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Review Article

Applications of virtual reality in the field of anatomy: a review article

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ABSTRACT

Medical colleges are adopting new technologies to facilitate medical students in learning new medical procedures. The new technologies include leap motion, Microsoft HoloLens, oculus rift, and HTC Vive devices. These devices allow for the visualization of 3D images in virtual or augmented reality. These devices range from non-immersive desktop systems with or without motion tracking to immersive CAVE systems and head-mounted display (HMD) systems such as the HTC Vive and oculus rift. With HMDs, the user enters a virtual environment by wearing goggles with screens for both eyes. Anatomy is a widely used subject in virtual reality (VR) applications. By studying the structure and mechanisms of the human body, we can create extensive online databases with human images and information in the form of CT/MRI scans. The virtual dissection table "Anatomage" is a computerized teaching tool that reconstructs CT scans of humans into a 3D format, which can be viewed using digital media. Students have the opportunity to analyze thin cross-sectional slices of the human anatomy and identify organs and their positions through different planes. By learning Anatomage, they can essentially perform an electronic dissection of a virtual cadaver. To evaluate the efficiency of virtual dissectors in the field of anatomy, a pre and post-test performance of medical students was conducted. The results showed that more than two-thirds (72%) of the students preferred the incorporation of 3D imaging in "Anatomage", as it enables them to understand anatomy envisioned through medical imaging more effectively.

Keywords: Virtual, Cadaver, Images, Dissection, HMD

INTRODUCTION

Medical colleges have adopted new technologies to educate medical students and train other individuals in innovative medical procedures. These technologies involve the use of devices such as leap motion, Microsoft HoloLens, oculus rift, and HTC Vive. These devices enable users to view 3D images of medical applications in virtual or augmented reality VR is a technology that creates a representation of the real environment on a device, such as a PC, TV or mobile phone. It mimics reality so accurately that the user feels as if they are physically present in the environment. It is a human-computer interface that enables users to engage in a three-dimensional visual and sensory environment that imitates various realistic scenarios and conditions.[1] VR technology is particularly beneficial in improving the learning of surgical procedures before they are practised in the operating room. In comparison to reading textbooks, VR offers better knowledge retention as users are exposed to multiple senses. Medical students, for example, can use virtual dissectors instead of drawing and visualizing on paper, which allows them to learn by drawing complex images on tools placed in a 3D space. This helps them explore challenging 3D anatomical relationships in a more immersive and interactive way.[2]

LITERATURE SEARCH

During three months, from April 2023 to June 2023, a review was conducted using four databases: PubMed, Embase, Wiley Library, and Google Scholar. The search terms used were "Anatomage table," "virtual anatomy," "virtual dissection," "residency program," "residency training," "undergraduate training," and "diagnostic." This search aimed to find articles that explore the outcomes of using Anatomage tables for cadaver anatomy education. In addition, literature on the use of Anatomage tables for medical student programs, both undergraduate and postgraduate, as well as in paramedical programs, was also reviewed.

VR-A EVOLVING TECHNOLOGY

VR is a technology that allows users to interact with a computer-simulated environment, whether it's real or imagined. It's becoming increasingly popular as a virtual learning platform. VR systems range from classic desktop setups (like PC, Mac, and PlayStation) with or without motion tracking (such as Nintendo Wii and Microsoft Kinect), to more immersive setups like CAVE systems (multiple large projected surfaces) and HMD systems (such as HTC Vive and oculus rift). With HMDs, users wear goggles with screens for both eyes, which allows them to enter a virtual environment. The goggles make use of sensors to provide accurate information on the user's movements and position. HMD systems allow students to physically move around in the environment, and interact with and explore objects from various angles. The immersion level describes how well the computer-generated environment can replace the perception of the real world, and how students' learning is influenced by the virtual environment's stimuli and actions. The position and movements of the HMD system are tracked to allow the student to explore the virtual environment from different angles and positions. Unlike traditional learning environments, the events and interactions in a VE are not pre-defined and can be generated for continuous interaction.[3]

