REVIEW ARTICLE

Exploring the Potential Use of Supplementary E-learning Tools for Integrated Anatomy-Radiology Teaching

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ABSTRACT

The evolution of anatomy education yields a variety of instructional strategies to enhance students' comprehension of gross anatomy. Apart from these multi-modality approaches, various studies suggest that anatomy instruction is more effective when it is taught with radiological integration during the early phase of the medical curriculum. Studies have shown that the introduction of basic radiological knowledge in anatomy learning enhances visuospatial skills, which are important for safe clinical practice. Nevertheless, considerable variation in the radiological anatomy teaching exists in terms of delivery methods, radiological materials, and teaching time. One way to address these limitations is by using integrated radiology anatomy e-learning platforms. Recent advancements in technology have given rise to immense attention to e-learning platforms, which have been considered to be an effective modality in optimising the student learning process. Hence, this article explores the potential use of e-learning tools, namely integrated with radiological imaging, in teaching gross anatomy.

Keywords: Anatomy education, Gross anatomy, Radiological imaging, Clinical practice, E-learning.

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INTRODUCTION

Anatomy is the basis of medical curricula, and a considerable comprehension of the subject is fundamental to ensure safe clinical practice (1). However, medical students fear anatomy and perceive it as a cognitively challenging subject as its contents are heavy and dry (2,3). Moreover, students require good three-dimensional (3D) visualisation and visuospatial abilities to understand anatomy (4,5). Novice medical students who experience difficulties understanding anatomy or perceive it as complex not only become demotivated and disengaged but also tend to lose their interest to learn the subject. They tend to limit their anatomy learning at a surface-level approach, such as by practising rote learning (i.e. a memorisation technique based on repetition), rather than proceeding to deep learning approaches to understand anatomy (6). This short-term solution does not contribute to long-term memory retention, leading them to forget or unsuccessfully recall the information during their clinical practice and the working phase (3).

To help undergraduate medical students master the subject, multiple instructional materials have been developed, involving a combination of teaching modalities, namely lectures, virtual dissections, 3D models, and computer-based learning via various approaches (e.g. blended learning, flipped classroom, pre-lecture activities) (5,7–9). However, no single method has been proven to be superior to another (3,10,11). Cadaveric dissection was previously considered the principal cornerstone of anatomy teaching (12,13). However, debate continues about how cadaveric dissection remains important in the modern anatomy teaching era (14,15). Since additional medical subjects are incorporated in new medical curricula, the teaching of anatomy has been considered to be time-consuming (16,17). The struggle in finding the most suitable instructional strategies to overcome the challenges in teaching and learning anatomy has resulted in the emergence of innovations in anatomy education. The current COVID-19 pandemic has brought increasing challenges in teaching and learning processes which need to be conducted through online platforms (18).

Apart from multi-modality and multi-approach in teaching, various studies suggest that anatomy instruction is more effective when it is carried out in the clinical context (19,20). Common clinical

contexts integrated into teaching are classified into four categories, namely clinical skills, pathology, radiology and surgical procedures (21–23). However, along with advancements in radiological imaging technology and its expanding role in clinical practice, medical schools inevitably need to incorporate more radiology education into the undergraduate medical curriculum. To date, the integration of radiological imaging, together with didactic lectures, cadaveric dissection and case-based scenarios in pre-clinical years, has shown positive outcomes (7,11,24,25). Although the outcomes have been encouraging, a substantial number of publications still highlights the insufficient integration of radiology in undergraduate medical education (26,27). Hence, this article explores the possibilities and provides insight regarding the implementation of radiological imaging via e-learning, a learning tool commonly used by medical students as an instructional strategy in gross anatomy learning.

EVOLUTION OF ANATOMY CURRICULUM

In the early 1990s, due to the cognizance of the behavioural and social aspects of medicine, the pedagogy of medical education was changed, involving the integration of other subjects at the expense of anatomy teaching hours (28,29). The reduction of contact hours for anatomy education caused a shift of focus to more clinically relevant topics (29,30). Conventionally, cadaveric dissection, combined with didactic lectures, was the gold standard teaching methods of anatomy education (9). However, nowadays, some medical institutions no longer include cadaveric dissection in their undergraduate medical program due to religious beliefs, culture, cost and time constraints (10,31). Although cadaveric dissection has been considered as the gold standard simulator for learning anatomy, modern medical education of the 21st century has challenged its usefulness as technological advances have allowed innovative modalities, such as virtual dissection and 3D prints, to replace it (9,31,32).

