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Role of New Technologies in Teaching Anatomical Sciences and Future Direction Based on Artificial Intelligence

Función de las Nuevas Tecnologías en la Enseñanza de las Ciencias Anatómicas y Dirección Futura Basada en la Inteligencia Artificial

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SUMMARY: Anatomy is a complex subject taught in undergraduate medical curriculums, with significant changes over time. The invention of CT scans by Hounsfield and the first interactive computer graphics led to the development of interactive computer graphics. Magnetic resonance imaging (MRI) in the late 20th century revolutionized medical diagnosis and teaching, with engineering advances enhancing image display and use. Digital anatomy continued until the late 20th century, with the Visible Human Project (VHP) being a prominent example of digitalization. VHP provided a better understanding of body and internal organ structures. The first virtual reality (VR) and augmented reality (AR) in medicine was applied in 2004, and in 2024, the Apple Vision Pro headset marked a significant evolution in this field. Medical students often face learning obstacles during their early years, leading to a decline in academic performance. To promote rational learning and long-term retention of anatomical knowledge, new curricula and innovative teaching strategies have been developed. Artificial intelligence (AI) has gained popularity in recent years, enabling deep learning, data storage, remote teaching, and quick feedback. AI has been used in medical diagnostics and treatment planning. Advanced AI techniques like Artificial Neural Networks (ANN), Convoluted Neural Networks (CNN), and Bayesian U-Net are used for teaching anatomy. AI can also be used to deliver AR and VR experiences, particularly for complex regions in the human body. AI can also change assessment techniques to suit individual learners.

KEY WORDS: Learning technology; Anatomy education; Medical sciences; Artificial intelligence; Digital technology.

INTRODUCTION

For centuries, anatomy has been a fundamental component of medical education. Anatomy was considered one of the most important and vital subjects taught in the curriculum when the first medical school in Italy was founded in Salerno in 1235. The publication of his main works marked the beginning of a new era in scientific human anatomy, thanks to Andrea Vesalius, the father of modern anatomy. At the end of the 20th century, dissection was also considered the cornerstone of medical education (Zampieri *et al*., 2013). For many years, pedagogical and administrative officials at universities have faced challenges related to staffing levels and the amount of time dedicated to teaching anatomy. Traditional methods of teaching and learning are followed by few schools, while many have changed their curricula and embraced an integrated approach. Students generally think anatomy courses are boring, uninteresting, and use antiquated teaching methods. There was no evidence to support the superiority of any one model or teaching strategy (Estai & Bunt, 2016; Wilson *et al*., 2018), with the integration of multimodal methods into the learning process appearing to be the most successful strategy. With the introduction of computers and other associated products of the technology revolution in the 20th century, anatomists have been adopting novel teaching modes on a growing basis."Digital dissection" is the term for a recently produced generation of items in this area. Here, in a manner akin to in-person dissection sessions, students can undertake virtual dissection by excising layers or certain bodily components (Ackerman, 1999). The most popular illustration of this class of cutting-edge anatomy teaching techniques is the anatomage table. Virtual reality (VR) and augmented reality (AR) technology can be used to create applications that properly display anatomical features on mobile devices and headsets (Martín *et al*., 2018; Alasmari, 2021). The latter

