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Technologies-Enhanced Anatomical Study in Undergraduate Medical Students in One of the Medical Schools in Thailand

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Anatomy is an essential preclinical subject of undergraduate medical education. The traditional practical studies on cadavers are widely used in medical schools. It enhances active and deep learning, preparing students for clinical practice. However, the high costs, the time-consuming, and the health problems from chemical hazards, to which the staff exposed are considered. Computer-based learning (CBL) technologies can increase the efficiency of students in understanding anatomy. This review provides an overview of CBL technologies such as Anatomage table 7.0, zSpace, Complete Anatomy app, and 4D Interactive Anatomy that prepare Ramathibodi medical students for enhanced anatomical understanding and self-learning. The integration methods between traditional cadaveric dissection and the CBL in the curriculum can enhance the classroom experience, student engagement, learning, retention, and improvement of Ramathibodi medical student's knowledge in anatomy.

Keywords: Anatomy, Medical education, Computer-based learning, Traditional cadaveric dissection

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Introduction

Human anatomy (Greek word; 'ana'-up; 'tome'-cut) can be described as a basic medical science that studies the normal structures and the relations between organs in the body. Anatomy plays an essential subject in the undergraduate medical curriculum. Currently, the traditional practical studies on cadavers are widely used for anatomy teaching in medical schools.[1-2] The Southeast Asian region has a rich tradition in medical education, and teaching by cadavers are much higher compared to other regions in the world.[3] In Thailand, human anatomy is taught in a preclinical course; cadavers are called Ajarn Yai (great teacher) which are respected by teachers and students.[4] Cadaver-based dissection is still appropriate for undergraduate training by enhancing active and deep learning, preparing students for clinical practice. Besides, using models, plastination, computer-based learning (CBL), medical imaging (computed tomography [CT], magnetic resonance imaging [MRI] and ultrasound) and living anatomy can enhance the efficiency of students in understanding anatomy.[5]

CBL refers to any type of computer-assisted learning. It includes any computer software, tool, or application created and designed to improve student learning.[6] Furthermore, CBL resources are increasingly being used in the anatomy curriculum to facilitate student learning.[5]

The division of clinical anatomy (AN), Chakri Naruebodindra Medical Institute (CNMI), Faculty of Medicine Ramathibodi Hospital (RA), Mahidol University, is preparing the resources to provide appropriate tools and enhance self-learning of the undergraduate medical student. The subjects taught by AN are shown in Table 1. The RA medical students can dissect and study structures on cadavers, providing at the student's desk. Moreover, students can use anatomical models, plastinated specimens, and other traditional resources such as textbooks and lecture files to understand anatomical structures and their relationships. This review provides an overview of CBL technologies that prepare RA medical students for enhanced anatomical understanding and self-learning.

Table 1. System-Based Subjects in Medical Curriculum of Faculty of Medicine Ramathibodi Hospital Which is Participated by Clinical Anatomy Staff

Courses	Years
RAID137: Basic human structure and development	1st
RAID209: Cardiovascular system	2nd
RAID210: Respiratory system	2nd
RAID211: Renal and urinary system	2nd
RAID212: Gastrointestinal hepatobiliary system	2nd
RAID308: Nervous system I	3rd
RAID310: Endocrine system	3rd
RAID311: Reproductive system	3rd
RAID313: Musculoskeletal and integumentary systems	3rd

Anatomage Table, zSpace, Complete Anatomy, and 4D Interactive Anatomy are some of the CBL tools available to RA medical students. Each tool offers a unique interactive activity, so there are several options to enhance students' learning.

