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Real-World Deployments of AR In Medical Training and Surgery

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Abstract: Numerous advancements have been recognized as potentially disruptive technologies in the surgical workplace due to the continuous improvement of the surgical environment in the digital age. Augmented reality in healthcare can improve the effectiveness of procedures, including anatomical services, medical education, and the most crucial surgical setting. Augmented reality technology has found important applications, particularly in surgery and medical education, through the overlaying of digital information in the real world. AR-based training can successfully and effectively teach medical staff and has many potential advantages. In addition to offering a safe learning environment and focusing on certain professional abilities, augmented reality (AR) programs are employed in medical education to enhance students' learning experiences. This new artificial intelligence is used in surgery as real-time visualization platforms quickly advance. Computed tomography (CT), ultrasonography, magnetic resonance imaging (MRI), and mammography are crucial real-time data surgeons need during surgery. Using AR, these data can come in handy as a 'see-through display' replacing the traditional 'head's up display.' This research paper provides case studies and examples of real-world deployments of AR in medical training and surgery, showcasing successful implementations and lessons learned.

Index Terms – Wearable devices, AR Technology, Machine Learning, Algorithm, Augmented Reality, Computer Vision.

I. INTRODUCTION

Augmented reality (AR) is among the latest technologies in healthcare. As many comprehend it, AR is widely used in gaming and entertainment. Still, it has extended beyond these realms, offering innovative solutions to healthcare providers attending to their patients [1]. Also, AR technology has found significant uses in medical education and surgery by superimposing digital data on the natural environment. According to Alkhabara (7), AR is the technology combining virtual and actual environments by using specialized software and programming to display them on smart devices. This technology provides a dynamic, immersive, and interactive platform for professionals and students. AR can use various devices like tablets, computers, and smartphones to achieve a fully immersive experience and create a highly dynamic learning environment [1, 2]. The rise in the use of AR was experienced during the COVID-19 pandemic. Currently, the use of AR-based education systems within medical institutions worldwide is rising due to the particular learning benefits that AR provides, such as interactive simulations and remote learning [1].

Besides, everyday surgeons depend on data from MRIs, X-rays, CT scans, and related patient records to establish surgical techniques and requirements they can employ to bring forth the safest and best results while ensuring that patient recoveries are short and complete [3]. With the introduction of AR, with the advent of AR, surgeons are now able to view the information immediately in front of them without moving their hands off the operating table or diverting their focus. In this sense, AR possesses various benefits to the healthcare sector. It has enhanced the learning experience by immersing students and practitioners in realistic 3D medical scenarios. Besides, AR improves patient outcomes because AR-guided procedures improve accuracy while lowering mistakes. This research was conducted to comprehensively explore various real-world AR deployments in medical training and surgery, showcasing successful implementations and lessons learned.

II. AR IN MEDICAL TRAINING - SUCCESSFUL IMPLEMENTATIONS AND LESSONS LEARNED

Medical personnel may be successfully and efficiently trained via AR-based training, which offers many potential benefits. AR programs are used in medical education to improve learners' experiences, provide a secure learning environment, and target specific professional competencies [1]. Figure 1 below highlights six main AR goals in student's medical education.

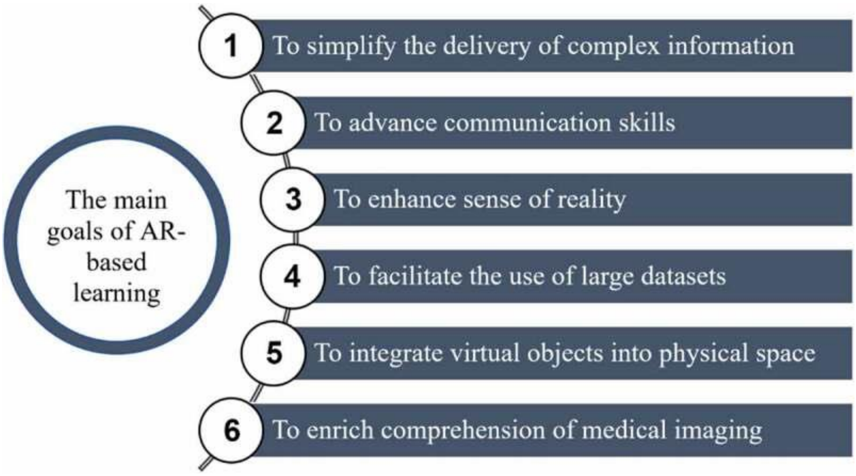

Figure 1. Six main goals of AR in medical education [1]

