Living anatomy in the 21st century: how far can we go?

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Abstract:

Living anatomy, defined as the anatomy revealed on living humans, is gaining importance in modern anatomy education, and has even been considered to replace cadaver-based anatomy study. We discussed the modalities through which living anatomy can be studied and explore the feasibility of using them to replace cadaver-based anatomy. We believe that the study of anatomy via the three main modalities of living anatomy, namely, surface anatomy, medical imaging and surgical procedures, rely on a foundation of sound knowledge of the three-dimensional anatomy.

While a cadaver is still the best study material for the construction of a three-dimensional image of human anatomy, considering the pressure to reduce the hours geared towards anatomy education, education in anatomy in 21st century must be revolutionized to utilize the state-of–the-art modalities to formulate a contemporary anatomy course. Such modalities allow students to carry on self –directed learning, leading to a positive outcome in anatomy education. The problem arises if we have to incorporate more living anatomy, the time necessary for dissection needs to be minimized or compromised. We sincerely believe that the time has come to address this issue in the anatomy curriculum.

Keywords: anatomy; medical education; cadaver dissection; living anatomy

Introduction

If we ask ourselves how doctors normally encounter anatomy in clinical practice: the answer may entail the greater part of "living anatomy". The question then arises: how should we best teach anatomy? Will it make sense to teach in the context of living anatomy right from the very beginning? The study of living anatomy in medical curricula is on the rise and with the advents of imagining technologies we can now visualize the human anatomy on living subjects. If our medical students can study human anatomy on living subjects, why fall back onto the costly, hazardous, and pungent preserved cadavers? (Aziz et al., 2002) After all, they are going to practice medicine on living people. Thus, it appears to make much more sense to teach living anatomy, and to emphasize less on the traditional cadaveric dissection (Mclachlan and Regan De Bere, 2004). In this paper, we would like to examine the nature, the pedagogical values of living anatomy and then we ask the question - are we prepared to spend less time on cadaveric dissection in order to incorporate more living anatomy?

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Nature of living anatomy

(1) Living subjects

The first characteristic of living anatomy is that the subjects being studied are alive. This stands in sharp contrast to the traditional subjects: the human cadavers. The implications are manifold. The living subjects must understand the nature and implications of the procedures or studies to be done on them and give explicit consent. Some procedures are done for diagnostic or therapeutic purposes on patients. During these procedures, the anatomy is revealed and can be used for teaching and learning purposes. The study of anatomy is an added-value procedure and does not impose additional procedures and risks to the subjects. Nevertheless, informed consent needs to be obtained for the procedures. When the procedures or studies on the subjects are done for the sole purpose of the study of anatomy, consent must also be obtained.

In the study of surface anatomy, the living subjects need to consent to exposing parts of their bodies to a large number of students, especially in cultures, in which body exposure carries significant meanings (Aggarwal et al., 2006). In using ultrasound to demonstrate live anatomy (Heilo et al., 1997; Miles, 2005), the nature of the scan should be explained to the subject being scanned. The subject should be explained the possibility of accidental discovery of pathologies and that failure to demonstrate any pathology does not necessarily imply the absence of pathology; unless the scan was

performed by a radiologist, in which case the radiologist has to bear the responsibility. The subject should also consent to being scanned in front of a large number of students, which is often the case when the scan is done for teaching purposes. This brings in the privacy issue. Any accidental discovery of pathology, anatomical variations or pregnancy will be known to all students taking part in the teaching session.

Both normal individuals and patients with anatomical pathology can be used in the study of living anatomy. Demonstrating pathological anatomy has the advantage of showing how normal anatomy can be distorted in pathological conditions and what their consequences are (Pabst et al., 1986; von Lüdinghausen, 1992). However, we believe that the students must learn the normal anatomy first because normal anatomy is the basis on which the students build their understanding of the pathological conditions.

(2) Methods of study

The fact that the subjects being studied are living dictates the means of studying their anatomy. No harm must be done to the living subjects. Thus, the traditional method of studying anatomy on cadavers, by dissection, manipulation, and exploration, cannot be used. The methods that can still be used fall into three main modalities: surface anatomy, medical imaging methods and therapeutic procedures such as open surgery, laparoscopy, and arthroscopy.

