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Abstract
The teaching of anatomy at the undergraduate level in medical schools varies between institutions and has evolved significantly over the years. Cadaveric dissection was once the cornerstone of anatomical lessons, but its use has declined due to cost, regulation, and availability. In addition, there are a number of other modalities using modern technologies that call in to question the need for continuing cadaveric dissection. This article explores the value of cadaveric dissection and assesses the place in contemporary undergraduate medical education. The expectation that all should participate is now outdated and unrealistic. An amalgamation of different modalities is likely to be the best compromise; computer-assisted learning and techniques such as plastination should be used for all undergraduates as they are powerful, accessible and relatively economical. Selective cadaveric dissection should be reserved for the subset of undergraduates who will benefit most from the tactile experience, such as those expressing an interest in surgical specialities.

Key Words
Cadaveric; Dissection; Medical School; Anatomy; Teaching

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Introduction

The evolution of anatomy teaching has taken us a long way from Herophilus[1] to the early medical schools, where teaching was based largely on cadaveric dissection (detailed analysis of a dead body by cutting it apart). Technological advances have provided a variety of media with which it can now be supplement. Modern medical school curricula use these methodologies as an alternative and, in many institutions, cadaveric dissection has been superseded entirely, with computer-led simulation tools becoming the cornerstone of anatomy teaching. This review will analyse the relevant issues, set out some of the central arguments for and against cadaveric anatomy teaching, and answer one central question: should cadaveric dissection continue to be available to all medical undergraduates?

Historical Review and the Momentum for Change

History of Anatomy Teaching

Considered the Father of Anatomy, Herophilus (c335BC – c280BC) undertook the first scientific human cadaveric dissections, revealing major anatomical discoveries.[1] Some 400 years later, Galen advanced anatomy teaching, believing that dissection enabled him to progress significantly in medicine, with an anatomic conception of disease.[2] Although not a doctor, Leonardo da Vinci is credited with furthering our anatomical knowledge through work reliant on careful cadaveric dissection[3] conveying this information brilliantly in drawings.

It was not until Vesalius that significant further anatomical studies and literature were published. Until then, anatomy teaching was Galenic, and apprentice barber-surgeons may have gained little knowledge from their lessons. Vesalius, in 1537, was given the duty of lecturing on anatomy. Vesalius set precedence by introducing cadaveric dissection to medical school anatomy teaching. This was a major novelty, and the interest increased the supply of dissection material using executed criminals authorised by the local official, at times delaying an execution to a time suitable for dissection.[4]

Despite the gruesome historical sourcing of dissection material, some form of governance in the United Kingdom has existed for centuries. The Murder Act of 1751 legislated that only corpses of executed murderers should be used for dissection,[5] while the Human Tissue Act of 2004 governed the

removal, storage, use, and disposal of human bodies, organs, and tissues.[6] The regulation evolved to meet the changing public expectations of medical professionals, while recognising the ongoing requirements.

Modern Developments

Technological advancements have changed the face of medical practice, and this is reflected in medical teaching. Radiological imaging and multimedia tools have long been adjuncts to cadaveric dissection in anatomy teaching in medical schools. More recently, the development of computerised three-dimensional (3D) models has been a paradigm shift, providing detailed images of both normal anatomy and the changes seen in disease.[7] Unlike books and older technologies, 3D tools allow a view of spatial relationships. Prosections (a dissection by an experienced anatomist for demonstration) have been more widely used, and more recently plastination (a preserving technique where water and fat are replaced by certain plastics)[8] has been developed.

