

Are We Facing the End of Gross Anatomy Teaching as We Have Known It for Centuries?

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Abstract: The status of anatomy education in undergraduate medical education has dramatically changed over the course of the past century. From the most important and time-consuming component of the preclinical program, anatomy education has reduced in size and status, and yielded in curricular space to accommodate other disciplines and topics. Meanwhile, radiology has become more prominent, as a means to visualize anatomy, not only in clinical care but also in education. For this perspective paper, the authors, all with backgrounds in anatomy, radiology and/or medical education, conducted structured conversations with several academic colleagues with similar backgrounds, reviewed pertinent literature and analyzed the causes of the historical decline of a knowledge domain of medical education, that nevertheless is widely considered essential for medical students and graduates. After this analysis, the authors propose four ways forward. These directions include systematic peer teaching and development of anatomy education as a scholarly domain, further vertical integration with postgraduate medical education, full integration with radiology education, and capitalizing on educational technology. Schools in several industrialized countries have made steps in these directions, which can be further strengthened. In less affluent countries, and in countries with curricula strongly determined by tradition, these steps are less easy to make. To respond to changes in global health and health care, combined with the inevitable technological progress, and international mobility, we believe all schools will move in these directions, slower or faster.

Keywords: anatomy education, radiology education, vertical integration, technology, future

Introduction

Since Vesalius (1514–1564), the founder of accurate anatomy texts and drawings, and arguably the father of current anatomy teaching, medical education in the universities has had a strong emphasis on anatomy, if not being its core pillar for centuries. Around the turn of the previous century, two to three years of the preclinical curriculum devoted to morphology (anatomy, histology, and cytology) was considered time well spent, and around 1960, Dutch curricula still contained 225 to 572 hours of anatomy teaching.¹ Likewise, in 1901 medical schools in the United States had about 549 hours of anatomy teaching, and by 1955 approximately 330 hours.² The latter half of the 20th century showed a continuous decrease in the absolute and relative time devoted to teaching and learning anatomy in terms of curricular hours and in time students spend studying anatomy. While the same century has witnessed many changes in medical curricula, often aligning with Harden's SPICES model (more student-centered, problem-based, integrated, community-based, and systematic),³ the decrease in time and effort to acquire anatomical content knowledge stands out. In one Dutch curriculum, the absolute time devoted to anatomy (and other basic sciences) decreased by 60% to about 100 hours in the period between 1990 and 2010,⁴ in which year Australian/New Zealand medical schools ranged in total hours of anatomy teaching from as low as 56 to as high as 560.⁵ A similar process happened in less affluent countries. In Nicaragua, by

2019, the medical curriculum contained 102 hours of anatomy teaching,⁶ a reduction of 68% compared to 320 hours 20 years prior.

Not all knowledge that, in the past, was considered relevant for medicine and patient care is still current. Some knowledge has become irrelevant, outdated, or discovered as incorrect. Regular adaptations in education are thus needed and justified. While new insights and advances in knowledge of basic and clinical sciences have been continuously added, and clinical training has become more prominent, existing components of the medical curriculum must decrease to make space.

However, the decrease in time and attention for anatomy in medical education is in sharp contrast with a universal acknowledgment by practitioners and educators of the importance of anatomical knowledge for physicians.⁷ In some specialties, particularly surgery, there are serious worries that the decrease of anatomical education has led to a decrease of knowledge that must be supplemented with postgraduate anatomical education.^{7–9} Gross anatomy is considered an undisputed core component of the medical curriculum.¹⁰ Anatomical knowledge is indispensable for adequate physical examination of patients, irrespective of specialty, but it is also a foundation of the language of medicine. If inter-collegial and interprofessional communication cannot use the language rooted in the names of anatomical structures, adequate patient care for a variety of health professionals would be impossible.

The recent decrease in curricular time for the basic sciences includes other domains than anatomy, but the latter is the focus of our current contribution.

Given the continuous decrease, medical educators need to ask themselves the following questions: what may have caused the quantitative decline in anatomy teaching? And, most relevant, what are the ways forward to guarantee adequate quality anatomical knowledge of physicians in the future?

What May Have Caused the Quantitative Decline in Anatomy Teaching?