VR AS A TEACHER IN PRECLINICAL SETTINGS

Anatomy is a widely used subject in VR applications. By studying the structures and mechanisms of the human body, large online databases can be created to store human images and information in the form of CT/MRI scans. The visible human project (VHP) was first established by the university of Colorado in 1991. The project contains over 7000 digital anatomical images of male and female versions, occupying over 50 gigabytes of space. The national library of medicine (NLM) has made this project free and accessible to everyone. Other similar projects include the Korean model called Visible Korean Human (VKH), the virtual body, the virtual human embryo, and the visible human server. After obtaining data from these databases teaching can be enhanced in the form of VR. Anatomy also uses tablet, smartphone-based augmented reality applications that project extensive information, visual 3D structures, and links onto the traditional pages of anatomy textbooks.

Recently, other hardware platforms, such as the Hololens glasses by Microsoft, started to support these relevant applications. The human brain can also be elaborated with the help of 3D reconstructed MRI data.[4] The VHP, the VKH, and also Chinese visible human involve serial sectioning of whole cadavers, producing cross-sectional images. Cross-sectional medical images can be transformed into 3D images of anatomical structures through volumetric reconstruction. These 3D images can be compiled to create a library for medical education and research purposes. The primary goal of the project is to expand the existing library of 3D anatomic images and help users better understand and utilize serially sectioned images. The first step in visualizing and understanding 3D objects from 2D cross-section images is to construct a 3D data set from 2D micrographs. This data set can be generated by aligning images in an edge-to-edge fashion to form a layer. Once each layer is reconstructed, it can be stacked and registered to form the third dimension of the data set.[5]

ANATOMAGE AS VR

virtual dissection table "Anatomage" is a computerized teaching tool in which CT scans of humans have been reconstructed in a 3D format that can be looked through using a digital medium. Students can take thin cross-sectional slices through different planes of the human anatomical structure to identify organs and relate them to anatomical positions. With learning Anatomage, students have the opportunity to essentially perform an electronic dissection of a virtual cadaver. Its main advantages are the level of detail and clarity of those anatomical structures built into the software, the ability to look through any section, and the capacity to zoom the images in and out.[6]

Table 1: Different applications of virtual dissectors in anatomy based on various technologies.

Authors	Session	Technology	Results
Patra et al[7]	2022	Computer simulation technology	It provides a realistic visualization of the 3D anatomical details of a virtual cadaver. One can do-undo-redo the dissection repeatedly.[7]
Pasricha et al[8]	2023	Computer simulation technology	One can understand 3D relations of Body structure grasping surface anatomy. They help with quick revision and quick recall and enhance performance in examinations.[8]
Boscolo-Berto et al[9]	2021	Interactive touch display	Can manipulate structure in any plane or slice in cross-section, can create 3D reconstruction at multiple angles and label that selected anatomy.[9]

Continued.

Authors	Session	Technology	Results
Ong et al[10]	2023	Touch screen technology	Students can understand congenital anomalies and anatomical structural variations.[10]
Chaudhry et al[11]	2023	Computer simulation technology	Explore structures in the human body by reconstructing CT scans and section images in various planes They can visualize the sectional structure in detail by magnifications.[11]

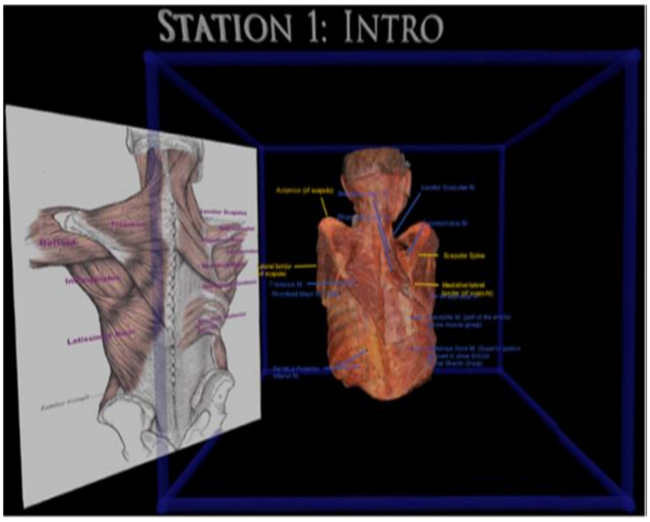

Figure 1: Labelled 2D and 3D images of back muscles.

