensive coupled with a shortage of anatomists	
Excessive reliance on rote learning	
Cadaver unavailability	
Cadaver anatomy different to normal anatomy because of post-mortem changes	
Expensive to obtain, prepare, store, maintain and dispose of	
Unaesthetic	
Outdated archaic technology	
Potential health hazard	Dangers of embalming fluids
	Infectious diseases (human immunodeficiency virus, tuberculosis, hepatitis)
	Psychosocial stressor

From Ashraf Aziz et al (2002)

Many of the disadvantages of dissection can be overcome by using prosections to teach medical students anatomy. Prosection involves the predissection of the cadavers (by anatomy tutors or surgical trainees) and the subsequent use of these by the students. It means less cadavers are needed, it is less time-consuming for the students, they have less exposure to the hazards associated with dissection, and important anatomical structures are preserved. However, this can mean that the student may not begin to develop manual dexterity and as good three-dimensional comprehension of the human body (Ellis, 2001; Ashraf Aziz, et al, 2002).

Much of the evidence regarding cadaveric teaching is based on descriptive papers and professional opinions. There are several studies comparing the use of prosection instead of dissection in the teaching of anatomy (*Table 3*). It can be seen from this that either no significant differences were seen in exam results between those taught by dissection and those by prosection, or prosection yielded better results.

There is currently no evidence from medical students who are taught anatomy without the use of cadavers. However, in 2002 the Peninsula Medical School, UK accepted its first year of medical students onto a curriculum that does not use cadavers. The course uses a combination of extensive surface and living anatomy, medical imaging combined with three-dimensional animation and clinical skills laboratories using interactive simulators (McLachlan et al, 2004). This will be discussed later in this article.

There is much strong feeling in the medical community regarding the use of cadavers in the teaching of anatomy. However, there are also disadvantages and practical issues associated with this. There is also evidence that dissection may not be the optimal method of teaching anatomy, but whether withdrawal of cadavers from the curriculum is the answer is as yet unclear. The outcome of the first students to graduate from the Peninsula Medical School will be met with much interest for this reason.

LITERATURE AND LECTURES

The use of literature and the lecture theatre in higher education, regardless of subject, are two of the most traditional methods of teaching. The library allows access to vast amounts of information and with the advent of the internet this asset has increased exponentially. Private study and the use of literature enables access to all the necessary facts and information for the study of anatomy, however, it requires a self-directed learning process. It also necessitates the use of rote learning and does not offer the visual or other sensory stimuli that dissection and other learning modalities offer.

One of the main arguments in favour of the use of cadavers in the teaching of anatomy is that it enables the student to develop a sound three-dimensional awareness of the human body, which books cannot offer.

Studies into the various methods of teaching anatomy have been driven in part by the reduction of hours devoted to the subject in medical schools. Nnodim distributed questionnaires to a cohort of medical students in Nigeria, asking them to rate learning in preferential order of perceived usefulness (Nnodim, 1988). This study demonstrated that reading and private study followed by lectures were rated the most useful. While the circumstances

in a Nigerian medical school cannot necessarily be extrapolated to other institutions, every university operates under time and financial constraints and therefore the students' perception of what is the most useful teaching method should not be ignored.

The lecture theatre enables the distribution of information from one teacher to large numbers of students. With multimedia technology, lectures can be distributed to several sites, vastly increasing the audience. It is an opportunity for those with experience and enthusiasm for the subject to convey basic concepts and ensure that the relevant core syllabus is covered. It is, however, a didactic process which is not very personal. A lecture will not necessarily cover the material at a pace suitable for every student in the audience. As with the use of literature, lecturing does not offer a perception of touch and only gives a two-dimensional view of anatomy.

Problem-based learning

Problem-based learning requires the student to define his/her own objectives, go off and collect the information and use problem-solving skills within a group to draw together all the relevant facts. Thus it requires self-directed learning and teamwork skills. This method is used to teach anatomy, but there is much variation in how it is implemented (Heylings, 2002). Problem-based learning may not suit all students, e.g. those who do not lend themselves so well to self-directed learning. However, there has been no formal assessment of outcomes comparing problem-based learning with other teaching modalities.

MODERN METHODS OF TEACHING ANATOMY

Systems-based anatomy

Traditionally, anatomy was taught regionally, i.e. thorax, abdomen, lower limb, whereas it is now commonly taught by systems (Heylings, 2002), e.g. the gastrointestinal system and musculoskeletal system. However, there is evidence that the implementation of a systems-based course had a negative impact on students' knowledge of surface anatomy (McKeown et al, 2003).

Radiology and the teaching of anatomy

Medical imaging has been used for some time in the teaching of anatomy, incorporating a clinical application to the subject. Ultrasound has been incorporated into living anatomy courses (Teichgraber et al, 1996). In this study, 48.7% of the students felt that their topographical knowledge of the abdomen had improved. The authors also commented that this method improved the students' three-dimensional anatomical knowledge, allowed accurate determination of organ sizes and enabled comparison of cross-sectional ultrasound images with cadaver cross-sections (Teichgraber et al, 1996). Radiological imaging can also be digitally stored and transmitted, making it more accessible to a wider audience.