One cause may be the decreased academic status of anatomy in medical schools. Research weighs in on this change of status. Significant anatomical discoveries were made frequently in the 19th and early 20th centuries. In the second half of the last century, anatomical discoveries happened,¹¹ but modestly, research diminished, and education became the primary mission of anatomy departments, which consequently decreased in size, funding, and academic staff. Medical graduates with academic research ambitions are now less likely to choose (gross) anatomy as a career unless education is their passion,^{6,12} resulting in an often voiced lack of qualified anatomy teachers.¹³

A legitimate wish to turn fragmented and disconnected courses in the medical curriculum into a coherent program based on clear objectives derived from patient care may be another cause. Horizontal integration (ie, the combined educational contributions of various basic sciences) and vertical integration (the integration of clinical subjects with basic science information) have been hallmarks of modern medical curricula,^{14–16} as well as a legitimate shift from memorization of facts to problem-solving.¹⁷ Integration makes the contributions of separate basic sciences less demarcated than discipline-based courses, and an unintended consequence of integrated tests is that they allow students to pass with relatively low scores for minor parts of these integrated tests (ie, such as anatomy), whereas previously the anatomical knowledge had their own tests, which required adequate knowledge to pass the tests.¹⁸

Next, the notion—correct or not—that much of what is learned in medical school is not directly useful in clinical practice may have fueled discussions in curriculum committees when searching for space to incorporate new elements in educational programs. Depending on clinical specialties present around a committee's table, clinicians may not always have acknowledged how much time and effort it takes for students to acquire new (anatomical) knowledge.¹⁹ Encapsulated knowledge, once acquired, may become tacit in experienced clinicians,²⁰ causing this underestimation.

Finally, the (again legitimate) push toward more and earlier clinical training in the medical curriculum requires space because curriculum lengths hardly ever increase. This space must be found by decreasing components that seem less relevant. In addition, the substantial costs of anatomy education would be lowered, which may have weighed in with considerations to reduce it.

This multifold background is not so much a *deliberate* restriction of anatomy education because of its irrelevance; instead, this effect rather seems to be a consequence of wishes to integrate and include new topics in curricula and lower the space and cost of anatomy education.

What are Ways Forward?

The authors of this opinion article do not intend to judge what is an acceptable amount of anatomy education and acknowledge, as there is a wide variety in the amount of anatomy education in medical curricula worldwide. Instead, looking to the future, they propose to explore ways medical education might adapt to secure that medical graduates and specialists have sufficient anatomical knowledge to provide high quality and safe patient care.

The status of anatomy education will not return to where it came from. De-integration is not likely to happen (in most schools), and an increase in curricular hours or proportion is not foreseen (in most schools). It is also not expected that gross anatomy will become the central area of research as reflected in the past. Consequently, the future of anatomy teaching and learning is likely to be fundamentally different from the past.

To meet this challenge, multiple conversations with a variety of educators at Utrecht University (notably from anatomy, surgery, radiology, family medicine, and veterinary medicine – see acknowledgments), both directly before the COVID-19 pandemic and two years later, combined with internal discussions among the authors and references to a selection of pertinent literature formed the basis for this opinion piece. We requested from the colleagues with whom we had the conversations, an informed oral consent to record and transcribe the sessions and use the content as inputs for our analysis and discussions. The authors conducted focused literature searches using electronic databases and virtual libraries of medical education journals; the search terms related to terminology such as anatomy education approaches, future of anatomy education, the continuum in medical education, and integration in anatomy teaching. The analyses and proposals for various perspectives on the way forward are not a direct reflection of the consulted expert opinions only, nor just of the literature, but a vision among the authors that has matured over the past years. The statements in this perspective article are the authors' informed opinions rather than representing a research report.

We offer four ways forward.

Systemic Near-Peer Teaching and Anatomy Education as a Scholarly Domain

The introduction of massive near-peer teaching is the least radical but a sound approach that meets both the lack of anatomical staff and is a theory-based educational method.

A constructivist learning principle is that advanced concepts must connect to a learner's existing knowledge base, which is a reason to create such a knowledge base of gross anatomy early.

While there is nothing wrong with attempts to make learning as joyful as possible, acquiring new knowledge and skills is often, and for many students, not necessarily pleasant. In cases where the return on the investment of a student's effort occurs only in the longer term, there is a phase of mental plowing that is simply unpleasant, requiring stamina. Most top musicians and sporters will recognize this. One way to shorten that period is to engage senior students in near-peer teaching for junior students. Students as teaching assistants have for a long time been part of anatomy education, but that opportunity is usually reserved for a minority of students as an extra-curricular, often paid activity. In contrast, having all students teach anatomy as a mandatory curricular activity for credits would serve several purposes.²¹ First, it would provide a much faster relevant purpose for applying acquired anatomical knowledge and an antidote against knowledge decay.^{22,23} Second, teaching, including the preparations for teaching, is considered a highly effective way of learning.^{24,25} Third, it would enable organizing small-group education, and faculty members' role may be limited to guiding peer teachers rather than teaching students directly. Fourth, while many schools recognize the usefulness of teacher training for medical students, only a few have operationalized this.²⁶ Finally, the interest in a teaching career, such as in anatomy, can be stimulated by teaching experience in medical school.²⁷