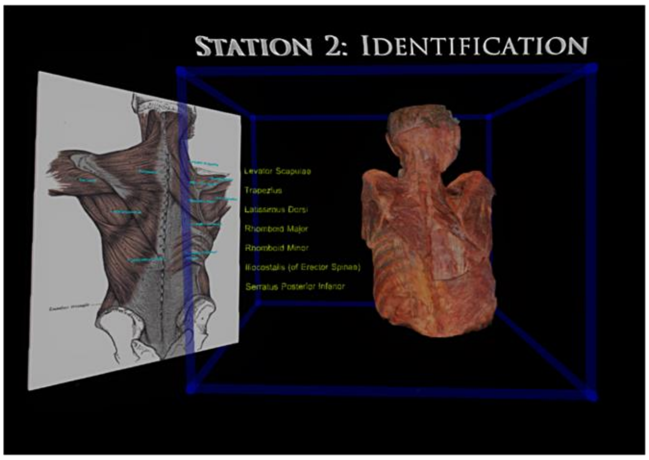

Figure 2: 3D image of back muscles.

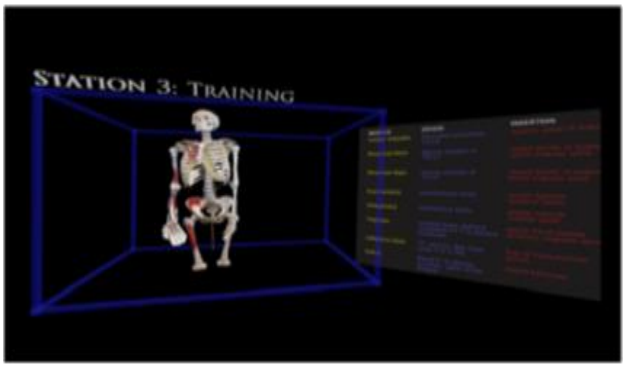

Figure 3: Drawing muscles on 3D images which have been given in the list.

The VR headset utilized for the study was the HTC VIVE manufactured by HTC corporation in Xiandian district, New Taipei City, Taiwan. The anatomy training module environment was created using Tiltbrush, a product of Google LLC located in Mountain View, CA.

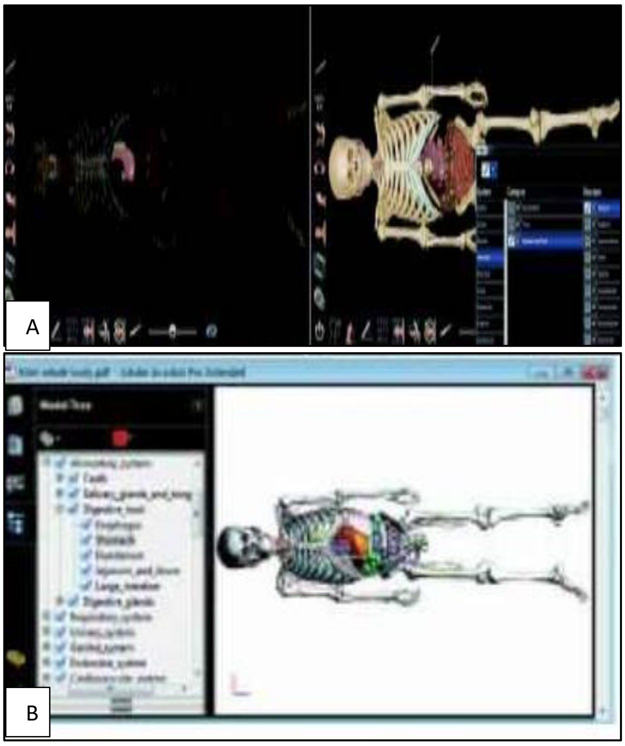

Figure 4 (A and B): Virtual dissection table showing stereoscopic model of stomach.