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places the virtual structures on top of a real-world background or environment, whereas the former is entirely virtual and has no link to the actual world. Doctors can perform guided surgeries with images through small incisions on the body and use AR and VR tools to help advance the surgery (Chytas *et al*., 2020). Body painting is an additional technique for teaching anatomy. "The painting of internal structures on the surface of the body with high accuracy and nature" is the definition given for body painting (Finn, 2010). When compared to the immediate post-session period, colored body painting improves recall of knowledge four weeks later (Finn *et al*., 2011). Additionally, body painting can lower the high expense of alternative forms of living anatomy, such simulated patients (Azer, 2011), and more conventional cadaver-based courses (Op Den Akker *et al*., 2002). The seventeenth and eighteenth centuries are considered the golden age of anatomy. So "spirited" that the task of the famous painter of that time was to portray the anatomical science. The most famous is Dr. Tulp's Anatomy, painted by Rembrandt in 1632. At the end of the nineteenth century, with the development of the X-ray machine in December 1895 by Wilhelm Röntgen, it became possible for the first time in history to display living human bones without a dissection of the body (Scatliff & Morris, 2014; Barragán-Montero *et al*., 2021). Contrast media can now depict the entire vascular system of the body with the names angiography, arthritography, phlebography, and lymphography (Wu & Qiao, 2023). Following, two major revolutions in the technology for anatomical imaging occurred in the twentieth century: CT scan, which was invented by Godfrey Hounsfield (1970), and the MRI technique, developed by Peter Mansfield and Paul Lauterbur in 1975. Both technologies provide the possibility of anatomic imaging through multiple layers or by reconstructing the anatomical structures in three layers. It was through these approaches that body dissection and visualization entered the virtual era (La Riviere & Crawford, 2021; Schulz *et al*., 2021; Weiskopf *et al*., 2021; Shi & Liu, 2023). The goal of the computer science discipline known as artificial intelligence (AI) is to develop software and algorithms that mimic human thought processes and decision-making. The development of powerful algorithms, reasonably priced graphic processors, and large annotated databases has contributed to the quick rise of AI in today's world (Briganti & Le Moine, 2020; Thurzo *et al*., 2021; Lazarus *et al*., 2024). AI has become a crucial component of healthcare education in recent years and is being used by numerous medical schools (Chan & Zary, 2019; Sapci & Sapci, 2020). Three methods exist for AI to impact student learning: empower the learner (many students can work together to solve a complex problem after receiving feedback from the teacher), support teaching (playing a supporting role and collaborating with students as they learn), and direct teaching (imparting knowledge to the student while acting as a teacher) (Chan & Zary, 2019; Sapci & Sapci, 2020; Varma *et al*., 2023). The knowledge, proficiency, and comprehension of difficult medical ideas among students can all be improved by incorporating AI tools into the learning process. VR creates a realistic-feeling computer-generated environment for the user through the use of glasses or a head-mounted display. However, augmented reality (AR) enhances the real world by superimposing virtual elements on a user's vision of it through the use of a smartphone or other device (Ma *et al*., 2016; Tang *et al*.,