(a) Surface anatomy

Surface anatomy is the study done on the surface of the subject by inspection, palpation and manipulation, in relation to the anatomy under the skin. It elicits students' interest in gross anatomy, showing them what they learned from books, lectures, and dissection are actually present in living persons. Although it is an obvious fact that should need no demonstration to be convinced, the surprises and joy students show when they first 'discover' what lies under the skin tells us that surface anatomy is an invaluable method of instruction.

Surface anatomy has become increasingly important in anatomy education in the recent decades (Blevins & Cahill, 1973; Rosse & Boudreaux, 1978; Metcalf et al., 1982; Boon et al., 2002; Aggarwal et al., 2006). The main reason is that surface anatomy forms the obvious connection between basic gross anatomy and clinical practice, because it is the basis of physical examination (Metcalf et al., 1982).

Often, students themselves are the subjects in the demonstration of surface anatomy (O'Neill et al., 1998; Rees et al., 2005). Peer examination allows them to feel how it is like to be inspected, palpated and manipulated, i.e., to be a patient and to show patient empathy in for future practice (Metcalf et al., 1982). However, using students themselves as subjects for surface anatomy demonstration should be carefully planned, because of the cultural and social sensitivity (Metcalf et al., 1982; Aggarwal et al., 2006). The alternative is to use professional models, especially for sensitive regions such as the breast, pelvis and perineum.

Also included under the study of surface anatomy are the projection technique (Patten, 2007) and body painting (op den Akker et al., 2002). Both use the body surface as the medium for presentation of images of internal anatomy. They use either commercially available images or hand painted images to enhance students' learning of surface anatomy.

(b) Medical imaging

The most powerful tool available nowadays for the study of living anatomy is no doubt the medical imaging technologies, such as X-ray, CT, MRI and ultrasound. Their primary purpose is to reveal anatomy, normal and pathological, in patients. The use of these medical images in the teaching of anatomy is a by-product of these technologies.

The most widely used medical imaging modality in anatomy education is expected to be radiographs. It has become an essential part of most, if not all, medical anatomy programs, sometimes even with support from radiologists (Erkonen et al., 1990, 1992; Miles, 2005; Ganske et al., 2006). Plain radiographs primarily allow students to study skeletal anatomy. Only limited aspects of the soft tissue structures in living humans such as the shape and level of the diaphragm, the appearance of the lung field, and the gas shadows in the abdomen can be shown on plain radiographs. The study of soft tissue anatomy using radiographs relies on the use of contrast, in studies such as barium meal, barium enema, intravenous urogram, hysterosal-pingogram, and endoscopic retrograde cholangio-pan-creatography. We believe that these contrast studies have much educational value because they can show, even though only indirectly, the appearance of soft-tissue structures in a living person.

Other medical imaging modalities commonly used in anatomy education are MRI, CT and ultrasound. The first two introduce the study of sectional anatomy, transforming the three-dimensional structures and relationships into two-dimensional representations. Ultrasound, due to the lack of significant side effects, has been used for real time demonstration of anatomy on living subjects, often times the students themselves (Heilo et al., 1997; Miles, 2005). However, the use of ultrasound on students for demonstration of anatomy still needs to be done with care, because ultrasound does carry certain adverse effects (Kieler, 2002) and because of accidental discovery of pathology or pregnancy which will then be made

known to other students in demonstration sessions, and because of the possible failure to discover as yet unknown pathology in the subjects.

Incorporating these medical imaging modalities in the study of anatomy is appropriate not only because they offer ways of visualizing the anatomy of living subjects, but also because they are the very same diagnostic means which the students will use in their practice. Training in sectional anatomy is known to increase their future ability to interpret diagnostic sectional medical images (Erkonen et al., 1990, 1992). Therefore, it is sensible to teach our students how to interpret these images from the beginning. We believe that it is important to introduce sectional anatomy at this early stage because students will have the opportunity to correlate these sectional images side by side with the dissected or prosected specimens. This is important for students to understand how the two-dimensional images represent the three-dimensional structures.

Voxgram R images are true three dimensional holograms of anatomy. They are the state of the art 3D tool for assisting educators with the challenges of effectively teaching clinical anatomy. Teaching sectional anatomy to medical students remains one of the greatest challenges for medical educators. These holograms of anatomical structures project out in three dimensional space as exact replicas of actual human anatomy and pathology. Students learn from 3D x- rays that clearly illuminate the complex anatomical relationships of the human body. A single life sized voxgram image produced from actual MRI or CT scan provides a unified comprehensive display of the key anatomical structures and dramatically helps students overcome the difficulty of mentally integrating 2D information. It is felt that students who easily visualize and exactly reach in and trace anatomical structures develop faster and more accurate understanding of the complex three dimensional structures (Ganguly et.al 2003).