As many learners report, AR learning is much fun. It addresses the three critical components of Mayer's cognitive theory of multimedia learning—the delivery, presentation of that instruction, and the use of sensory systems [1, 4]. Many learning organizations have realized that adopting AR learning is easy since most of their students have a high level of digital literacy and can access and use smartphones and tablets. Learning institutions focuses their learning outcomes on three main impact domain: practical skills, knowledge, and understanding.

III. Knowledge and Understanding

Medical education mainly comprises information about human anatomy and bodily function. Institutions have developed AR digital programs like virtual cadavers to gain knowledge and understanding of the intricate human body. For instance, Case Western Reserve University has developed the HoloAnatomy® Software Suite based on the Microsoft HoloLens. With Microsoft HoloLens technology, the AR-based instructional application HoloAnatomy offers an immersive understanding of the human body. Holographic simulations of the human body may be interacted with by students. Learners with HoloLens headsets may see and interact with complex anatomical features, which helps understand the human body in greater detail.

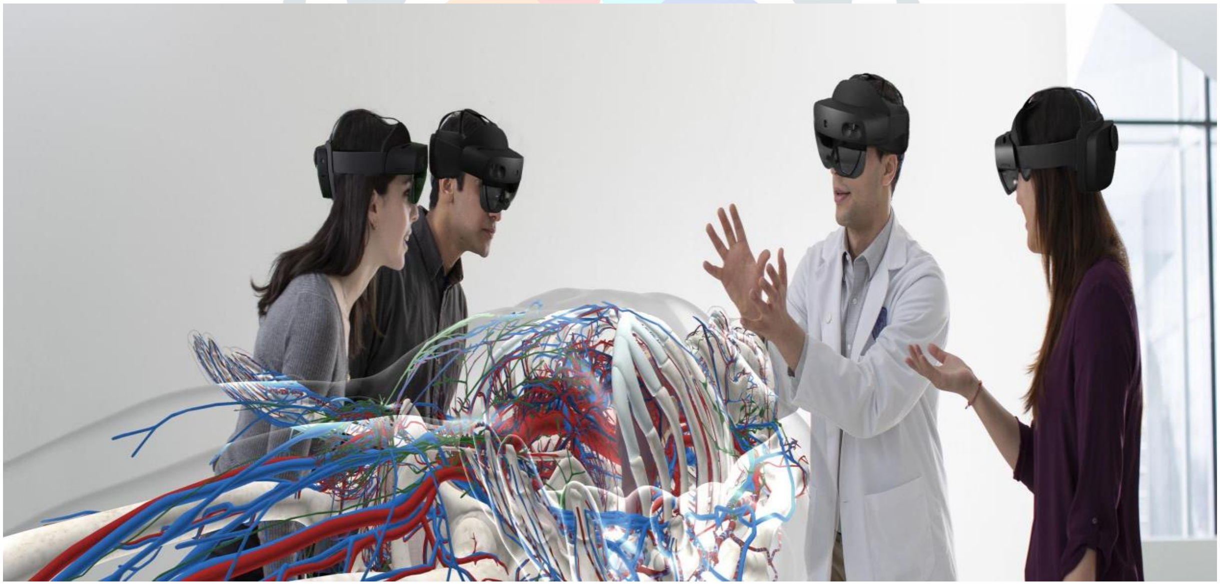

Figure 2. A 3D cadaver as seen using HoloAnatomy Software Suit [5].

From the figure above, the instructor (in the white lab coat) in Figure 2 uses Microsoft's HoloLens and cutting-edge 3D mixed-reality software to teach human anatomy without using a real cadaver. The nervous, circulatory, and diaphragm are examples of "difficult to see" anatomy that learners may see alongside other anatomical components and systems. Learners may walk around, work together, and communicate with one another. [5] They can engage with the anatomy more intuitively and easily pan in and out of the holograms.