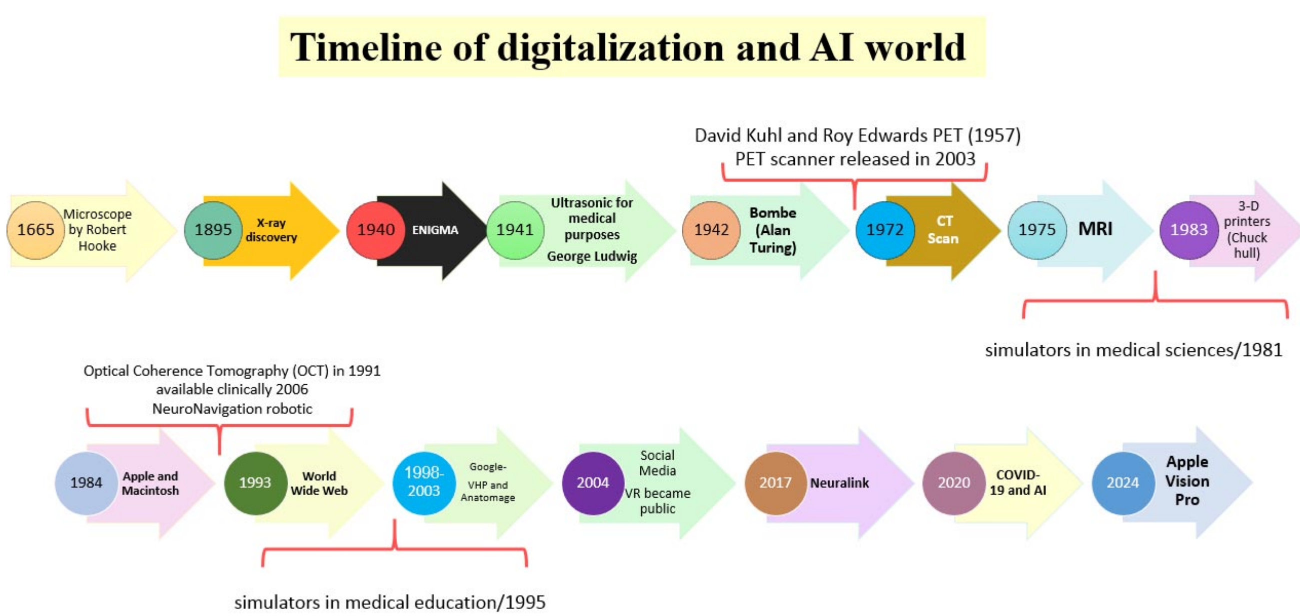

Fig. 1. A history of technology in devices and equipment over time in the development and progression of medical and health professions.

2020). By using these technologies, educators can provide students the opportunity to investigate and interact with intricate clinical scenarios in a way that enhances and optimizes their learning process. Procedural skills can be evaluated through virtual reality (VR), in which the learner performs an operation on a simulated patient in a virtual setting. Subsequently, the system will provide instantaneous feedback and automatically evaluate them based on the steps they take. Medical institutions are gradually establishing VR facilities. The best use case for VR is evaluating postgraduate students' surgical skills (Pottle, 2019; Brown *et al*., 2023) (Fig. 1). Different clinical case situations are taught by AI using problem- or case-based methodologies. This type of instruction can also be utilized as a tool for evaluation. In order to evaluate the learner's understanding, AI can create its own unique sets of case situations if all the case data details have previously been completed. This will identify the higher order critical thinking and diagnostic abilities. AI is also capable of creating dynamic, real-time scenarios according to the learner's level of knowledge and modifying them accordingly, allowing for personalized assessments and targeted improvement of weak points and areas (Han *et al*., 2019; Cooper & Rodman, 2023). A significant advancement in natural language processing (NLP) and AI is the creation of large language models (LLMs). AI applications such as chatbots, machine translation, and question-answering have already made use of LLMs because of their exceptional ability to analyze and comprehend natural language data (Wang *et al*., 2020; Sallam, 2023). The ability of ChatGPT and Google Bard, two of the most well-known LLMs, to comprehend textual data and produce contextually appropriate replies has drawn a lot of attention (Rudolph *et al*., 2023).

MATERIAL AND METHOD

This study comprised the retrospective, prospective, clinical trial, cross-sectional, meta-analysis and review studies published the findings of AI or new technologies for anatomy teaching in peer-reviewed journals. PubMed, ScienceDirect, and Web of Science were selected as the search databases. The search strategy was based on the relevant keywords in the title and abstract of the articles including anatomy, medical sciences, learning, assessment, educational reform, and curriculum revision. Finally, the following search strings were used to explore relevant articles in the selected databases.

- In the PubMed database: ((Artificial intelligence[Title/Abstract] AND anatomy[Title/Abstract]) AND (medical sciences[Title/Abstract] OR learning[Title/Abstract] OR curriculum revision[Title/Abstract] OR machine learning[Title/Abstract])))
- In Web of Science and ScienceDirect databases: ((Artificial intelligence AND anatomy) AND (assessment OR educational reform OR teaching OR learning)).