(c) Surgical procedures

A successful surgical operation depends, in addition to many other things, on a sound knowledge of anatomy on the part of the surgeon. However, surgical operations are far from being ideal for the study of living anatomy. The surgical exposure is mostly determined by the pathology, the procedure to be performed, the regional anatomy, and the surgeon's experience, but never on pedagogical considerations that best demonstrate the anatomy to the students. The exposure of the anatomical structures will be adequate to allow the procedure to be completed successfully and safely. It is unethical to do otherwise. The patient is the centre of the operation. Every consideration is given to foster the successful completion of the surgical operation. Teaching activities can still take place during the procedure, provided that it does not affect the procedure and the patient. However, students can only learn those aspects of anatomy which happen to be demonstrated during the operation. The scope of study of living anatomy is contingent upon the surgical procedure.

Laparoscopic surgery is a modern surgical technique in which surgery predominantly in the abdomen is carried out through small incisions. The key element in laparoscopic surgery is the use of a laparoscope: a telescopic rod lens system that is connected to a video camera and a fiber optic cable system. The video can be used as an excellent resource for students to understand living anatomy. Students should immediately appreciate the difference between a living and dead liver in terms of appearance, texture and relationship with the cystic artery. Similarly, other endoscopic procedures, such as bronchoscopy, gastroscopy etc. can be great tools for normal and clinical living sessions. These are computer based programs which are extremely useful for learning/teaching purposes.

Pedagogical values of living anatomy

Living anatomy is an essential part of anatomy education. It provides some of the essential knowledge for performing physical examination, it introduces clinical encounter in the early part of medical education and even gives students the patient's perspective when students are subjects of physical examination. It introduces students to sectional anatomy in medical imaging technologies, which is now an essential part of clinical practice. More importantly, living anatomy enables students to connect basic gross anatomy and clinical practice, so that they realize that gross anatomy is an important subject, as has been repeatedly emphasized by practicing doctors (Mutyala & Cahill, 1996; Cottam, 1999).

Although living anatomy is an essential part of anatomy education, we do not think that it can replace the traditional cadaver-based anatomy study. We believe that students need to have reasonably good knowledge of three-dimensional anatomy, gained through cadaver-based anatomy study, before they can benefit from the studies in living anatomy.

The learning of the three-dimensional anatomy is a very important part of the medical curriculum (Graney, 1996; Marks, 1996, 2000; Jones, 1997), not only to those who will train to become surgeons, but to all medical graduates, because even simple needle procedures require a thorough understanding of the three-dimensional structure of the human body, and because many clinical problems have significant anatomical basis, such as tumors, spread of infection, and neurological dysfunction (Graney, 1996). Furthermore, a foundation of three-dimensional anatomy is the pre-requisite for the study of living anatomy.

(a) Surface anatomy

Surface anatomy cannot be appreciated without good knowledge of internal anatomy. The observed contours of the body surface due to underlying muscles and the palpated bony prominences due to underlying bony landmarks have to be interpreted using the underlying internal anatomy. That is why surface anatomy is taught by showing what lies beneath the skin (Burns and Colenso, 1900; Donnelly, 1990; Patten, 2007).

(b) Medical imaging

We strongly believe that medical students should be trained in the interpretation of sectional medical images, for they are now essential in almost any medical practice. But in order to successfully interpret sectional images, they need a solid foundation of three-dimensional anatomy. We live in a three-dimensional world. It is more natural and "economical" to remember the three-dimensional anatomy than a series of two-dimensional images, which can change according to the directions and levels of the sections. What students need to learn first is the three-dimensional anatomy, and then how the two-dimensional images can result from the three-dimensional anatomy. The anatomy laboratory is the ideal place to learn the correlation between the three-dimensional anatomy and the two-dimensional sectional images, for cadaveric material can be put side by side with the sectional images, and the spatial correspondence between them can then be visually inspected (Erkonen et al., 1990, 1992). The interpretation of the two-dimensional sectional images demands a strong understanding of the three-dimensional anatomy (Beahrs, 1991).