Figure 3. The augmented reality software HoloHuman, just like HoloAnatomy, displays a simulated corpse on an authentic examination table.

Using a HoloLens headgear, the moderator (pictured) may communicate with the model and user interface. Visual narratives and digital dissection tools are fully supported, allowing for the examination of various structures, organs, and systems separately or in combination [1]. With the help of HoloHuman, educators and learners may investigate parts of the body, 11 distinct body systems, and over 4,500 identified and detailed structures [6].

Such AR applications make it simple to manipulate digital content, enabling the identification and exploration of spatial connections in three dimensions. This makes it possible to investigate intricate branching nerve and blood artery courses in isolation in terms of anatomy, which is challenging to perform with standard cadavers since these structures lose shape if they are torn away from the supporting tissue. The capability of choosing systems or areas of interest and accessing various information about them also helps with learning the names of the numerous anatomical structures [1, 5]. According to Case Western Reserve University [5], HoloAnatomy has been implemented successfully, effectively, and efficiently. Students have mentioned that it helps retain information for longer, boosting knowledge and understanding of a topic in study.

IV. PRACTICAL SKILLS

It is anticipated that graduates of medical schools will possess a wide range of information about the human body, illnesses, and treatment options, as well as physical examination, communication, clinical, and practical abilities. Various medical curricula and pedagogy produce competent professionals in their medical field. However, these professionals can still use an extra hand from AR to improve their surgical and practical skills. Although clinical assignments have greatly enhanced the students' practical skills, a lack of intensive hands-on instruction frequently prevents them from mastering these techniques [1, 8]. Physical models, which are more complex and successful, often fill this gap.

Learners have admitted that using AR, for instance, Human Anatomy Atlas, enhanced their anatomy skills. Learners can explore human body-animated 3D models. They can see body movements and view medical animations of pathologies. Besides, the University of South Carolina's Medical School used a sophisticated Cardiopulmonary Patient Simulator manikin among its students and found out that on tests like the MCAT and USMLE, students taught cardiac assessment abilities using the simulator outperformed those who used patient models or standardized manikins. AR develops learners' practical skills by boosting the mental retention of what is learned [1]. Besides, since AR learning can be found in devices like smartphones, it helps increase student-paced understanding. Students can learn skills even when not in school.

In the current medical stream, medical institutions have mostly adopted HoloAnatomy, OculAR SIM AR, and HoloHuman to help boost students' knowledge, understanding, and practical skills. These AR programs have garnered recognition for improving anatomy instruction by making it more exciting and approachable. Students' recall and comprehension of intricate anatomical structures have increased, which has enhanced their readiness for practical medical practice.