Evolving Medical Curricula

There has been a decline in the amount of time devoted to undergraduate anatomy teaching over the last 20 years. 7 Contributing factors include the reduced length of undergraduate curricula, a shift in the emphasis from basic sciences to patient-centred teaching, and the need for a wider range of subjects including humanities. Reformers argue that traditional basic science teaching did not connect students with living patients.[9] Many view dissection-based learning as an archaic, privileged 'Rite of Passage'[9] rather than an educationally enriching process.[8]

Anatomical knowledge remains the cornerstone of medical education, and today's litigious society demands a good foundation in anatomy.[8] Since the high-profile plastination exhibits of Professor Von Hagens,[8] the public expects that all doctors have sound anatomical knowledge, irrespective of their specialty. However, a major area of the debate must centre on timing. Should undergraduate education be focused on training generalists or specialists?8 Approximately half of medical students in the United Kingdom (UK) will become general practitioners.[10] This does raise the question of cause or effect. One report suggested an increased need for general practitioners and proposed a need for training to shape this change.[11]

Limited availability of cadaveric supplies has led to a need for the development of alternative learning resources.[7] The dissecting room is expensive.[9] Students can use computer-based teaching models at their convenience and the software is not subject to the same rigorous regulations as cadaveric models.[7]

Judging the adequacy of anatomical knowledge is contentious. Some studies argue that as few as a quarter of medical students had anatomical knowledge deemed adequate for clinical practice.[12] Worryingly, reports have suggested an increase in the number of adverse clinical incidences relating to poor anatomical knowledge (Goodwin, 2000).[13] Settlements of claims based on a finding of "damage to underlying structures", attributed in part to gaps in anatomical understanding, are of grave concern for patient safety and have significant financial implications for the National Health Service (NHS).[13]

In this context, we will explore the following three questions in detail:
1) Why dissect at all?
2) Does cadaveric dissection have a place in modern anatomy teaching curricula?
3) Is cadaveric dissection irreplaceable?

Why Dissect at all?

The Arguments for Dissection:

The evolution from the "body-snatching" era to modern methods of donation has been an important step in changing anatomical dissection from simply a tool for knowledge acquisition to a "vehicle for moral and ethical education".[14] Respect and reflection on issues around death are brought to the mind of the learner through dissection while developing one's professional values and accountability.[15] It assists the development of clinical detachment and empathy,[15] a careful balance for each individual. Swick viewed dissection as a modality to guide students in learning how to effectively use their affective responses while promoting active learning of professional behaviour and attitude.[16]

Dissection has a role in acclimatising students to the realities of death and teaching manual dexterity and touch-mediated perception.[7] Indeed, the sensation of feeling human flesh learnt while dissecting cannot be provided in any comparable way with alternative learning tools.[17] Another important lesson harnessed by the dissection room teaching is that of teamwork between collaborating students, realising the importance of effective communication within the group.[18] This encompasses another important principle of "Tomorrow's Doctors" in the UK,[19] providing students with not only the necessary knowledge but also the skills and behaviour required in the medical profession.

Knowledge acquisition through dissection improves

mental imagery and recall capacity.[20] A parallel has yet to be proven with other methods. Inaccuracies may be recorded in atlases which may have significant implications surgically and will only be detected by those who dissect on a frequent basis.[15] There is unpredictable anatomical variation in cadavers9 which cannot be replicated in models. Hildebrandt goes further to suggest that collective anatomical knowledge may be diminished if we abandon the art of dissection.[15] Sugand supports this, stating that a move away from cadaveric teaching may result in "incompetent anatomists and healthcare professionals, leaving patients to face dire repercussions".[17]

The Arguments Against Dissection:

We live in an era in which we would hope to promote the development of compassionate and caring medical professionals. Should we continue to subject them to acts requiring "a certain inhumanity" during their training, as described by William Hunter,[15] or, as Ware put it to students in 1851, creating a "difference between us and other men in the feelings with which we regard the remains of the dead"?[15] Several studies have shown that students experience considerable anxiety and stress with dissection,[21] and failure to develop defence mechanisms may make this incapacitating. An overdevelopment of these mechanisms may result in detachment, and indifference and cynicism may emerge.[21]

The reform of medical education in The United States of America was deemed necessary to fulfil the potential of active student-driven learning and a move away from lectures.[15] Within the reform of anatomy teaching, those who had admittedly appreciated dissection within their own learning recognised the need to shift towards a curriculum in which "only the essential and part of the useful become required work".[31] It was apparent that, for the majority of medical trainees, anatomy would not be the main focus of their education, and additional elective courses could be provided to those students who desired a deeper understanding of the subject. This anatomical teaching doctrine was considered highly successful and influential at the John Hopkins Medical School.[15]

Flexner delivered a fairly scathing assessment of dissection rooms in his report in 1910 as "rarely clean, always unattractive and not frequently unpleasant".[22] This highlights the health implications of working with cadavers which, in such times, involved prolonged exposure to formalin.[22] Medical training in the past has been guilty of teaching students excessive detail with little comprehension of the clinical relevance.[8] Anatomical knowledge accrued in this way has very little educational validity.[8] Modern teaching places clinical applications at the centre of its focus, thus encouraging a more student-led approach to understanding anatomy in a systems-based way.