This model, applied to clinical reasoning training for junior medical students, has been successfully applied at Utrecht University for over 15 years. All final year medical students must attend teacher training, including the teaching of junior medical students. This clinical reasoning course is entirely run by students, with just teacher oversight. It is one of the most highly valued, practical, and low-cost courses in the curriculum.^{28,29} A similar model might work for anatomy teaching and be cost-effective, even if it does not reduce infrastructure costs.

The focus of anatomy as a domain of educational scholarship fits the development of medical education as a scholarly discipline.^{30–32} Rather than through new anatomical discoveries, the anatomical discipline can distinguish itself in the future through new *educational* approaches using technology and other means.

Vertical Integration Across the Educational Continuum

Vertical curriculum integration, often translated as early clinical education in the medical curriculum, also encompasses the teaching and learning of basic sciences during later phases of medical education. The divide between undergraduate preclinical and clinical education has always been the focus of vertical integration,^{16,33,34} but the extension to postgraduate training is a logical next step. Medical specialties differ in need to rely on specialized anatomical knowledge. Surgery, radiology, neurology, gynecology, and orthopedics all require specialized anatomical knowledge bases, which need not be fully required for family medicine, dermatology or psychiatry. Focused clinical anatomy education and assessment in postgraduate training should secure specialty-specific clinical proficiency. The joint anatomy knowledge base that all medical graduates must master should be enough to enable smooth interaction with any clinical consultant, orally and through writing, and should enable anatomical explanations to patients in primary care settings, such as needed for shared decision making, involving discussion of images in an electronic health record.

Vertical integration over a prolonged time, which implies a regular repetition, also serves knowledge retention and has been recommended for anatomy education²¹ to prevent loss of basic science knowledge.^{22,35} Baker has stressed the need to employ clinically qualified anatomy teachers to establish vertical integration, which extends beyond the contribution of radiologists in anatomy teaching, as explained in the next section.²¹ Mandatory clinical and applied anatomy training, incorporated in residency programs, will be needed to guarantee sufficient and appropriate anatomy knowledge for specialists in surgical disciplines, neurology and radiology.

Integration with Radiology Education

A more radical approach to teaching the morphology of the human body is a complete integration of radiology and anatomy education.

Classic teaching of gross anatomy has relied heavily on corpses for dissection and prosection. The living body has become translucent with the discovery of X-ray imaging in 1895. Given the rapid speed of development in the past decades of modern medical imaging techniques like Ultrasound, Computed tomography, Magnetic Resonance Imaging, and Nuclear Medicine, the specialty of radiology, encompassing all these imaging techniques, has now become the discipline to reveal the gross anatomy of the living body. The primary focus of radiology in patient care is to identify, localize and characterize pathology, but the educational potential of radiology for gross anatomy education is immense. The integration with anatomy teaching is increasing^{36,37} as the interpretation of medical imaging has become an agreed-upon skill for all physicians.³⁸ This vertical integration of anatomy and radiology within the medical curriculum serves the preparation for the way physicians will interact with anatomy in their practices.²¹ Increasingly, patients can view their radiological images in patient portals of their hospitals. Explanations will be asked from primary care providers who need to be able to interpret these images to patients, if not as an expert, then at least sufficiently for patient consults. In addition, handheld ultrasound devices are becoming common in primary care practice, and an increasing number of schools acknowledge that using point-of-care ultrasound (POCUS) will be an essential skill for all medical graduates. Chang Chan found that ultrasound imaging is less intuitive for the untrained medical student than other radiological images.³⁹ Interpreting POCUS images is complex and requires extensive practice and special skills; the ultrasound's view does not coincide with the mental image that one develops along the three orthogonal anatomical planes when studying anatomy.³⁹ Nevertheless, there is no reason why junior medical students should not start practicing POCUS to acquire anatomical knowledge that reflects the anatomy they will face in later practice. Many medical schools have incorporated POCUS training, be it yet in a modest sense or with limitations^{40,41} but there is significant international consensus that medical schools should incorporate it.⁴² Until half a century ago, first-year medical students in many schools were asked to possess a set of anatomical dissection utensils for gross anatomy, a microscope for histology and cytology, a white coat, and a stethoscope. While the first is no longer the distinctive attributes of a medical student, a tablet computer and a

handheld ultrasound device may very well be the attributes of a medical student in the future, as they become increasingly affordable.