The virtual dissection table and PDF file can be used to identify the stereoscopic model of the stomach. By selecting the stomach's volume model, the model is highlighted and its name is displayed on the top left. Conversely, selecting the stomach text will annotate the stomach model on the top right. If the stomach is selected on the surface models or on the model tree texts, both will be highlighted at the bottom.[12]

Here is a clearer version of the text you provided: This image (Figure 6) shows the anatomy of the right subcostal oblique scan for sonography. It includes virtual anatomical images A as well as corresponding plane images B and C. The black line in the image represents the cutting line, while the yellow box shows a sonography-like view. The image also indicates the right hepatic vein (RHV), middle hepatic vein (MHV), and left hepatic vein (LHV).[12]

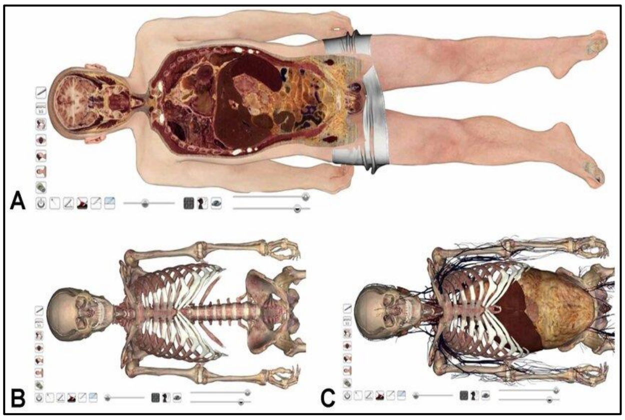

Figure 5 (A-C): The Anatomage virtual dissection table images. Life-size dissection image of human anatomy on the coronal plane. The skeletal system and composite images of the skeletal, vascular, and digestive systems.[12]

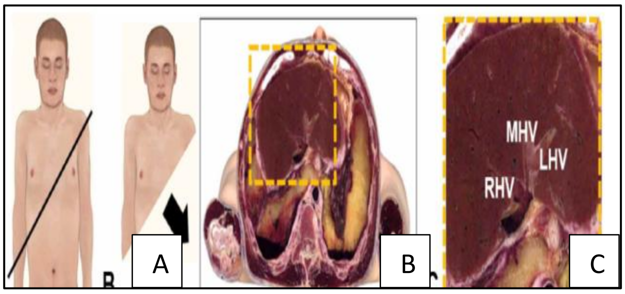

Figure 6 (A-C): Anatomy of the right subcostal oblique scan for sonography.

Priority of virtual dissectors as VR in anatomy

The Anatomage table offers a virtual dissection platform supplementing or even substituting cadavers. The real-life scale cadaver along with colourful cryosections, scanned data of real-time patients, quiz mode and pro-section allows instructors to preach anatomy. The table offers male and female virtual anatomy, with an excellent rendering of the muscles, bones, nerves, and internal organs. Students can use the table for self-assessment or self-review using labelled structures and annotations. The various layers can be sliced or removed to enhance the user's interest.[13]

A study conducted by Zhu et al revealed that a 3D model of the human skull (Figure 7) can be reconstructed from computed tomography (CT) scans. The team used 3D studio max 2016 to modify several defective structures, such as the ethmoid plate, crista galli, anterior clinoid process and inferior orbital fissure, on the 3D skull model. Each bone of the skull was isolated and painted in different colours. Finally, the model was imported into the unreal engine VR platform through the HTC VIVE software development kit and unreal engine 4.15. The HTC VIVE CE, a VR HMD with a resolution of 2160×1200, is compatible with the unreal engine VR platform. Seventy-three participants completed a course that included a theoretical lecture followed by a cadaveric dissection of the same duration. At the end of the course, there was a theoretical test and an identification test for objective assessment. The participants were divided into three groups: the VR group (n=25), the cadaver group (n=25), and the 2D atlas group (n=24). All participants completed pre-intervention tests, attended a 30-minute PowerPoint-based introductory lecture on cranial bones, and then had a 30-minute self-directed learning session using skull VR, cadaveric skulls, or 2D atlases. After the learning session, a post-intervention test was conducted to evaluate the educational efficacy of each model, and a perception survey was completed by each participant. The pre-and post-intervention tests comprised the same set of theory tests and identification tests. No statistically significant difference was found across the three groups in the pre-intervention tests for the total score, theory score, and identification score. In terms of the post-intervention test, there were no statistically significant differences across the three groups in either the total score or theory score. However, the VR group performed better in the identification test compared to the cadaver and atlas groups, although this difference was not statistically significant.[14]