RESULTS

Although the learning strategy, scenario, and methods should not be the same for everyone, until recently, traditional education systems did not have such a platform and implementation conditions for customized learning. With technological tools and modern interfaces, it is now possible to design educational courses with variety and high quality based on the needs, the academic level of learners and students, and the type of course unit. Teaching anatomy is one of the branches of science that has a great tendency to use technology (McMenamin *et al*., 2014). Fasel *et al*. (2016), showed that 3D prints have an appropriate qualitative and quantitative correlation with the anatomical status of organs in vivo, so they can be included as part of the undergraduate anatomy curriculum. At McMaster University, there is a program called the McMaster Education Research, Innovation, and Theory (MERIT) Program, which deals withthe effective factors in learning anatomy in a VR environment. Hasan *et al*. (2022), investigated whether VR-based clinical scenarios can help improve anatomy learning. The results showed that VR clinical scenarios can increase the cognitive load reduce the factors that can disrupt learning and increase the spatial visualization ability and stereoscopic vision capacity (Hasan *et al*., 2022). While the integrated presentation of anatomy and radiology can support anatomical education at the undergraduate and general medical levels, interpreting the complex 3D spatial relationships in cross-sectional and radiological images is likely to be difficult for novices. Considering the value of advanced and multifaceted strategies, it seems that digital and physical learning at the same time can increase the student's understanding of cross-sectional anatomy. Dedicated resources for 3D anatomy visualization are available, including Sectra (Linköping, Sweden) and Anatomage (USA) virtual beds (Yammine & Violato, 2015). Anatomage was designed by a company in the United States in collaboration with the Department of Anatomy at Stanford University School of Medicine. In this system, a series of multi-dimensional photos of different parts of the human body are included, and by using reconstruction software, the photos are reconstructed in such a way that they show the whole body. The student will be able to dissect the reconstructed body and remove superficial layers to depict deeper layers and organs. It is possible to change gender in anatomy. Anatomage has radiological imaging (CT/MRI) facilities to support the integration of anatomy and radiology into the curriculum. Anatomage has recently been used in maxillofacial and general surgery courses. One of the important advantages of anatomage is that it can be reused several times and compared to the traditional dissection of a corpse, it does not require ethical approval (Fredieu *et al*., 2015). Combining 3D visualization and 3D printing approaches can provide educational benefits for self-learning outside of the anatomy classroom. If the 3D-printing models are produced with sufficient accuracy and detail, the costs related to the periodic purchase of various anatomical models will be reduced. Bork *et al*. (2019) study investigated the effectiveness of the AR Magic Mirror system compared to the Anatomage virtual dissection table in combined anatomy and radiology training. The results show that the magic mirror system is more effective in understanding and learning than anatomy and radiology atlases; 79.17 % of students reported the magic mirror and anatomage as excellent tools to enhance their 3D understanding of topographical anatomy (Bork *et al*., 2019). Cercenelli *et al*. (2022), at the University of Bologna, Italy, used an innovative anatomy teaching tool based on a combination of AR technology and 3D printing called AEducaAR (abbreviation of Anatomical Education with Augmented Reality) to teach 62 second-year medical students. Their results showed that students describe AEducaAR as an enjoyable experience (82 % agree or strongly agree) and recommend it to their colleagues (79 % agree or strongly agree). Additionally, 93 % of students found this technology useful for greater confidence with new medical devices. Indeed, studies conducted in recent years have shown a positive correlation between video game experience and robotic skill simulators, so the use of new digital technologies for educational purposes has important implications for the evolution of robotic surgery education (Cercenelli *et al*., 2022). Bogomolova *et al*. (2020), investigated the effects of stereoscopic AR technology (with the help of HoloLens) on leg anatomy learning of medical students at Leiden University (Netherlands) in a randomized controlled trial study. Another goal of this study was to evaluate the impact of visual-spatial abilities on learning and how they change in students. Participants were randomly assigned to one of three groups: 1-stereoscopic AR model, 2-group of computer images group, and 3-group of 2D anatomy atlas. The results showed that the overall post-test scores in the stereoscopic AR group (47.8 %) were similar to the computer images group (38.5 %) and the 2D anatomy atlas group (50.9 %). In individual intra-group evaluations, the students of the stereoscopic AR group obtained higher grades compared to the computer images group. As a result, the use of stereoscopic AR visualization technology in anatomy education can lead to more effective results for students with low visual-spatial abilities. These