Presently, anatomy is primarily taught during the first two to three years of undergraduate medical curricula, which is known as the pre-clinical years. Due to the changes in anatomy education since the early 1990s, medical graduates' knowledge of gross anatomy has become inadequate, and their knowledge retention in anatomy has also declined (33,34). The decline in anatomy knowledge has continued to be a concern among doctors in various specialities globally (20,27). Inadequate knowledge of anatomy causes difficulty in developing and retaining clinical knowledge and skills, which tends to lead practitioners to make medical errors (35). As a result, many medico-legal litigations related to poor anatomical knowledge, particularly in interpreting radiographs, have been reported (36,37). Furthermore, clinicians with a poor anatomy foundation cannot defend themselves against the litigations (20).

ROLE OF RADIOLOGY IN ANATOMY EDUCATION

Senior clinicians have realized that poor anatomy knowledge is alarming among junior doctors. Thus, anatomy faculties worldwide are committed to reconstructing anatomy curricula to produce competent medical graduates (11,20). It is believed that students learn effectively when a system-based approach is integrated with other pedagogies to complement one another (11).

A frequently implemented pedagogy is the set of different modalities of radiological imaging, namely radiographic imaging, computed tomography scanning and magnetic resonance imaging. This pedagogy is a valuable complement to both cadaveric dissection-based and non-dissection-based curricula. In a dissection-based curriculum, radiological imaging enhances the quality of laboratory instruction and the efficiency of student dissection time (38). In a non-dissection-based curriculum, radiological imaging not only allows the in-vivo visualisation of the anatomy and physiology but also provides insight into pathological processes (11,27). Hence, radiological imaging, combined with other anatomy teaching pedagogies, is sufficient to compensate for the absence of cadaveric dissection instruction in undergraduate curricula (27). Radiological imaging, especially CT scan and ultrasonography, improves the appreciation of an anatomical spatial relationship (10,24).

In medical practice, clinicians, including surgeons, frequently encounter internal human anatomy in radiological images (7). However, medical graduates who struggle to interpret simple radiographs may produce a misdiagnosis (26). This situation highlights the importance of training sessions for medical undergraduates in interpreting basic radiological images to ensure safe clinical practices. Radiological imaging allows clinicians to practice and apply their anatomy knowledge in clinical settings (11). Students who experience the tasks to apply anatomy knowledge earlier in the pre-clinical years will appreciate the importance of anatomy instruction and increase their motivation to learn the basics of gross anatomy (39). Hence, integrating radiology in anatomy teaching seems pertinent in promoting the clinical application of anatomy knowledge.

Nevertheless, formal radiology anatomy teaching during the pre-clinical phase of medical study is an uncommon practice in many medical schools. Instead, radiology teaching is used as an adjunct to other anatomy teaching methods (40). Although some anatomy departments incorporate radiological input in their anatomy curriculum, a considerable variation still exists in terms of delivery methods, radiological materials, qualification of instructors and teaching time (41). It was reported that radiological anatomy teaching provided a strong visual

input for learning in a contextualized environment, especially when it was conducted synchronously with cadaveric dissection (41). Radiological anatomy teaching was found to improve spatial and sectional anatomy knowledge; enhance observational and visual thinking skills; support the appreciation of pathology knowledge and inculcate the value of radiology for future clinical practice (40).

A recent survey by Sadler et al. (42) revealed an increasing trend of radiological anatomy teaching in medical curricula with a high number of radiologists teaching anatomy to undergraduate medical students. Although the students and faculty members offered positive remarks on radiology anatomy teaching by radiologists, the applicability of this method is still limited by a shortage of manpower (i.e. radiologists need to juggle between clinical work and teaching radiology to undergraduate medical students), resources (e.g. lack of portable ultrasound machines for teaching anatomy and lack of computers that are suitable for radiological images display) and time (e.g. limited anatomy slots in the schedule) (42). To address these limitations, many medical schools deliver radiological anatomy instruction using various methods, such as synchronous presentation with anatomy lectures, incorporation in PBL instruction and self-directed learning through a digital platform, such as e-learning (41).