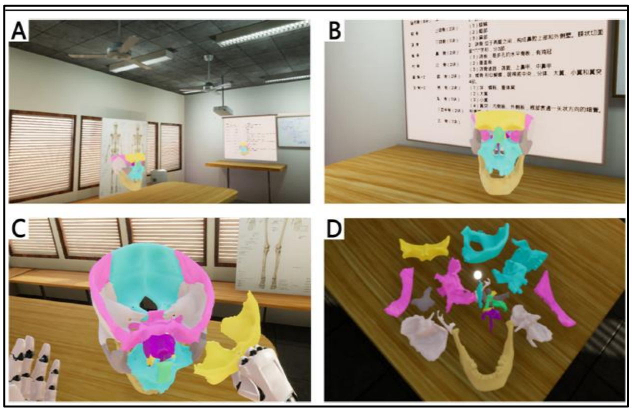

Figure 7 (A-D): 3D human skull.

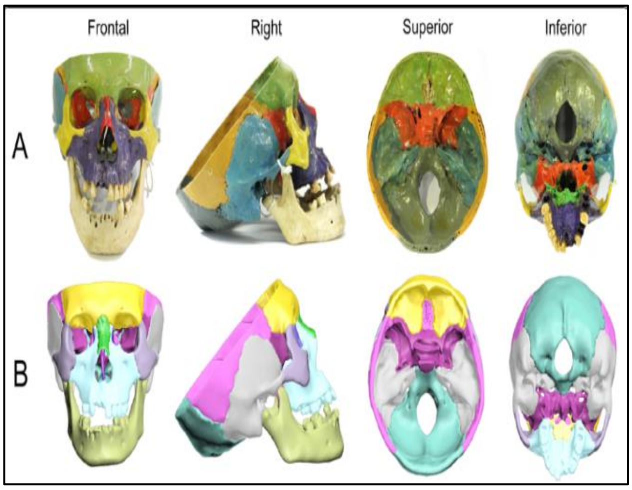

Figure 7 (A and B): 3D human skull.

ADVANTAGES AND DISADVANTAGES OF VR IN MEDICAL EDUCATION

There are both advantages and disadvantages of using virtual reality in medical training. Some disadvantages include the high cost of simulators and studies, the need for identification of effective factors and conditions, potential harm to learners without supervision, limited course of studies, and the inability to fully replace real environment training. However, the advantages include a decrease in training frequency and ease of training, positive psychological effects, increased accuracy and reduction of errors, improved teamwork, increased self-confidence in learners, decreased harm to patients, better learning of anatomical positions and organ relationships, valuable approach for standard education, increased surgeon skills and safety for patients, and decreased costs and increased efficiency. Overall, virtual reality can lead to significant performance improvement in medical training.[15]

CONCLUSION

The benefits and drawbacks of virtual learning: This essay could explore the advantages and disadvantages of learning in a virtual environment, specifically discussing the effectiveness of virtual learning in teaching anatomy. It could also touch on the impact of virtual learning on student engagement and collaboration.

The ethics of using cadavers for medical education: In this essay, the ethical considerations surrounding the use of cadavers for medical education could be explored. It could also delve into the alternatives to using cadavers for anatomy education, including VR and other simulation technologies. The future of VR in medical education: A paper on this topic could discuss the potential for VR technology to revolutionize medical education. It could explore the different ways in which VR could be used to teach anatomy and other medical concepts, as well as the challenges that need to be addressed to make VR a viable alternative to traditional education methods.

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