findings show the importance of paying attention to individual needs and talent-environment interaction in designing educational programs using 3D stereoscopic technology (Bogomolova *et al*., 2020). In the study of Maresky *et al*. (2019), the effect of using VR on teaching cardiac anatomy to 42 medical students in Toronto (Canada), was investigated. Compared to the control group, the students of the VR group scored 21.4 % higher in the overall content. VR provides a suitable and attractive visual-spatial environment that enables 3D interaction. The results of this study showed that the use of VR in the teaching of cardiac anatomy leads to the improvement of students' understanding of cardiac structures and the development of their anatomical skills (Maresky *et al*., 2019). Integration of medical imaging in preclinical anatomy courses is currently being done in many medical schools. 3D visualization of medical images can facilitate orientation. Modern volume rendering techniques are currently used to create 3D images from medical imaging data, which is called Cinematic Rendering (CR) (Dappa *et al*., 2016). In this regard, Binder *et al*. (2021), at the University of Erlangen (Germany), which was a two-period randomized crossover study, investigated the effectiveness of two imaging techniques, CR and CT scan, on the understanding of anatomy. 16 students were randomly placed in two evaluation sequences. During each evaluation period, the participants answered 15 questions related to anatomy, which were divided into three categories: parenchymal, skeletal-muscular, and vascular anatomy. After a 14-day rest period, an evaluation of the second reconstruction technique was performed. The results showed that the power of depicting the skeletal-muscular and vascular anatomy with the CR technique was significantly higher than with CT scan reconstruction algorithms. In contrast, the ability of CT visualization to show parenchymal anatomy was higher than that of CR technique. These results show that CR can potentially increase the acquisition and transfer of knowledge from medical imaging data in medical education (Binder *et al*., 2021). Neuroanatomy is one of the most difficult subjects of anatomical sciences for medical students. The study of Familiari *et al*. (2013), in the Faculty of Medicine of Sapienza University of Rome (Italy), investigated the effectiveness of tensor tractography (DTI) images on the motivation and learning outcomes of third-semester medical students and then evaluation conducted with a questionnaire and a Likert scale. In this study, 260 students were taught different methods such as traditional routine lectures, prosection and plasticine samples, nervous system plastic moulages, and DTI images. The results showed that a large number of students agreed that the recommended textbooks and atlases are useful for basic knowledge of anatomy and to a lesser extent for understanding the topographical relationships between skeletal, vascular, and neural structures. Results showed that a large number of students stated that courses involving neuroanatomical images obtained during MRI-assisted brain surgery improved their general knowledge of neuroanatomy. Students who attended all of the integrated neuroanatomy lectures had significantly higher test scores than students who attended only occasionally or not at all. It seems that this integrated neuroanatomy teaching model can guide students in the direction of their professional future without any additional costs to the university. Consequently, interactive learning tools, such as lectures integrated with MRI/DTI images, encourage students to study and enhance their neuroanatomy education (Familiari *et al*., 2013). One of the main challenges of teaching the neuroanatomy unit is the lack of objective observation of the basal nuclei in the moulage or during the dissection of the corpse. The basal nuclei are deep in the brain above the diencephalon and below the cortex and include substantia nigra (SN), subthalamic nucleus (STN), globus pallidus (GP), and striatum. MRI techniques provide the possibility of imaging 3D anatomy, connectivity, and function of the brain without invasive intervention. Newly emerging high-field MRI scanners such as Siemens 7 and 9.4 Tesla offer the opportunity to examine the human brain with higher resolution, higher contrast, and lower noise compared to 1.5 and 3 Tesla scanners (Ivanov *et al*., 2023; Ladd *et al*., 2023). Plantinga *et al*. (2016), investigated the anatomical structure of the substantia nigra, the subthalamic nucleus (STN), and the globus pallidus and the connections between these nuclei in the human brain with an MRI machine with 7 Tesla (Maastricht University, Netherlands). The quantitative tractography approach revealed a degree of connectivity not previously documented. For example, there were more subthalamic nucleus projections to the reticular part of the substantia nigra compared to projections to the internal part of the globus pallidus (Plantinga *et al*., 2016). Depicting nerve pathways and how fibers pass through imaging techniques may lead to a revision of anatomical pathways in the brain. Because these connections are depicted in humans and are real, and on the other hand, many of these pathways undergo changes during the preparation of histological techniques, it is difficult to observe them with these techniques, and it is also possible to examine them. There is no such thing in animals (because of the diversity of species).