Multi-dimensional imaging, using volumetric imaging data acquired with CT or MRI, has been extensively applied in radiological anatomy education in the undergraduate medical curriculum of the University Medical Center Utrecht in the Netherlands, both for teaching and for student assessment.⁴³ As a result of such developments, radiological anatomy is becoming an essential and likely growing component of anatomy teaching in medical schools.

Educational Technology and Other Innovations

Dissection practicums and lectures, as century-old dominant methods of anatomy teaching and training, have been supplemented with several new approaches in the 20th century, including models, body painting, and early computer-assisted instruction methods. The 21st century has witnessed tremendous development in technological approaches to anatomy teaching.

Dynamic three-dimensional (3D) images, with features of rotation, displacement, zooming, changeable transparency, and allowing virtual dissection, are rapidly appearing on the market and in non-commercial provisions.^{44,45} A recent randomized study revealed that students using 3D models of hand and foot answered more subsequent test questions correctly and needed less time than students who completed the assignment using anatomical atlases alone.⁴⁶ Augmented reality and virtual reality techniques are also quickly emerging,⁴⁷ while discussions about their precise nature and use are still ongoing.⁴⁸

Life-size virtual dissection tables have emerged in the last decade as an option to replace cadavers and allow students to use their fingers as scalpels to dissect virtually. One study showed how teaching with a virtual dissection table, combined with “live” cadaver CT scans, appeared more beneficial to acquiring anatomical knowledge than traditional radiological anatomy seminars and conventional anatomy training.⁴⁹ New technologies will include holographic and haptic techniques, often first developed for surgery but, with increased availability and lowering cost, very well suited for broader education.

The discussion of whether dissection of cadavers will disappear from medical curricula and be replaced by technology, given the excellent simulation models that have emerged and other technology that will appear on the market, is not one of technology only. Dissection of human cadavers of deceased individuals has an important ethical component. Dissection has long been considered an initiation rite for medical students,⁵⁰ and some schools have elaborated this education to pay tribute to the life of the deceased and the family, regarding the corpse as a “silent mentor” for the student.^{51,52}

Discussion

Anatomy education may be at a crossroads in the history of medical training. Curriculum developers will need to carefully weigh a new position of anatomy education for medical students and residents. And learning anatomy simply requires time; decreased time spent on learning anatomy may not be easily compensated by modern educational techniques.⁵³

The proposed directions that we offer, as food for thought, include a clear education foundation of anatomical knowledge in a very early phase, primarily conducted as near-peer teaching by more advanced students who learn through teaching, and an integration of anatomy with radiology education across the subsequent years. In addition, dedicated postgraduate clinical anatomy education geared to the specialty of interest will likely yield a better learning effect than a concentration of anatomy education in the undergraduate phase. In all phases, technology will have an important role. With augmented reality, images created and combined with images derived from advanced 3D models will allow for a just-in-time learning process that can extend across the educational continuum.

Not all innovations in anatomy education will be available for low-resourced countries.⁵⁴ While some schools in the more industrialized world have made significant steps in these directions, other, more traditional schools, less involved in curriculum modernization, may have difficulty making such radical steps within a short timeframe. While in low- or middle-income countries (LMIC), technology could represent a problem, other dynamics than economic issues may be more of an impediment to change. Even in those countries, basic and easily accessible technological tools are often

available. Rather, major curriculum reforms do not happen as they often disrupt existing practices, power structures, and educational philosophies.⁵⁵ Hofstede's theory of dimensions of national culture, determined by power distance (PD), in uncertainty avoidance (UA) and in the individualism versus collectivism (IDV) and other dimensions,⁵⁶ provides a useful lens to reveal that LMICs often have high PD and UA and low IDV. Jippes showed how these dimensions can hamper medical curricular changes.⁵⁷

Technology is not a replacement of the human senses, needed to discern anatomical structures and its aberrations in pathology. For instance, a handheld ultrasound device to first explore parts of the human body may evolve in the near future into an important diagnostic tool for the physical examination of patients, but requires substantial training and should become an indispensable tool for all medical students, as stethoscope and reflection hammer.⁴² Therefore, training students, teachers, and professionals in using such technology should become a cornerstone of anatomy training. It will be a matter of global social responsibility to provide access to technological innovations to low- and middle-income countries.

We believe that with rapidly increasing international information exchanges, innovations are likely to spread and be picked up much faster than decades ago and schools will generally move in these directions, slower or faster. With this perspective paper we hope to have contributed to this movement.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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