The Peninsula Medical School anatomy course, which does not use cadavers at all, relies heavily on the use of radiology. This course uses medical imaging such as ultrasound and uses radiologists and radiographers to teach the course (McLachlan et al, 2004). There is evidence that specific radiographic anatomical facts are poorly retained by medical students (Feigin et al, 2002). However, if radiology is used as a means to demonstrate anatomical structures and to reinforce clinical relevance, perhaps the specific facts are less relevant. Is the application of the knowledge more important?

TABLE 3.
Comparison of evidence of dissection vs prosection

Author	Methods	Conclusions
Jones et al (1978)	Compared examination results between students who dissected and those who underwent a multimedia anatomy course involving audiovisuals, computer-assisted instruction and tutorials involving prosection. Intra- and extra-mural examination results compared	No significant difference in extra-mural exam results between two groups. In intra-mural examinations, dissecting students performed better in three examinations compared to six in the prosection group
Peppler et al (1985)	Half the medical students dissected either the upper or lower extremity and studied the opposite extremity already dissected by the other medical students	No significant difference in examination results between groups regardless of whether dissected or prosected
Nnodim (1990)	Comparison of exam performance between dissection and prosection group. Dissection group used dissecting manual and tutor assistance. Prosection group had an advance handout, pre-tutorial, demonstration with prosection directed reading and group review. 14 hours less study time was spent with the prosection group	Prosection group performed significantly better in examinations. Follow-up questionnaires found that students thought that more structured private study was more effective and that dissection may cause damage and loss of superficial structures
Nnodim et al (1996)	Follow up of Nnodim (1990) study: students reassessed to see if mode of learning had any effect on their recall 5 years later	No statistical difference in exam performance. Less guesswork in prosection group and prosection group judged to have performed better in the oral examination by two blinded examiners
Yeager (1996)	Comparative study between dissection and having the region studied demonstrated by peers on the prosected specimen	No significant difference in exam scores. However, thought that dissectors may have performed marginally better, but prosection an adequate substitute
Nnodim (1997)	Comparative study between traditional dissecting group and experimental group, divided into two halves, alternating between dissection and subsequently demonstrating the dissected material as a prosection to the rest of the group	Experimental group performed significantly better than the traditional dissecting group

Computed tomography (CT) scans have been integrated into anatomy courses and this, coupled with a more clinically relevant content, is thought to encourage the understanding of anatomy and aid clinical thinking (Boon et al, 2001). CT scans can also be reconstructed to give three-dimensional images. These have been used to teach medical students and have been found to be effective in demonstrating surgical anatomy (Mastrangelo et al, 2003). Magnetic resonance imaging (MRI) has also been used to teach anatomy, in particular to demonstrate soft tissue structures (Collins et al, 1991).

Intraoperative instruction of anatomy

Many novel methods used in the teaching of anatomy focus on the clinical application of the subject. Possibly the best example of the application of clinical anatomy is surgery. It allows visualization of structures in a living individual and is therefore not subject to the post-mortem changes that can make cadaveric images structures less easily delineated. There is evidence that education in the operating theatre is effective in teaching anatomy (Park et al, 2001). This study used laparoscopic cholecystectomy to demonstrate upper gastrointestinal anatomy to medical students. This received positive feedback and knowledge of laparoscopic anatomy significantly increased after the procedure.

As with radiology surgery adds clinical relevance to anatomy and is also thought to improve student interest and subsequent retention of facts (Park et al, 2001). Procedures involving laparoscopy or endoscopy also lend themselves well to multimedia projection, thus increasing the accessibility of the information (Carr-Locke, 1990).

Website advances, software, multimedia and personal digital assistants

The internet allows mass distribution of information and there are websites dedicated to anatomy learning, e.g. www.vesalius.com and www.anatomy.tv (*Figure 1*). www.anatomy.tv is an interactive website that enables the student to study the anatomy from all angles and through different planes while gradually removing tissue layers. All the cross-sectional images correspond to MRIs so that structures can be compared to their radiological equivalents.