1) Anatomage Table

Anatomage Table 7.0 (Anatomage Inc, Santa Clara, USA) is used at CNMI to increase anatomical understanding and clinical correlation (Figure 1A). The Anatomage Table is a multi-touch screen virtual 3D dissection platform, with a life-size that includes both full-body male and female gross anatomy, high-resolution regional anatomy, medical image (CT and MRI), over 1300 clinical cases, and microscopic histology scans. The newly updated table version 7.0 introduces physiology simulation, heart motion and nerve connection, physiological pathways, 3D pro-sections, and 3D catheter simulator tools.[5, 7] Students can dissect, rotate, move, zoom in, and out the anatomical structures into various viewing positions and save files in a local folder. Moreover, pathological files (eg, DICOM files) can be viewed on the Anatomage Table, using for a diagnostic tool and 3D reconstruction. Quiz mode is included to help with self-learning or instructional evaluation.[8-9] Anatomage Table is a tool that can facilitate anatomical learning, increase perception of

the amount learned during a given lab, and students can self-study and test their anatomical knowledge all in the same place.[8, 10, 11] Anatomage Table has been integrated into gross anatomy courses in many universities around the world, most Anatomage Tables were distributed in the USA (Table 2).[7]

2) zSpace

The CNMI provides 2 different anatomy software packages for medical students, which consist of Human Anatomy Atlas (Visible Body, Greater Boston, USA) and VIVED Anatomy (VIVED Learning, Coralville, USA). Both are installed on zSpace all-in-one (AIO) pro and laptop models (Figure 1B). The zSpace system (zSpace Inc, Philadelphia, USA) combines augmented reality (AR) and virtual reality (VR) technologies in an AIO computer and laptop, which allows for the visualization in 3 dimensions.[12] It consists of stereoscopic display, stylus, 3D tracking, and 2D follower eyewear enhanced interactive experience for students learning. The identification of the anatomical structures, quiz questions, fully dissectible and labeled images are provided in the zSpace software.[12-14]

3) Complete Anatomy

Since 2009 the Complete Anatomy (3D4Medical, San Diego, USA) has been developed and has been used in many universities and clinical organizations. It is a 3D anatomy application platform consisting of interactive anatomy models, clinical video animations, virtual dissection tools, and a medical imaging library (Figure 1C-D).[15-16] The CNMI provides 2 appropriate licenses (educator license) for AN instructors to create and manage learning materials that can then be shared with all RA medical students who also have a student plus license. This application is available for iOS 11 or later, macOS 10.13 or later, Windows 10 (version 1607, build 14393 or later), and compatible with Android devices and Chromebooks on Android 7.0 (Nougat) or later.[16] This application allows students to access data through the internet almost anywhere at any time.

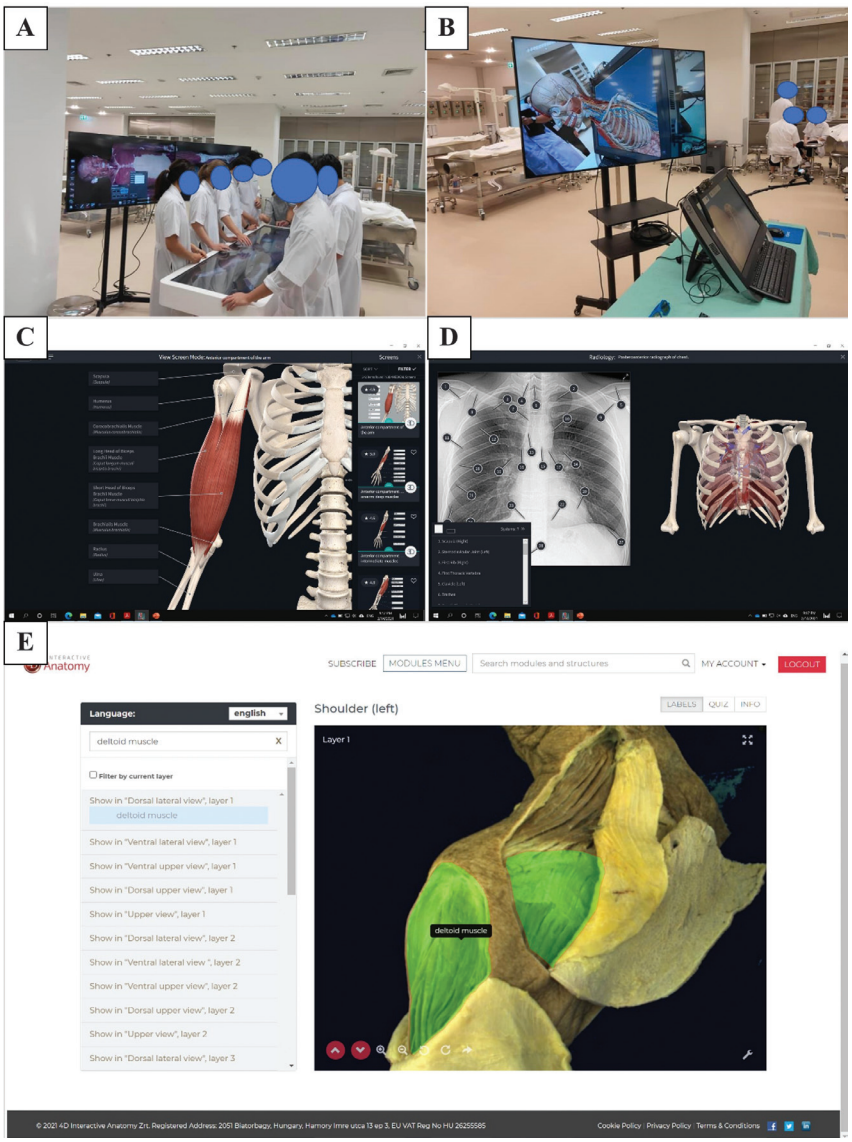
Table 2. The Anatomage Table is Distributed in Many Universities Around the World