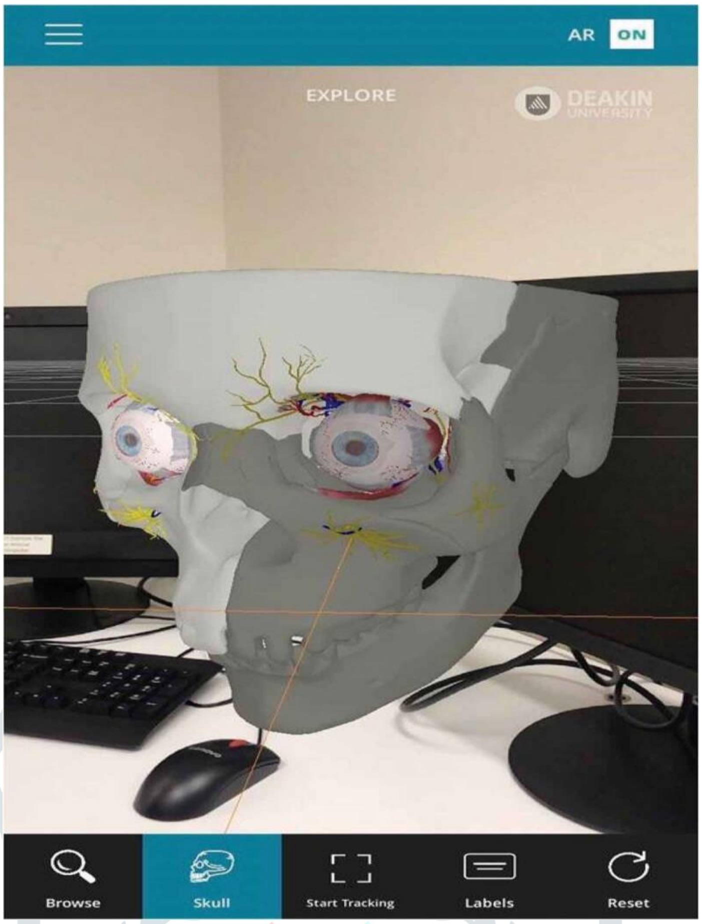

Figure 4. The OculAR SIM AR program

Figure 4 above presents Deakin University's OculAR SIM AR program used in examining the human eyes and related parts for abnormalities and defects. Optometry students at Deakin University and other institutions worldwide can now access innovative 3D and AR-based learning to get acquainted with the human eye and its neighboring structures, identify the various parts and their functions, and self-evaluate their understanding [9].

Despite the success of AR, there have been difficulties in applying it to medical education. These include the steep upfront expenditures of AR technology and software, the ongoing need for content upgrades to maintain it accurate and current, and the requirement for enough training for educators to use AR in the classroom effectively. These difficulties emphasize the importance of planning carefully and investing in infrastructure and faculty development to successfully integrate AR into medical education. However, the HoloAnatomy program at Case Western Reserve University demonstrates how AR could change how medical students study and become ready for placement. It highlights the advantages of improved training experiences, interaction, and personalization.

V. AR In Medical Surgeries - Successful Implementations and Lessons Learned

Augmented reality integration in surgical procedures has brought about a new age of innovation and accuracy in the healthcare industry. By superimposing computer-generated data, such as 3D models, over a surgeon's view of the patient, augmented reality (AR) technology enables real-time assistance, increased visualization, and better decision-making. This blending of the physical and digital worlds has demonstrated incredible potential in various medical treatments, from intricate interventions to minimally invasive surgery. Using augmented reality (AR) technology, the surgeon may access information and view data in real-time during surgery. We understand the significance of this, given that it facilitates more rapid and accurate diagnosis and treatment.

AR also can offer remote assistance during surgical procedures; practitioners can collaborate remotely. A surgeon can do activities more effectively by using AR, which involves adding artificial information to one or more of their senses. Video, computer-generated models (CGM), and overlaid pictures can all achieve this. One example is the AccuVein, a projector-like device that projects a map of the vasculature on the skin, or Google Glass (GG), a head-mounted display (HMD) with produced objects overlaid on real-time photos [10]. Google Glass and AccuVein are based on a 'see-through' display, replacing the traditional 'head up' display.

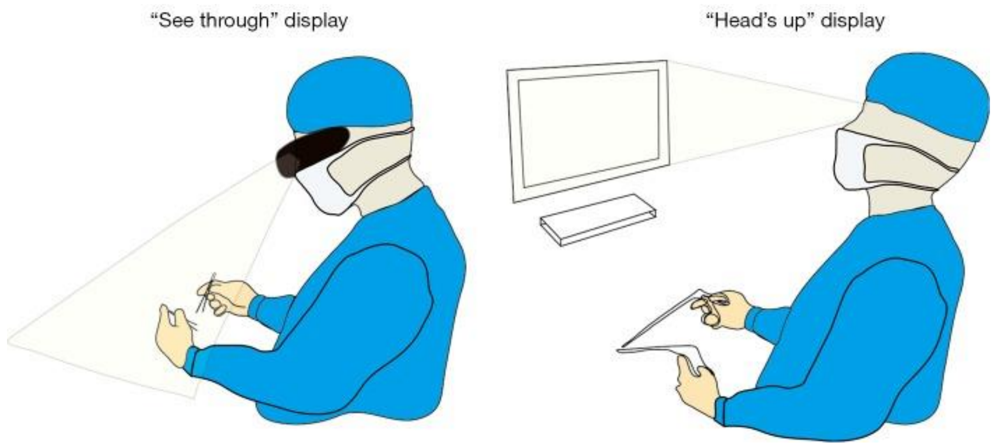

Figure 5. Contrast between head-up and see-through display.