DISCUSSION AND CONCLUSION

When undergraduate or professional doctoral students enter university, they face several challenges related to study style and learning rules in higher education. These problems in learning and teaching anatomy are far more than other subjects of the basic science course. Learning challenges that are likely to arise during anatomy training include the unfamiliarity of anatomical terms and their large volume, complex 3D spatial relationships of organs, practical dissection techniques, and identification of different body structures on a cadaver due to the use of homogenous fixatives. 3D printed models have been successfully incorporated into anatomy teaching, allowing students to take the models home. In the past, the science of anatomy started with the dissection of a corpse, the design of plastic, and polyester moulage, and the production of histological slides, and finally, in the last few decades, it ended with web-based 3D software and smartphone apps, which only cover the field of macroscopic anatomy. but in the previous few years, the advancement of block chain technology and machine learning (such as VR and AR), neuroimaging methods and technologies, 3D printers, ultrasonic tools, etc., led to huge changes in the ability to teach anatomy in the functional level was even in the display of cellular events of embryonic development or neurotransmitter transmission and neural circuits. After that, various areas of anatomy such as surface, radiological and cross-sectional, anthropological and endoscopic anatomy, and systemic and cellular embryology were expanded. The changes and developments that occur in the world of educational technology directly affect the teaching and learning systems. To what extent the use of technology in education is important and how professors, students, and teaching units are synchronized with this technology is a big concern in medical sciences. One of the main goals of digital anatomy is to understand more of the body's spatial structure and internal organs. VR and AR are very valuable for this. Using VR, people can immerse themselves in a graphic display of the body, while with AR anatomy it can be a real body reflector. Just as X-rays and CT scanners revolutionized therapeutic education in the twentieth century, so will medical imaging analysis revolutionize the 20th century's medicine and create powerful new tools designed to help with clinical diagnosis and modeling, simulation and better guidance of patient treatment. Digital technologies are transforming anatomical training by improving the sustainability of learning with new tools such as a virtual desk. A prominent example of the visible human digital anatomy project (VHP) was presented by the U.S. National Library of Medicine in the late twentieth century. VHP-based digital atlases have enabled movement in the human body in three dimensions and have proven to be very valuable as an educational tool. In recent years, thanks to the dramatic growth of computers, graphics processors and machine learning algorithms, there has been a real revolution in technology that could be called the VR and AR Renaissance. Suddenly, countless tangible interactive technologies emerged with spatial power, stereoscopic and dynamic capabilities that could transfer images and anatomical structures from cabinets and rooms to phones and computers. This is a golden opportunity for digital anatomy to design more interesting and exciting interactive paradigms and approaches to anatomical learning. Compared to conventional WIMP interfaces, VR and AR allow for more motion and more accurate control of the camera (such as head, hands, arms, legs, whole body). In megaprojects such as the Visible Human Project (launched in 1998) (Ackerman, 1999), the Korean Visible Human (launched in 2005; Park *et al*., 2005), and the Chinese Visible Human (launched in 2003) (Zhang *et al*., 2006). Serial cryotomy of the corpses was performed and cross-sectional images were obtained and converted into 3D models using advanced visualization and segmentation techniques. Collecting these 3D images created an archive needed for medical science education. This project, which was initially conducted on educational studies, was later expanded to include virtual surgery, virtual endoscopy, surgical planning (image-guided surgery) and practical simulation. The advancement of modern technologies has given teachers and professors the possibility to use various digital devices and tools in their curricula. Today's anatomy students now have access to smartphones and tablets with faster processing power and larger memory. This allows them to access digital anatomy textbooks, anatomical videos, virtual dissection applications, and medical imaging datasets (Trelease, 2016). Many of these technologies are now ubiquitous in students' daily studies. Major methods now making their way into modern anatomy labs include VR, AR, and Mixed Reality (MR). Implementing these as educational tools can enhance interaction and increase the learning experience and potential (Moro *et al*., 2017). For experienced anatomists who are less confident in technology, the idea of using VR headsets or AR devices can seem very daunting. A modern anatomy curriculum, like any other, requires constant modification of the content and tools used in teaching (Moxham & Plaisant, 2007). This revision of the curriculum is complicated due to the large volume of study units and the reduced duration of the basic science course in a modern medical program and must be accompanied by future developments and technological changes in medical sciences (Estai & Bunt, 2016).