Universities	Countries
University of Heidelberg	Germany
University of Michigan	USA
University of Botswana	Ghana
Macau University of Science and Technology	China
University of Plymouth	UK
Horus University	Egypt
Ziauddin University	Pakistan
University of Milan	Italy
University of Saskatchewan	Canada
Qatar University	Qatar
Odessa National Medical University	Ukraine
University of New South Wales	Australia
Ateneo de Manila University	Philippines
Nanyang Technological University	Singapore
Mahidol University	Thailand

4) 4D Interactive Anatomy

4D Interactive Anatomy (4D Interactive Anatomy Zrt, Biatorbagy, Hungary) is an internet-based platform that supports realistic anatomy interactive learning over a million high-resolution photographs that were taken from 20 human cadavers and consists of 24 interactive dissection modules. The instructors can develop their multimedia by content management tools (export images, presentations, build custom quizzes and export results), quiz management features (more than 2000 quiz questions) for students' self-assessment toenhance medical student's experience especially identifying the anatomical structures and dissection skills (Figure 1E).[17, 18] Moreover, it is appropriate for other learners such as allied health student, a postgraduate or a surgeon who can use 4D Interactive Anatomy to review their knowledge.[17] The CNMI provides a 4D Interactive Anatomy student license for all RA medical students that can be used to access the learning platform through the internet anywhere and anytime.

Figure 1. Computer-Based Learning Technologies; Anatomage Table, zSpace, Complete Anatomy Application, and 4D Interactive Anatomy



A, Students in the CNMI can use the Anatomage Table to make surgical cuts and dissections. It also includes quizzes, games, and tests. Behind the students, a virtual cadaver is displayed on the screen.

B, Human Anatomy Atlas (Visible Body) program represents in a zSpace all-in-one (AIO) pro. Displays on all zSpace systems have tracking built in. The user's zSpace stylus and glasses are tracked by these sensors. zSpace dynamically updates to display the correct perspective in full, high definition as the user tilts their head to view around an object.

C- D, Screen capture of complete anatomy application represents anterior compartment of arm and posteroanterior radiograph of the chest, respectively. Complete Anatomy's content is available at anytime and anywhere. Students have downloaded it through the Apple, Mac, Android, and Microsoft App Stores on all devices (smartphones, tablets, and computers).

E, A screenshot of the 4D Interactive Anatomy platform represents real deltoid muscle with the green color labeled. Real human specimens can be tilted, rotated, manipulated, and dissected by students.

The Anatomage Table 7.0, zSpace, Complete Anatomy Application, and 4D Interactive Anatomy can enhance the classroom experience, student engagement, learning, retention, and improvement of the medical education for students.[11, 13-15, 17] Table 3 compares the features of Anatomage Table, zSpace, the Complete Anatomy Application, and 4D Interactive Anatomy.