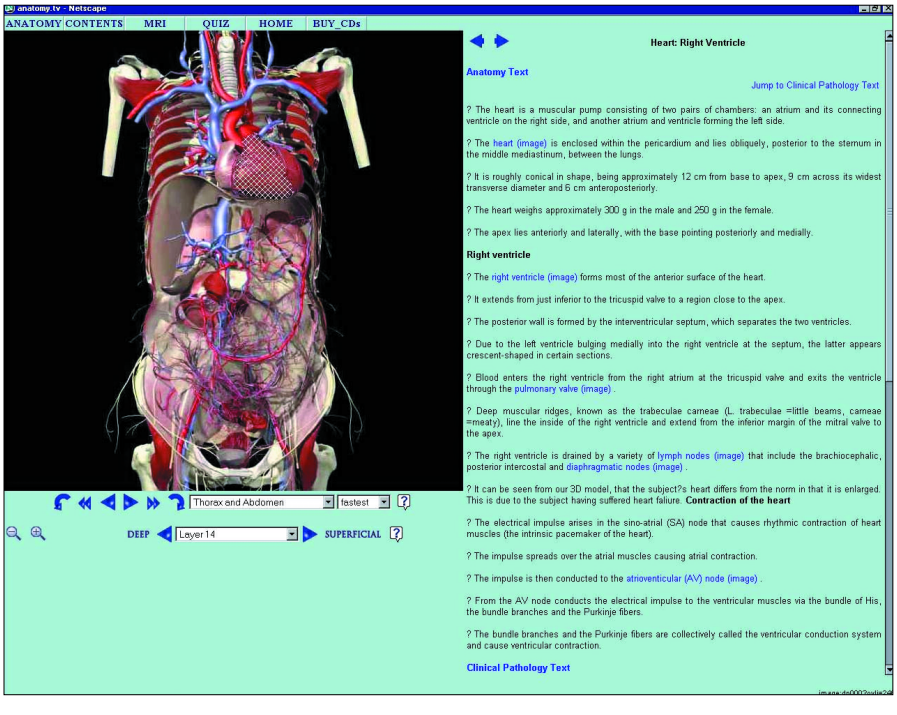
The visible human project, which was initiated by the National Library of Medicine in the United States, aimed to provide a complete digital catalogue of human anatomy. It involves images taken at 4 mm cross-sections and correlating these with radiological images. It has led to the development of many projects and software including interactive three-dimensional models and animations (Jastrow and Vollrath, 2003).

Some work suggests that using interactive web-based software does improve students' anatomical knowledge (Hallgren et al, 2002). There is a high student demand for computer-aided instruction in anatomy (Jastrow and Hollinderbaumer, 2004).

The use of these websites requires self-directed learning, they need to be reliable and they require adequate access to hardware and software. This coupled with purchasing access means that costs will be incurred. Subscription to www.anatomy.tv for 300 students for 1 year equates to approximately £40 per student. This relies on access to computers that is common in universities today, so the facilities needed to teach anatomy via this medium are likely to be already in place and available for other subjects and indeed for other students. In contrast, dissecting room facilities are used solely for dissection and prosection, have to be run and maintained according to stringent health and safety regulations and can only be used by those students who study anatomy as part of their course.

Personal digital assistants (PDAs) are being used increasingly in medicine (Wiggins, 2004). They have been used successfully in teaching medical students and allow self evaluation while on the move (Bertling et al, 2003). As yet there are no clinical trials comparing students being taught with PDAs with those without. The authors believe that they offer the facility for revision and testing knowledge on the move, and to refresh memory of a procedure before carrying it out, but there is clearly a need for trials assessing the effectiveness of this. There is software available which is dedicated to anatomy (e.g. Netter anatomy, Icon

Figure 1. Interactive thorax and abdomen. From www.anatomy.tv



learning systems, Teterboro, New Jersey, USA; icon@medimedia.com). From the authors' experience companies are very keen to promote their software in medical schools.

SUGGESTIONS

Anatomy teaching should be integrated as much as possible with clinicians from different specialties. There should be access to the new technology available on an individual level (with PDAs) and on a mass level with web resources and clinical skills models to practice practical skills. Cadaveric teaching may not be the most efficient method of demonstrating anatomy, and as has been discussed, there is little strong evidence that it is the best means of teaching. Perhaps its detailed use should be reserved for postgraduate surgical education. This could still enable undergraduate access to cadavers for prosection study.

Gross and surgical anatomy should be integrated both into surgical firms and earlier on in the basic sciences with the use of video transmissions from operating theatres and demonstrations (Park et al, 2001). There is very little evidence as to the effect of continuous assessment on medical training. However, it is this department's experience that, in both undergraduate and postgraduate teaching, most final year medical students and basic surgical trainees would prefer regular reinforcement of clinically relevant anatomy throughout medical school. The authors suggest that this can be incorporated into the teaching of junior medical students and re-examined during surgical firms, and again in surgical finals, with an emphasis on clinical relevance.

CONCLUSIONS

There is less time in the modern medical curriculum devoted to the teaching of anatomy. This requires the most efficient teaching methods to be used. As has been demonstrated, there is little strong evidence as to which techniques are the best. Advances in software and computer technology offer the potential for efficient distribution of anatomical knowledge and the authors believe that these tools should be introduced into a more clinically integrated anatomical course taught by clinicians. This knowledge should be subject to assessment at the end of the basic science course, during surgical firms and as part of final exams. HM

Figure 1 *is used by kind permission of Mr Laurie Wiseman, Founding and Publishing Director, Primal Pictures Ltd, London.*
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KEY POINTS

- There is less and less time devoted to anatomy teaching in medical schools.
- Junior doctors need sound anatomical knowledge to perform examinations and procedures expected of them.
- Cadaveric dissection may not necessarily be the best method of teaching anatomy, especially with less time available for hands-on teaching.
- The use of clinical radiology and surgery in anatomical teaching adds a further applied dimension and can improve anatomical knowledge.
- Advances in software may be used allowing distribution of interactive information, enabling interactive learning, revising and testing anatomy from any location.
- Anatomy teaching and examination should be continuous throughout medical school and there should be a clinically relevant anatomical component to all surgical examinations.