In the category of learning with VR and AR techniques, there are six determining factors including cognitive load, cybersickness (caused by too much work with electronic devices and social networks), interactivity, student perceptions and ability to understand, sereopsis (calculation of the depth of information) and spatial understanding play a role. A teacher should approach the use of VR or AR from an educational perspective in the same way that you would implement any new teaching method into your existing curriculum. These technologies have their advantages in different situations, but they can be just as destructive if used incorrectly. Anatomy is inherently a visual subject, and therefore, the use of additional visualization tools and methods can enhance deep learning. Digital anatomy is emerging as a new discipline (Bartoletti-Stella *et al*., 2021; Patra *et al*., 2022; Adnan & Xiao, 2023), representing the intersection of converging disciplines, including medical imaging, 3D printing and reconstruction, AR, AI, and robotics (Wickramasinghe *et al*., 2022).

Ultrasound is suitable as a complementary method in teaching and learning anatomy because the dynamic nature of this imaging method allows students to see the inside of the body live and in real-time, and it is also a good interface to connect gross anatomy in the basic sciences to functional anatomy in the clinical course. In the future, ultrasound may even be used in molecular imaging and imaging of cells, allowing micrometer-scale imaging. To develop optimal curricula, barriers including cultural and ethical considerations must be addressed along with infrastructure implementation to ensure successful integration of ultrasound across anatomy curricula. Also, with the presence of 1.5 and 3 Tesla MRI scanners inside the country and the high capacity of PACS data storage systems in internal servers, it is possible to create a database of different images with multiple MRI sequences for functional systems, especially the nervous system, cardiovascular system, created skeletal-muscular, urinary-genital, and digestive (Fig. 2). Also, entering the new decade, which is mixed with new technologies, many medical specialty trends need to work with medical images, and it is appropriate to train the future generation to be strong and capable, from now on, their learning foundations should be solid. Learning challenges are prevalent in these early years of medical school, and they often result in a downward spiral in academic performance. In order to promote logical learning and long-term retention of anatomical knowledge—a fundamental idea in all medical practice—continuous attempts have been made to develop new curricula and include cutting-edge teaching, learning, and evaluation methodologies. In recent years, AI has grown in popularity. While AI employs machine learning models to store, compute, analyze, and even enhance huge

