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Anatomy and its impact on medicine: Will it continue?

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EDITORIAL

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Introduction

Anatomy is the study of the human body's structure. That visible to the naked eye is known as gross or topographic anatomy and is the focus of this editorial. In reflecting on the impact of anatomy on medicine, two approaches will be taken.

The first approach is from a research perspective: anatomy as a field of knowledge progressively transformed via the findings of investigation. This raises a corresponding set of questions. Is anatomy ossified as a field of knowledge? Alternatively, is anatomy on the threshold of a renaissance? If so, what are its recent and likely future advances, particularly those that parallel advances in medicine? These are discussed while considering anatomical research past, present, and future.

The second approach is from an educational perspective: anatomy as a subject taught. This also raises a corresponding set of questions. Is anatomy education being threatened with extinction? Alternatively, is the teaching of anatomy continually evolving and reinventing itself? If so, what are the current and likely future educational breakthroughs and their implications for both undergraduate medical students as well as postgraduate specialty trainees? Similarly, these are discussed while considering anatomy education past, present and future.

Anatomical research (past)

Much of what we know in medicine seems to be taken for granted. However, it is useful to put this in context by indicating some concrete examples of major issues and associated responses. Early advances in surgery were directed to overcome the hurdles of: access, bleeding, infection and pain. These advances were: using anatomy, the ligature, antisepsis, and analgesia, respectively.

Although anatomical knowledge is a conspicuous and fundamental component of medical science and practice, in medieval times it was unsophisticated. Primitive squatting figures containing almost unrecognisable organs were the standard guides used by practitioners of medicine. Leonardo da Vinci's anatomical studies enabled him to establish a clearer idea of the functioning of the human body. They also provided an understanding of the structures lying beneath its surface markings (in particular the musculature), which had frequently been represented inaccurately by artists.[1] Interestingly, descriptive anatomy itself did not become evident as a discipline until Vesalius published his *De Humani Corporis Fabrica* in 1543 (24 years after Leonardo's death). That work opened the floodgates of documenting human structural detail, which occurred through meticulous cadaver dissection from then onwards.

Anatomical research (present)

Has not every part of us that can be seen with the naked eye already been discovered by now? Even if the human body may not seem to change, ways of viewing it, conceptualising it, and intervening with it, certainly do. Recent advances in surgery and the emergence of other anatomically related fields (particularly medical imaging) provided alternative access routes, became minimally invasive, prevented tissue rejection, and enabled selective

pain control. These advances led to the establishment of whole domains, including interventional radiology, endoscopic surgery, transplant surgery, and anaesthetics, respectively.

New developments in viewing the body are occurring through special imaging techniques involving computed tomography scans, magnetic resonance imaging, and ultrasound. Other interventional advances to emerge include reconstructive and microsurgical techniques, anastomoses, implants, and robotics.

All the advances outlined above have been associated with research acting in parallel to identify and describe the appearance and role of the relevant anatomical structures that have come into focus from the variety of views. Specific examples include tracing the direction of relaxed skin tension lines, as well as classifying zones and vascular segments of solid viscera (particularly prostate, liver, kidney, and lung). It has been necessary to identify the appearance of normal hollow organs, body cavities, and joint cavities on endoscopy. Similarly, the use of ultrasound guidance for peripheral nerve and plexus blocks has required defining the appearance of normal structures on ultrasound imaging.[2] What will happen when access to a diagnostic ultrasound machine becomes available to every first port-of-call medical practitioner? Technology may bring into view progressively finer detail within the human body, but we still have to interpret what can be seen. Certain previously invisible structures will not be easy to identify, while others could be mistaken for pathology. Hence, knowledge of anatomy is now more important than ever, so that we do not see too little or too much.[3]

Anatomy is also far more than names, labels, or mere description. New concepts are being developed, including angiosomes[4] for territories of vascular supply. I regard the angiosome concept as the single greatest anatomical advance over the past 100 years. This has revolutionised plastic surgery, enabling free grafts to be performed with the likelihood to remain viable. Another huge conceptual advance is that of the enteric nervous system,[5] which is revolutionising the diagnosis and management of gastrointestinal motility disorders.

Anatomical research (future)

What is on the horizon? More highly selective interventions will become available, particularly as new advances are continually evolving in surgical, imaging, and anaesthetic techniques. In parallel with new discoveries, we must simultaneously be aware of anatomical variants, which may impact on them. Thus, the way forward is to also look back. In other words, we need a rear vision mirror on our windscreen. This requires accessing past documentation of such variants (anomalies), which have been described in great detail, although not within the context of surgical interventions previously unimaginable. Furthermore, it is increasingly important that investigators obtain access to cadavers to verify surgical techniques (ideally) prior to them being performed on living patients. Complications resulting from a new procedure can be due to the presence of an unexpected anatomical variant. The dissecting room may be used to refine the technique taking this possibility into account rather than abandoning an otherwise valid surgical advance. Who would have thought that cardiac surgeons would be contemplating variance of arterial supply to the hand? However, this is vital when considering harvesting radial or ulnar arteries as potential conduits for coronary artery grafts.[6,7]

Future research hopefully will flush out associations between certain anatomical variants, which could help predict those most likely to be present. In all my years of coordinating dissection classes, I have not yet found a completely dissected cadaver with less than 30 surgically significant anatomical variants visible to the naked eye. I can imagine a time when we will all have our own “anomaly identity card” gleaned from total body imaging.

Anatomical research must also continue to revisit previous assumptions and dogma. Similarly, clinicians need to become aware of the outcomes from this.[8] Sobering examples can be seen with surface anatomy, which needs to be revised in the light of findings from living subjects using modern imaging techniques.[9–11] There are inconsistencies between and within anatomical reference texts, which have been based primarily on cadaver studies rather than being evidence-based *in vivo*. Certain commonly accepted surface landmarks and anatomical planes were found to be reliable while others were not. The effects of gender, age, posture, respiration, build, and ethnicity also deserve greater emphasis.