E-LEARNING IN ANATOMY EDUCATION

With the advancements of digital information technology, its implementation in the operation of the educational industry is inevitable. E-learning is a form of digital information technology that has been increasingly popular in the delivery of educational material. E-learning is an educational tool that can facilitate learning by leveraging information technology and communication to allow learners to access the required educational programs (43). Other terms for e-learning include web/internet-based learning, online learning/education, computer-assisted/based/aided instruction, multimedia learning, technology-enhanced learning and virtual learning (44). To date, e-learning is included in blended learning in anatomy education to supplement traditional face-to-face education (45). Concerning the kinaesthetic aspect of learning gross anatomy, completely replacing traditional teaching methods with e-learning is impossible and not preferable (45,46).

E-learning has been adopted into anatomy education in various ways through different forms. Learning management systems (LMSs), for example, allow students to access main and additional teaching materials, assignments and formative and/or summative assessments (47). Some LMSs also allow teacher-student and student-student communications. The most recent and advanced e-learning technologies in anatomy education are 3D printing and rapid prototyping, virtual reality and augmented reality. These technologies aim to represent anatomical structures in 3D to improve in vivo visualisation (48).

A past study comparing digital gross anatomy lectures and face-to-face lectures showed that digital lectures were preferred by students and improved their performance as they could revisit digital lectures when needed (49). Furthermore, preparatory e-learning activities conducted prior to traditional anatomy teaching also improved the engagement of students, eased their learning process and enhanced their long-term memory (8). The findings of these studies were concordant with those in a meta-analysis performed by the US Department of Education, which concluded that students who were exposed to an online learning platform performed modestly better than those who learned the same material via face-to-face discussions. The effect was further heightened in blended learning (44).

CREATING AN EFFECTIVE FRAMEWORK FOR E-LEARNING IN ANATOMY EDUCATION

E-learning modules should be designed and developed based on a strong foundation of instructional design framework to ensure that tools and materials are effective for learning. Instructional design is the practice of creating instructional experiences and materials to achieve an efficient, effective and appealing acquisition of knowledge and skills (50). The employment of an instructional design model as a guide in developing a course is fundamental to produce focused and organised instructional materials (50).

Many traditional instructional models have been proposed, and the most commonly used is the analysis, design, development, implementation and evaluation (ADDIE) model. This model was developed by the Centre for Educational Technology (Florida State University), and the acronym stands for the five phases of designing. This model provides systematic guidance for design with a focus on implementation and assessment (i.e. formative and summative) (50). However, the model demands an unrealistic analysis in advance (51). It also hinders creativity and inspiration due to its linearity and inflexibility (50).

Gagne's Nine Events of Instruction are also frequently adopted in designing an online instruction (52,53). They include gaining attention, informing objectives to learners, stimulating a recall of prior learning, presenting stimuli, providing learning guidance, eliciting performance, providing feedback, assessing performance and enhancing retention and transfer. This instructional design was developed based on the justification that learning occurs in a series of events based on the learning theory introduced by Atkinson and Shiffrin (54).

The increasing role of e-learning in education has prompted the need to develop specific instructional designs. Researchers have commonly developed novel models or frameworks based on the traditional ADDIE model. In the e-learning instructional model developed by Alonso, Lopez, Manrique and Vines (55), two phases, namely execution and review, have been added to the ADDIE model. Therefore, the model consists of seven phases of design, namely analysis, design, development, implementation, execution, evaluation and review (55). Siragusa, Dixon and Dixon (57) proposed the instructional design model for online learning (IDOL), which comprises three main steps, namely analysis, strategy and evaluation (56). The 24 pedagogical dimensions of IDOL accommodate the needs of diverse learners. However, it needs to be accompanied by other instructional design models (57).

A recently proposed framework is the e-learning engagement design (ELED) framework (58), which was developed based on the methodological framework of Lee and Jang for the development of instructional designs. It was produced after twenty studies on instructional design, including the ADDIE model, had been analysed (59). The ELED framework was designed to guide the development of online instructions that stimulate a high level of students' engagement. The framework comprises four phases of processes in a continuous cycle—instructional needs, instructional objectives, learning environments and summative assessment. It also suggests a feedback mechanism for each procedural phase (58). As the framework specifically focuses on designing online environments to foster student engagement, it was adapted to the development of tools in this study.