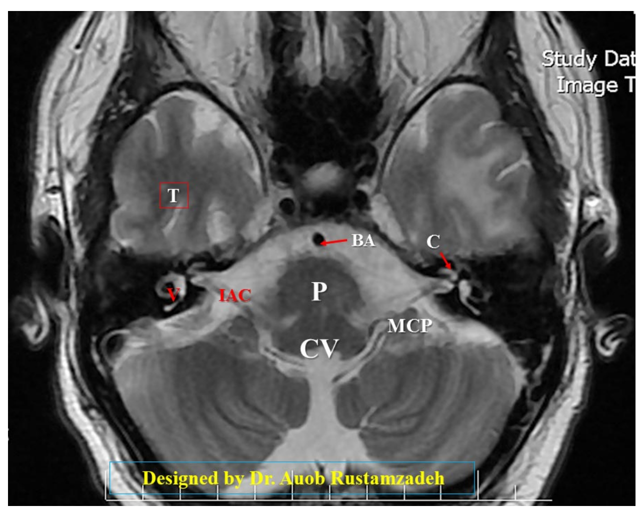

Fig. 2. Axial view of the T2W sequence (1.5 Tesla MRI scanner) of the structure of the ear and its connections. T: temporal lobe, C: cochlea, V: vestibule, IAC: inner ear canal containing paired 7th and 8th cranial nerves, BA: basilar artery, P: pons, CV: vermis of the cerebellum that protrudes into the fourth ventricle. MCP: middle cerebellar peduncle.

volumes of data to be retrieved when needed, the machine itself can be designed for deep learning, enhancing its efficiency through complex neural networks. AI in education offers many distinct advantages, such as deep learning, the ability to store vast amounts of electronic data, the ability to teach remotely, the ability to engage fewer staff members in the classroom, prompt response times from responders, creative assessment techniques, and user-friendly substitutes. AI has long been used in medical diagnosis and treatment planning. The current review focuses on cutting-edge and innovative AI approaches that have been utilized recently to teach anatomy, such as Bayesian U-Net and Artificial Neural Networks (ANN), which are more sophisticated than Convoluted Neural Networks (CNN). AI might be used to create AR experiences, particularly for complex human body parts like the brain's neuronal networks, the embryo's intricate growth processes, or the intricate middle and inner ears. With AI, assessment methods can take on new forms and expand to better meet the needs of specific students. Therefore, it seems that the current challenge is not to use more and more efficient digital technologies in anatomy curricula.

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RESUMEN: La anatomía es una materia compleja que se imparte en los programas pregrado de medicina, con cambios significativos a lo largo del tiempo. La invención de la tomografía computarizada por Hounsfield y los primeros gráficos interactivos por computadora impulsaron el desarrollo de estos gráficos. A finales del siglo XX, la resonancia magnética (RM) revolucionó el diagnóstico y la enseñanza de la medicina, con avances en ingeniería que mejoraron la visualización y el uso de imágenes. La anatomía digital continuó hasta finales del siglo XX, siendo el Proyecto Humano Visible (PHV) un ejemplo destacado de digitalización. El PHV proporcionó una mejor comprensión de las estructuras corporales y de los órganos internos. La primera realidad virtual (RV) y realidad aumentada (RA) en medicina se aplicó en 2004, y en 2024, las gafas Apple Vision Pro marcaron una evolución significativa en este campo. Los estudiantes de medicina a menudo enfrentan obstáculos de aprendizaje durante sus primeros años, lo que conlleva un descenso en su rendimiento académico. Para promover el aprendizaje racional y la retención a largo plazo del conocimiento anatómico, se han desarrollado nuevos planes de estudio y estrategias docentes innovadoras. La inteligencia artificial (IA) ha ganado popularidad en los últimos años, permitiendo el aprendizaje profundo, el almacenamiento de datos, la enseñanza a distancia y la retroalimentación rápida. La IA se ha utilizado en el diagnóstico médico y la planificación de tratamientos. Técnicas avanzadas de IA como las redes neuronales artificiales (RNA), las redes neuronales convolucionales (CNN) y las U-Net bayesianas se utilizan para la enseñanza de la anatomía. La IA también puede utilizarse para ofrecer experiencias de RA y RV, especialmente para regiones complejas del cuerpo humano. La IA también puede modificar las técnicas de evaluación para adaptarlas a cada alumno.

PALABRAS CLAVE: Tecnología del aprendizaje; Enseñanza de la anatomía; Ciencias médicas; Inteligencia artificial; Tecnología digital.

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