Can one work backward, i.e., to use two-dimensional images to reconstruct a three-dimensional picture of the human body? Certainly, and that is exactly how we interpret the images and deduce the pathologies (or the lack of such) from the images. Such reconstruction of three-dimensional anatomy from a series of two-dimensional images requires training and can benefit from the use of three-dimensional reconstruction softwares. Thus, the three-dimensional anatomy is the basis of understanding two-dimensional sectional images, and not the other way round. Although interpretation of sectional medical images is one of the goals of anatomy training, we cannot start teaching anatomy using these images without a proper foundation in three-dimensional anatomy. Doing so will be likened to learning to drive a Formula One car without going through the basic driving lessons on ordinary cars.

(c) Surgical procedures

In the study of living anatomy through surgical procedures, only certain aspects of the complete picture of anatomy can be shown, because the surgical exposure is never dictated by pedagogical considerations. The study of living anatomy is only a by-product of such procedures, of which the only goal is still the treatment of patients. Students would have seen only a very limited part of the human anatomy if they were to learn their anatomy totally from surgical procedures. They must learn their anatomy by other means and then re-enforce their knowledge by observing surgical procedure (Beahrs, 1991).

We believe that three-dimensional anatomy is best learned through cadaver-based anatomy programs (Graney, 1996; Marks, 1996, 2000; Jones, 1997; Moore, 1998; Aziz et al., 2002; Mitchell and Stephens, 2004; Older, 2004; Rizzolo and Stewart, 2006). Of course, cadaver-based anatomy programs also have other advantages that have been expounded by various authors: continuation of our hard-won privilege of receiving bodies by donation, appreciation of anatomical variability, promotion of team work, opportunity to confront death, promotion of humanistic value, etc (Dyer &Thorndike, 2000; Aziz et al., 2002; Gregory & Cole, 2002; Mclachlan et al., 2004; Mitchell & Stephens, 2004; Older, 2004). But with respect to anatomy education, the most important advantage of cadaver-based anatomy programs is that they offer the cadavers as the learning material. A true cadaver is the best available material next to living humans. It is true that the colors, textures, and mobility may be different from those of the living humans, but cadavers are closer to real humans in many aspects than what technology can offer today, because cadavers are real (Moore, 1998). The anatomical structures in cadavers can be seen, touched, palpated, explored with curiosity, and discovered with joy, awe and respect.

Computer assisted learning (CAL) of anatomy is offering high hope that one day cadavers can be eliminated once and for all. A computer is clean, has no smell, and will not become tired. There will be no shortage like the shortage of gross anatomist. Moreover, computers cost a lot less than gross anatomists. With rapidly progressing technology, even dissection and surgical planning and training are possible on computer (Spitzer & Whitlock, 1998; Spicer & Apuzzo, 2003; Wong et al., 2007). Computer technology has a great impact on anatomy education. However we do not believe that CAL can replace cadavers in anatomy programs. The reason is simple. Patients are real. Doctors interact with patients in the three-dimensional world, performing physical examination and procedures on them. Cadavers offer the only opportunity to learn from the real 'patient.' It is therefore reasonable to call the cadaver the students' first patient (Coulehan et al., 1995). Unless the interactions between the doctors and the patients occur indirectly in a virtual world through the "remote telepresence manipulator" as in robotic and telerobotic surgeries (Lanfranco et al., 2004; Herron et al., 2008), and

as long as the interactions between patients and doctors occur directly in the real world, cadavers are the best source to learn anatomy. The various difficulties in running a cadaver-based anatomy program (Aziz et al., 2002; Mclachlan et al., 2004; Leung et al., 2006) can be overcome once the significance of gross anatomy is understood and enough incentive is gathered.

Conclusion

As educators, it becomes indispensable for us to edify the material in a clinical fashion that can help students to encounter anatomy in real life. For this reason the study of living anatomy proves to be an important part of anatomy education, linking basic gross anatomy and clinical practice. Education in anatomy through cadaver dissection is still practiced in many medical schools and forms the foundation for studies of living anatomy. We have tried to illustrate the ways to incorporate living anatomy on multiple fronts. It is interesting to know that even if we are prepared to embrace more living anatomy in the expense of cadaveric dissection, the question remains how far we can go.

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