Currently, the traditional cadaveric dissection has been widely used in the teaching anatomy in medical schools, and it cannot be fully replaced by other resources, but their use could resolve a problem like shortage of cadavers and lack of teaching time. However, the disadvantages of cadaveric dissection include the high costs, the time-consuming, and the health problems, which the staff exposed to chemical hazards (eg, formaldehyde).[2, 5, 8, 11, 19]

In traditional teaching methods, medical students were expected to learn much detail with little understanding of the relevance, and they were suffering from this subject. Traditional teaching styles with much detail were time-consuming and not very helpful for medical students' learning.[20] In modern undergraduate medical curricula, instructors tend to reduce hours of anatomy teaching and have been looking to reduce curriculum content and innovate the learning experience. Moreover, some countries (eg, Greece) reported an inadequate number of cadavers for dissection.

Technology-enhanced learning (TEL) is now common practice and plays a significant role in the field of medical education. These include online learning modules, electronic portfolios, virtual patient interactions, massive open online courses (MOOC), problem-based learning (PBL), the flipped classroom movement, and CBL (eg, 3D software, medical education apps), which could be applied to enhance medical students' interest, retention of anatomical knowledge, and its clinical application.[20-22]

In 2021, Zibis et al[19] compared the performance of 4 groups of students who were taught anatomy using 4 different methods: a 3D digital software, plastic models, cadaveric dissection, and prosection. Each of the 4 groups was asked to identify anatomical structures in projected images. Students who learned anatomy using the 3D digital platform performed significantly better than those who learned anatomy using the other 3 methods.

CBL can provide students with intrinsic benefits such as increased learner immersion and increased engagement. However, there is evidence that CBL causes side effects such as headache, dizziness, and blurred vision.[23]

The integrated anatomy course with other resources such as ultrasonography, clinical cases, and digital resources was a positive experience for medical students by allowing for long-term retention of anatomical knowledge and will provide better coordination among anatomists and physicians to interchange and update knowledge from research in cadaveric and live patient's studies.[24-25]

Mobile learning refers to learning via a mobile device such as a smartphone or tablet.[3] The first smartphone was released in 1992; its effects have transformed personal and professional lives. The benefits of smartphones in education, such as recording learning, portability, and support learning strategies as inquiry-based learning, contextual mobile learning, game-based learning, or synchronous sharing.[26-27] In 2020, Zargaran, et al[28] found that many medical students already use their smartphones with medical applications to assist their learning of anatomy, and medical schools have been adopting and preparing the new innovative technology to enhance anatomy learning in modern medical curricula.

Both Complete Anatomy and 4D Interactive Anatomy are available to students who have access to the internet with their smartphones or tablets, and laptops without being limited by location, and can be accessed 24 hours a day. It provides flexibility and convenience for both RA medical students and instructors. In contrast, students can use the Anatomage Table and zSpace for individual, clinical and group study on working days between 8:30 am to 4:30 pm; working after office hours is not allowed or only reasons on solid ground will be approved. Therefore, students have limited time for self-learning and group discussion with both Anatomage Table and zSpace.

Table 3. Comparison of the Features of Anatomage Table, zSpace, Complete Anatomy Application, and 4D Interactive Anatomy

Feature	Anatomage Table	zSpace	Complete Anatomy	4D Anatomy
Based on	Computer station	Laptop station	Application device	Web browser
Medical images	Yes	No	Yes	Yes
Clinical cases	Yes	No	Yes	No
Quiz mode	Yes	Yes	Yes	Yes
Flexibility	No	No	Yes	Yes
Others	VR, real size, animation, histology, embryology	VR, AR, stereoscopic display, stylus, 3D and 2D eyewear	VR, AR, VDO animation, histology lectures	High-resolution photograph taken from cadavers

Abbreviations: 2D, two-dimension; 3D, three-dimension; 4D, four-dimension: AR, augmented reality; VR, virtual reality.