INCORPORATION OF RADIOLOGY IN E-LEARNING PLATFORM

E-learning platform has emerged as an essential teaching and learning strategy during the COVID-19 pandemic outbreak, which has dramatically transformed medical education (60). Prior to the COVID-19 impact, the radiology subject was conventionally delivered through didactic lectures and case-based discussions during clinical rotations (61). Although radiology has a remarkable impact in determining the diagnosis of a patient, it is only available as a supplementary subject in the undergraduate medical curriculum (62). Moreover, to encounter the challenges imposed by the COVID-19 pandemic which has impacted and hindered face-to-face teaching, sufficient exposure to radiology teaching needs to be emphasised through the e-learning platform.

Due to the lack of exposure, students often struggle to relate cross-sectional radiological images with structures seen in cadavers, anatomy model, and textbook illustrations (5). The preference of using radiological images as the clinical context in gross anatomy learning is justified by the growing importance of radiological imaging in the diagnostic, intervention and therapeutic aspect of modern clinical practice (5,7). Therefore, the exigency for current medical students to acquire a deep understanding of anatomy and apply the knowledge in interpreting radiological images is becoming more uncompromising (5,63). Thus, early integration of radiological imaging in the medical curriculum increases students' confidence in identifying structures and interpretation skills (5,7,25,62,64).

In addition, an ideal learning environment should be implemented to increase students' engagement, which is by fostering critical thinking and deeper learning (58). The revolutionary way of radiology e-learning platform could instil deeper learning interest among the students by the application of diverse digital resources and visual materials (65). The incorporation of radiological images into anatomy learning would assist students to construct a correlation between theory and clinical practice (64,66). This amplifies students' awareness of the importance of comprehending and retaining anatomy knowledge for their future career (64). Moreover, the radiology e-learning platform also can be constructed with various types of assessments, quizzes and exercises that allow the students to reinforce their comprehension of the radiological knowledge (65). Consequently, students will be more motivated and engaged in the learning process (5,7,64).

ADVANTAGES AND DISADVANTAGES OF E-LEARNING

E-learning has become increasingly popular in education because of its feasibility and usability, especially during the COVID-19 pandemic. Learners can learn at their own pace, and e-learning materials can be accessed anytime regardless of geographical location, provided that they have a good internet connection. E-learning also provides an opportunity for instructors to diversify their instructional materials by utilising technology. This situation creates the possibility of providing exciting stimulus to learners and increasing their level of engagement. E-learning materials can be updated easily according to learning needs and delivered rapidly and flexibly in various formats (44). Compared to face-to-face lectures, e-learning provides more opportunities for interactions and communication between and amongst learners and facilitators without having to worry about time limits. Systematic and organised e-learning facilitates the consolidation of learning as information is delivered in a logical manner to meet learning goals (67).

As e-learning increases learner autonomy, a systematic review on e-learning has reported variations in learners motivation, expectation, satisfaction, learning needs and objectives (68). It can be concluded that the lack of motivation results in poor engagement, poor self-

discipline and self-efficacy and less interaction with educators. E-learning also stands the risk of being poorly designed, which may result in incoherence with its learning objective. Furthermore, designing purposeful and effective e-learning is time-consuming, costly and labour-intensive. Although the current students are Generation Z who has grown up with ubiquitous electronic devices and technology, educators still need to consider the minority group of students who lack skills and knowledge in information technology due to individual intelligence and socio-economic reasons.

CONCLUSION

Radiological imaging, which can be done through e-learning platforms, should be incorporated in supplementary gross anatomy learning. However, the integration of e-learning into a curriculum is not as simple as it is expected. A thorough planning and a proper instructional design principle should be applied to ensure that the learning modules are engaging. Incorporating radiological imaging through e-learning platforms may increase the sense of value in learning anatomy as clinical applications are explicitly carried out. However, content should also be designed using a proper instructional design framework to ensure that no redundant information and extra cognitive burden are imposed on students.

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