AR's see-through display offers a fast and timely surgical experience since there is no obstruction. For the head display, a surgeon has to concentrate on a mounted display as they operate. This can reduce concentration, making the surgical operation long and tiresome [10].

VI. Uses of AR in Surgical Operations

Several opportunities exist within surgical healthcare, including anatomical evaluation, telementoring and education, and operative benefits. Several case studies and developed AR equipment are being used at the moment.

VOSTARS visor

The Policlinico Universitario S. Orsola in Bologna successfully performed the first surgical procedure in the history of the world utilizing virtual components. The surgeon could observe the virtual elements in front of him during the process, naturally in an actual operating room, and these elements could help and direct him. The surgeon made this feasible using a VOSTARS visor (Video and Optical See-Through Augmented Reality Surgical Systems) that combined Augmented Reality throughout the procedure [11]. The visors in the market project a few digital contents, for instance, a 3D picture of the organ undergoing surgery straight into the surgeon's line of view. In the past, surgeons often viewed these digital pictures produced by radiological scanners (CAT and MRI scans) before the procedure to help with preoperative planning. Because it is challenging for the human eye to focus on virtual and real items simultaneously, a visor has never been used to direct surgery previously [11].

One of the objectives that the VOSTARS visor addresses is blending the focus of virtual with real objects. Even as the procedure is being performed, this VOSTARS visor can show patient-specific information and more generic information about the organs being operated on right into the user's field of view without any fluctuation in the actual and virtual perspectives.

Fig 6. A surgeon is wearing a VOSTARS visor during surgery. VOSTARS is a wearable head-mounted display (HMD).

There has been a combination of AR and AI in minimally invasive surgeries to achieve the best surgical experience. An AR headgear, the Microsoft HoloLens, is frequently utilized for minimally invasive procedures [12]. The surgeon's field of view is overlaid with 3D models and crucial patient data, enabling accurate navigation and real-time guiding.