In the 21st century, the changes in medical education, influenced by many factors including the changing healthcare environment, the changing role of the physician, changing medical science, changing modern educational paradigms and technologies are a great challenge for anatomy learning.[1-3] Moreover, during the coronavirus disease 2019 (COVID-19) pandemic, it is difficult to hold cadaveric dissection laboratories because it is nearly impossible to enforce social distancing for students. The use of CBL in anatomy classes has increasingly become popular, and it can allow medical students to learn more interactively as they can observe 3D anatomical structures from many different viewpoints.[29]

The summarized benefits of CBL in medical education are as follows: 1) The use of CBL integrated with curricula is increasing and has already greatly benefited medical students in their self-directed learning, clinical and group discussion, increase perception, enhanced student engagement, and interactive experience; 2) The modified anatomy course with CBL allowing for long-term retention of anatomical knowledge; 3) CBL is easy to use and allowing medical students to learn at their convenience, and available at home; 4) CBL can reduce the amount of time spent on cadaveric dissection; and 5) CBL reduces the staff and medical students' time exposure to formaldehyde and other chemical hazards.

Conclusions

By 2021, RA medical students have first studied anatomy dissection at CNMI. The AN team is planning, preparing, and installing the TEL resources such as MOOC, PBL, and CBL to integrate with traditional cadavers' dissection. CBL offers many opportunities to get the better of future challenges in medical education. We believe that the Anatomage Table 7.0, zSpace, Complete Anatomy app, 4D Interactive Anatomy, and other interactive technologies can enhance anatomical study in undergraduate medical students. Further studies are needed to evaluate the integration methods between traditional cadavers' dissection and the CBL in RA medical curriculum.

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เทคโนโลยีสนับสนุนการเรียนกายวิภาคศาสตร์สำหรับนักศึกษาแพทยศาสตร์ระดับปริญญาตรีของโรงเรียนแพทย์แห่งหนึ่งในประเทศไทย

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กายวิภาคศาสตร์เป็นวิชาที่มีความสำคัญอย่างยิ่งต่อการเรียนหลักสูตรแพทยศาสตร์ในชั้นพรีคลินิก การใช้ร่างอาจารย์ใหญ่เป็นสื่อการสอนยังคงเป็นที่นิยมในหมู่โรงเรียนแพทย์ เนื่องจากสามารถส่งเสริมให้เกิดกระบวนการเรียนรู้ในเชิงลึก รวมทั้งเป็นการเตรียมความพร้อมให้นักศึกษาแพทย์ก่อนขึ้นชั้นคลินิก อย่างไรก็ตาม ปัญหาด้านค่าใช้จ่ายและระยะเวลาที่เพิ่มขึ้นจากการใช้ร่างอาจารย์ใหญ่ รวมถึงปัญหาด้านสุขภาพจากการได้รับสารเคมีอันตรายเป็นเวลานาน เป็นสิ่งที่ควรนำมาพิจารณาในหลักสูตร การใช้คอมพิวเตอร์เป็นพื้นฐานในการเรียนรู้ (Computer-based learning, CBL) จึงมีส่วนช่วยเพิ่มประสิทธิภาพในการเรียนกายวิภาคศาสตร์ บทความนี้มีวัตถุประสงค์ที่จะนำเสนอวิธีการเรียนโดยใช้ CBL ส่งเสริมกระบวนการเรียนรู้ เช่น Anatomage Table 7.0, zSpace, Complete Anatomy app, และ 4D Interactive Anatomy ให้แก่นักศึกษาแพทยศาสตร์ในระดับปริญญาตรี สังกัดคณะแพทยศาสตร์โรงพยาบาลรามาธิบดี เพื่อให้เกิดความเข้าใจเนื้อหามากขึ้น เพิ่มกระบวนการเรียนรู้ด้วยตนเอง โดยสอนด้วยวิธีการชำแหละอาจารย์ใหญ่แบบดั้งเดิมร่วมกับการใช้ CBL ในหลักสูตร เพื่อสนับสนุนการเรียนรู้ในห้องเรียน เพิ่มความกระตือรือร้นของผู้เรียน ส่งเสริมทักษะความจำให้ดีขึ้น และพัฒนาปรับปรุงองค์ความรู้ทางกายวิภาคศาสตร์ของนักศึกษาในหลักสูตรแพทยศาสตร์ระดับปริญญาตรี

คำสำคัญ: กายวิภาคศาสตร์ แพทยศาสตรศึกษา การใช้คอมพิวเตอร์เป็นพื้นฐานในการเรียนรู้ การชำแหละอาจารย์ใหญ่แบบดั้งเดิม

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