Does Cadaveric Dissection have a Place in Modern Anatomy Teaching Curricula?

The Arguments for Dissection:

Curricular reform has led to a reduction in time and content of anatomy teaching.[15] Drake's analysis in America saw a reduction in the curricular time spent on anatomy from 335 hours in 1955, to 195 in 1973, and 149 by 2009.23 Anatomical knowledge is at risk of falling short of a safe level,[17] and the shift away from cadaveric teaching may fail to provide adequate assimilation of core knowledge.8 The GMC's "Tomorrow's Doctors"[19] sets out an aim for a medical curriculum with a greater emphasis on communication skills. However, as observed by Dawson et al. "good communication requires a sound knowledge base".[12]

It is hard to compare the overall financial differences between cadaveric dissection and computer-based teaching as constructing computerised three-dimensional models is undoubtedly very expensive and no studies have compared this to the cost of cadaveric anatomy teaching overall.[7] Students need computers of a reasonably high specification to fully appreciate the best quality computerised models, thus imposing an additional cost to the software alone. Even then these models do not provide a sense of touch and are, at best, iconic abstractions of the real subject.[7]

Analysis of students' perceptions on use of cadaveric dissection in modern medical curricula shows ongoing support for its ability to enhance learners respect for the human body and made learning more interesting.[24] Participants have also conveyed that cadaveric dissection has deepened their knowledge and understanding of anatomy.[24]

The Arguments Against Dissection:

Modern physicians need not only scientific training but to develop humane skills such as empathy and compassion. This has been adopted by modern curricula that centre on this integration of skills in a problem-based and clinical-presentation based approach.[15] With this change in the emphasis of modern medical teaching, it is important that anatomy teaching becomes more efficient by providing essential knowledge at a clinically relevant level.[15] This has heralded the need for alternatives to dissection, with the use of radiology, computer models, and interactive multimedia tools. In conjunction with prosections, these allow students to integrate their acquired knowledge.

The fundamental philosophy behind modern medical teaching is the concept of active learning. The importance of this was recognised by Mall much earlier, but more recently it is based on insights from cognitive science.[15] In America, Mall's idea of basic anatomy for all and selectively taught higher level anatomy to those with specific interest has been highly successful[15] and widely implemented. Chevrel supports this idea, with the proposal of modern computer programs providing anatomy teaching at "successive stages of increasing specificity" tailored to meet the needs of individual students.[25]

The main disadvantage of cadaveric dissection, as perceived by the learner, is that it is a time-consuming learning method.[24] Sometimes this can come at the expense of teaching in other basic science subjects. In conjunction with the smell and the perceived difficulty in finding the assigned structures, non-attendance at cadaveric dissection teaching by a fifth of students[24] calls into question the role of such an expensive modality.

Is Cadaveric Dissection Irreplaceable?

The Arguments for Dissection:

There are modern technologies available that aim to replace dissection. Proponents of cadaveric dissection see these tools merely as supplements. Modernists claim that the implementation of advanced methods such as virtual reality environments require a "relatively modest" financial investment,[25] although there is a reluctance to quantify this further. High specification computers may not be an inconsiderable outlay, particularly when considering anatomy education globally. Computer-generated models lack variation and pathology of the real human body.[20] Plastinated models have been described as "waxy and brittle" and difficult to relate to reality.[20]

The Arguments Against Dissection:

The parallel of the outdated blackboard and the cadaver is highlighted by Chevrel, who sees modern imaging techniques as crucial to the diffusion of anatomy knowledge.[25] With computer tomography, ultrasound, and magnetic resonance imaging in static and functional modes providing 3D reconstructions, we are in a technological environment that has surpassed the need for archaic tools.[25] Integration of internet resources into anatomy teaching is an important innovation. The internet is widely available and allows flexible access to a wide range of learning materials. Interactive modules cover conceptually complex topics.[15] Computer availability to learners allows repetition and quick visual comparisons in a way that dissection cannot match.[26]

Computer-assisted learning and computer-assisted instruction describe interactive teaching methods using two- or three-dimensional training models, including virtual reality. This method of delivery has been compared to traditional methods of anatomy teaching using lectures and models. It compares favourably when measuring educational outcome levels and provides a time-efficient, convenient teaching tool.[27]

Discussion

Medical curricula in modern universities must consider cost implications, time constraints, and the volume of knowledge and skills to deliver. There is a lengthy historical background to dissection, which encourages us to continue to value this privilege. It is, nonetheless, perhaps outdated and cannot continue as the sole method of teaching anatomy, without considering the alternatives.

Advances in computer technology have enabled the development of virtual reality environments allowing 3D perspectives, unlimited repetition, and student-directed learning.[25] Interestingly, while educationalists may be tending to move away from dissection, there is evidence that students are keen to see it continue to form a part of their curriculum. However, the evidence from higher-level anatomy teaching, including surgical training, points to a move towards non-cadaveric-based learning. There is increased use of simulation models, often using animal tissue to reproduce the tactile experience.[25]

There are other advantages to newer technologies. Virtual collaborative environments provide more rapid knowledge acquisition and require less cognitive effort when compared to traditional educational practices.[28] Plastinated models have been shown to enhance students' learning and interest[15] and are durable and odourless.[26] Surgical prosections and plastinated models are a time-saving resource and are easily demonstrable, helping to overcome staffing issues and cadaver shortage.[26] The role of dissection in developing dexterity may also be replaced[29] with computerised tools and various surgical simulation modalities, including bench-top models, laparoscopic simulators, and robotics.[30]

There is however a lack of clear evidence on the effectiveness of the various approaches to the teaching and learning of anatomy, and newer technological alternatives to dissection have not undergone rigorous comparative testing. Most authors recognise a place for dissection alongside these alternatives as continuing to provide contact with the reality of the body and a clear understanding of the topography of different regions.[25] Sugand advocates the combination of

medical imaging with cadaveric dissection to produce a greater level of student interest in gross anatomy.[17]

Collins is undoubtedly right that the time given in the curriculum to anatomy is certainly unlikely to increase, and modern teaching must, therefore, deliver within this restriction.[29] However, his assertion that the benefit of dissection is limited to those requiring more detailed anatomical knowledge is contentious, and there is a need for further research to lay to rest emotive and anecdotal arguments.[29]

Dissection requires more time and specific training to meet the educational needs of the learner. With the significant reduction in the hours allocated to anatomy teaching in medical schools, this method may no longer be feasible.[20] In designing a medical course, Scott recognised the time pressures and, by tailoring the course expectations to the clinical needs of an early 'undifferentiated' physician, was able to reduce the course hours from 320 to 98.30 This Canadian course in the 1990s replaced dissection with prosections and radiological images and was deemed favourable by both students and faculty alike.[30] It also proved more efficient, requiring fewer faculty to deliver the curriculum.

Conclusions

Returning to the question posed at the outset of this review, the requirement for cadaveric dissection to be available to all medical undergraduates is supported. However, the expectation that all should participate is unrealistic. The ideal compromise is the continued availability of cadaveric dissection for a subset of undergraduates in all medical schools, catering for those with a particular interest to further their anatomical studies and who will benefit most from the tactile experience of dissection. This could take the form of regional centres catering for a group of medical schools to electively participate students in the form of a 'special study module' and would reduce cost.

A complementary amalgamation of cadaveric dissection with computer-assisted modalities is likely to provide the best format for acquiring both knowledge and skills. The evolution of anatomy teaching should reflect the significantly more advanced way in which we now operate and practice. We are a long way from the barber-surgeons of the past and, as we move towards an era of minimal access and robotic surgery, tomorrow's surgeons will value a similarly innovative approach to their training.

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