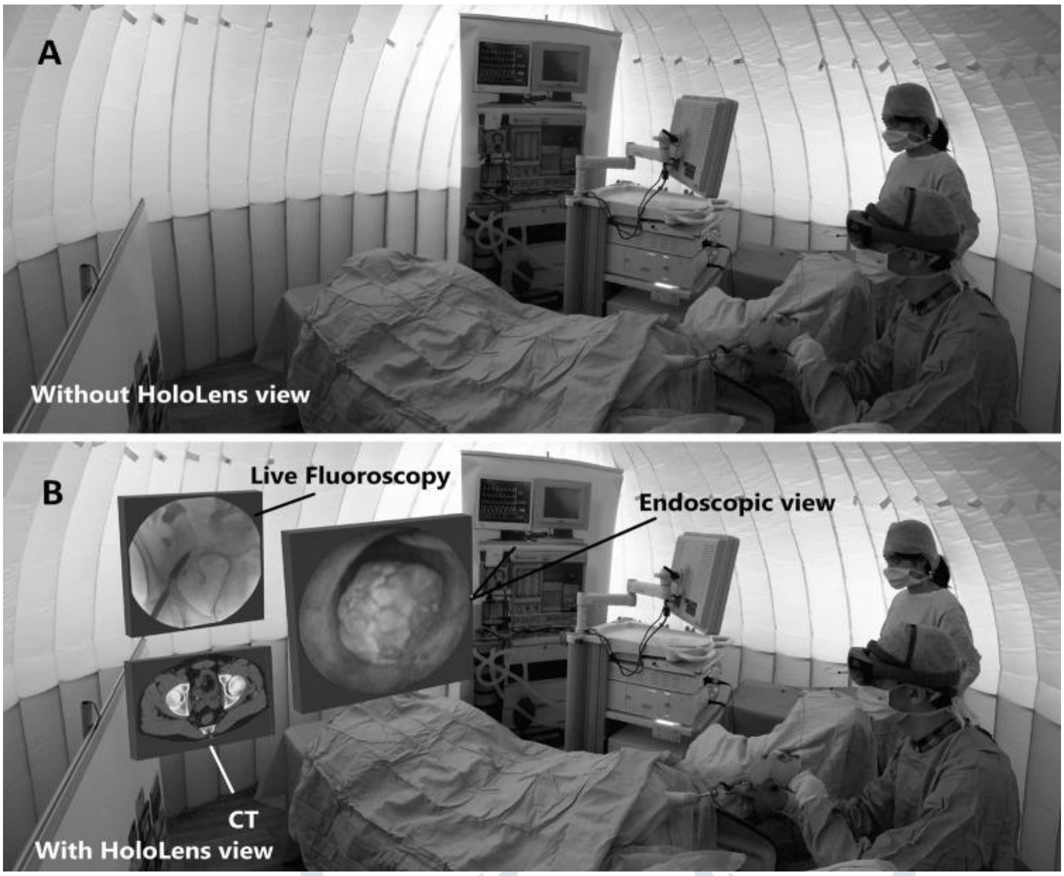

Figure 7. Participants performed ureteroscopy using the HoloLens in a full-immersion simulation setting.

When the HoloLens is worn, image A shows the user's perspective of the outside world, and image B shows a simulation of what the user wearing the HoloLens sees [12].

Besides, *SyncAR*, an AR technology developed by Surgical Theater in collaboration with Medtronic, allows surgeons to obtain all surgical information in one location rather than glancing up at displays to access patient data or better graphics, which slows surgery [13]. It features augmented - or digitally layered - 3D graphics that were produced utilizing Surgical Theater's *SyncAR* technology and was intended particularly for complicated neurosurgeries. Each picture, created using a patient's anatomical scans like a CT or an MRI scan, provides a detailed visual of the body portion undergoing surgery [13].

Figure 8. *SyncAR* technology.

To gain a clearer view of nerves, tumors, and tissues before surgery, the technology employs virtual reality to let neurosurgeons "fly" inside a patient's brain. Before surgery, a 3D model of the patient's brain is taken and generated, which is

used during surgery. Most AR solutions use video cameras, ensuring that the surgical pictures and the patient's radiological images are fully coherent and in focus when combined. [14].

Difficulties and lessons have been learned in applying augmented reality in surgical procedures. Integrating augmented reality technology into the current healthcare system can be difficult. To guarantee the smooth operation of AR systems, hospitals and surgical teams must invest in suitable software and hardware components. Besides, using AR technology requires significant training for surgeons and medical personnel. Surgeons must be acquainted with the equipment and software to avoid mistakes during surgery. A major setback in AR integration in medical education and surgeries is the initial cost of purchasing AR technology. However, the advantages of better patient outcomes and fewer problems must be carefully weighed against the initial expenses by hospitals.

VII. The Future of AR in Medical Education and Surgeries

Augmented reality (AR) has a bright future in medical education and procedures. Since it will provide more immersive, engaging, and accessible learning experiences. Students can practice on extremely realistic, patient-specific simulators throughout training, enhancing their surgical abilities and decision-making [15]. During operations, surgeons will increasingly rely on augmented reality (AR) overlays that provide vital patient information, real-time diagnostics, and surgical plans right in their field of vision. Also, AR will continue improving remote cooperation by enabling professionals to mentor less experienced surgeons in real-time, even from different locations [16]. Incorporating AR technology into medical institutions will increase as AR gear becomes more portable, powerful, and inexpensive, leveling the playing field for healthcare workers worldwide. If AR systems have not yet begun to analyze data, aid in diagnoses, and offer tailored advice to practitioners, they soon will. With ongoing innovation, AR will enhance patient outcomes, lower medical mistakes, and change medical education and surgical techniques to be quicker, safer, and more effective [1].

VIII. Conclusion and Recommendation

Healthcare technology is continuing to revolutionize with the introduction of innovative technologies. The introduction of AR and related AI-assisted technologies has ensured enhanced precision and safety in healthcare procedures that promote positive patient outcomes. AR is a dynamic bridge between the real world and the digital realm. Case studies like HoloAnatomy are a clear presentation of what AR is capable of performing. In integrating AR into medical education, students have expressed better comprehension and a boost of their practical skills in various medical fields.
Consequently, surgeons have become more confident and skilled. However, case studies like Google Glass show the need to address technological, governmental, and moral issues in AR implementation. The use of AR in surgical training and medicine has a promising future. Stakeholders should fund AR research and development to ensure affordability and accessibility. Continuous innovation is essential with prospects for AI integration and extending AR applications beyond anatomy and surgery into many medical fields.

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