Along with the emergence of new concepts older ones need to be redefined. In contrast to a proposed new evidence-based dermatome map, prior maps have been shown as inaccurate due to being derived from flawed or incomplete studies.[12] Dermatome maps can also represent different sensory modalities (touch or pain) which have differing degrees of overlap. Either way, dermatomes are portrayed as flat but should be regarded as three-dimensional entities (like angiosomes) and renamed neurosomes to reflect this.[13,14]

Anatomy education (past)

Anatomy expanded rapidly from the era of Vesalius in the mid-16th century. However, students have subsequently tended to struggle learning the subject due to overload of specific factual information.

In "traditional" medical courses anatomy is studied in parallel with physiology, forming a basis for the subsequent study of pathology and the clinical disciplines. Prior to the introduction of problem-based learning (PBL) medical courses, establishing an understanding of normal anatomical structure was regarded as a necessary preliminary to the second two areas of study. Within traditional courses, anatomy programmes typically had a regional organisation. All regions of the body were evenly distributed over the full complement of teaching weeks allocated to the subject. This arrangement inadvertently promoted the accumulation of details and isolated facts plus was compounded by an emphasis on didactic lectures and the slavish picking over a cadaver (devoid from a real-life clinical problem). However, the main danger of a traditional, purely discipline-based course was dislocation of the faculty aims by subjects, which can be taught in a vacuum.

Anatomy education (present)

The introduction of PBL courses was seen as a way of dealing with certain issues affecting traditional courses, including the artificial division between preclinical and clinical domains as well as the workload from knowledge explosion in all domains. PBL courses also aimed to achieve horizontal in addition to vertical integration. This lent itself to a system-by-system approach. Anatomy of the living was preferred to dissection, which was regarded as a vestige and disdainfully discarded by the more radical courses. Fortunately, the pendulum is already swinging back, hopefully to the midpoint of its arc. The ideal medical course is likely to be a hybrid, incorporating the best of traditional and PBL courses, where disciplinary knowledge is applied to professional situations.[15]

It seems most sensible to reach commonality by strengthening any programme at its base. This should be for "general anatomy"[13,14] akin to "general pathology". Anatomical terms and concepts can be introduced together with the principles of organ structure and the general arrangement of organs into body systems (before launching into the detailed study of specifics within a particular system) as well as the general arrangement of organs within regions and the basis for viewing them via imaging modalities. General anatomy with its foundation of anatomical literacy should be what all health science students receive in their initial teaching.

The overarching goal of anatomy education is to help the learner competently (and confidently) meet new situations in future practice, armed with the capacity to reason from first principles. Postgraduate anatomy programmes can refresh and advance, but they cannot be expected to teach the fundamental principles, which are expected as a minimum prerequisite for a graduate to already have acquired.[16]

Anatomy education (future)

On the horizon, there are many educational innovations that will impact on anatomy teaching in the future. These include such developments as: using interactive online multimedia as a comprehensive self-paced substitute for didactic lectures to help prepare students for practical classes.[14] Learning materials and teaching are intimately related. The latter can be transformed with appropriate use of the former. Interactive multimedia will not replace teachers, but can release teachers from being drained (with subsequent burnout) by covering much of the theory that would otherwise create a huge lecturing load. This would free time that can be devoted to lectures explaining principles as well as to practical classes (ideally dissection incorporating clinical procedures) involving active discovery of their implications and applications. Teaching can be transformed into being interpretive, rather than merely descriptive. This trade-off is a more productive use of expertise that is likely to be much more satisfying for teacher and student alike.

Other innovations that will be used increasingly are engaging students via body painting[17] and using 3D prints of anatomical specimens,[18] including to augment cadaver-based activities. Progressive dissection (as introduced at Monash University) enables each student (for an hour per week) to contribute to a predetermined stage (one of eight) in the collective dissection of the allocated cadaver. Dissection is also reinvented by students recording their own findings from the cadaver in a folder (akin to a patient history with specially prepared checklists of potential anatomical variants, pathological conditions, and surgical interventions). Discovering the abnormal while uncovering normal is an example of "flipped learning", by focussing on anatomical variants as a way to help learn the typical structure and position of organs.[19]

Conclusions

In attempting to determine viability of a discipline, the field of research enquiry should not be divorced from the subject matter as taught to students in courses of study. This is particularly important for anatomy in view of its

past and present contribution to medicine being so great and its future potentially so bright. The stakes are therefore high and it would be a shame for this to be dimmed either through neglect of continued collaborative research with interfacing medical and scientific domains or via educational myopia by failing to incorporate such findings in modern teaching programs.

At one extreme, if anatomy does not advance as a discipline, it will remain as a relic. Anatomical research and anatomy education are two sides of the one coin. For anatomy to reinvent itself, anatomists need to engage with anatomical research (from a clinical and/or a scientific perspective) as well as implement educational innovations (ideally while investigating the learning of their own students).

At the other extreme, if advances in anatomy are not taught to students they will be condemned to live in a past era of the subject. This also applies to learning materials as these should provide the major link to recent research findings as well as refinements to fundamental anatomical principles. Hence, the onus is on teachers of anatomy to do justice to the discipline in their teaching (as well as in the development and use of appropriate learning materials). This will also help provide their students with a secure foundation for future postgraduate training and clinical practice. Fear in surgery is said to be fear of anatomy (particularly from anatomical variation). At least this is not as bad as bravado through blissful unawareness.

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PEER REVIEW

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CONFLICTS OF INTEREST

The authors declare that they have no competing interests

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