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An operation standardized training system based on MR and 3D printing technologies

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Abstract

Development of modern science and technology puts forward new requirement for medical education so as to improve previous education system. A world constructed by MR technology is mixture and interaction of a virtual world and the real world. Compared with traditional education mode, MR technology and 3D printing technology combined application in education is an education way that is more conducive to training of medical students and can even bring about an educational revolution. A standardized training system that we constructed included three parts: database, virtual a 3D model and a 3D printing model. By importing a patient's medical record and a physician's diagnosis and importing image data, three-dimensional (3D) reconstruction was performed on basis of the patient's pathological diagnosis and imaging examination result and was recorded in system database; classification included each disease, and meanwhile, this was downloaded to mixed reality equipment for use or was read and learned online and 3D printing technology was used to print 3D model. This standardized training system helps promote standardized training of surgeons and improve current clinical teaching situation and can overcome shortcomings of VR which is "completely virtual but cannot interact with the real world", thereby achieving good teaching effect in practical teaching.

Key words: Mixed reality, 3D printing, medical education, standardized training, teaching system

1. Overview

With development of modern science and technology, human life style and thinking habit are gradually undergoing profound change. Medical education plays an irreplaceable role in the following causes: advancing development of medicine, cultivating medical talents and safeguarding human health. Development of modern science and technology has launched a new challenge to medical education. In order to adapt to this general trend, researchers have developed a series of systems and methods to adapt to this change and advance development of medicine. Among them, virtual reality and 3D printing technology are a crucial part. As a new rapid forming manufacturing technology, 3D printing technology can be combined with digital medical imaging equipment to customize individualized biological materials, so it is increasingly favored by medical community, especially orthopedic community [1]. Through display of a more intuitive model in teaching link, 3D printing technology not only makes abstract knowledge points easier to master, but also greatly improves students' interest in learning [2]. Cause why 3D printing shows strong vitality in medical training is its interaction with users. However, education mode reform that only stays at level of 3D printing technology is not comprehensive, and has not solved drawback of PPT teaching. Therefore, mixed reality technology can be introduced instead of PPT as a carrier of knowledge.

Mixed reality technology (MR) is further development of virtual reality technology, which builds an interactive feedback information loop among the real world, a virtual world and a user through presenting virtual scene information in a real scene, so as to enhance sense of reality in the user's experience. Human anatomic structure is very complex, and requirement for surgeons gradually becomes high and patients need more minimally invasive and individualized treatment. [3]

Emergence of mixed reality has brought new possibility for modern medicine. Some research teams have applied mixed reality technology to important operations (hip joint operation, lumbar discectomy, etc.) [4-7]. Additionally, in a study on level of hepatobiliary tumor operations, researchers performed differential analysis between experimental group and control group and found that there were significant differences in operation duration, bleeding volume, etc. between two groups of patients, indicating that mixed reality technology can provide an operator with an intuitive stereoscopic image, help clarify surgical approach, enhance the operator's judgment, and have good application prospect in hepatobiliary tumor operations [8]. Mixed reality technology can provide a user with real and 3D use experience and has strong interactivity. Therefore, we believe that a medical standardized training system based on mixed reality technology and 3D printing technology can be developed in a similar way.

A past study applied the combined mixed reality and 3D printing to teaching of lateral ventricle puncture, and also researched results; data obtained had very high stability and specificity and students' scores could be effectively improved [9]. Based on success of this experiment, we had reason to believe: This experimental method was very feasible and had wide applicability and high success rate; it had important reference significance for an experiment that we would do, and would provide guarantee for success of the experiment. With use of mixed reality technology in preoperative modeling, operation plan discussion and intraoperative real-time navigation, a mixed reality navigation system could guide operation process, accurately located a focus and displayed relative relationship between surgical devices and the focus. We believe: With advancement of science and technology, traditional education mode, in which PPT is combined with enlarged class and distance imposes limitation in clinical practice and medical students cannot operate by their hands, needs to be combined with 3D imaging to maximize restoration of the actual human body and close the distance between the medical students and a "model". Therefore, a new medical education system that combines MR technology and 3D printing technology is a brand-new education system that is more advanced, is more conducive to training of medical students and is easier to trigger revolutionary education system change than a traditional education system.

2. A medical standardized training system

2.1. Significance of a standardized medical training system:

Operation is a basic skill for clinicians and is also a basic skill that every medical student needs to master. However, for each of some complex operations, a considerable part of its procedures requires a doctor's rich experience and hand feeling, being very difficult for a medical student without standardized training and a young doctor who has just taken up his/her job. Risk and complexity of operations will have great impact on teaching. These phenomena are, in the final analysis, because a suitable and effective standardized training system does not exist. Hence, it is necessary to apply 3D printing technology and mixed reality technology in teaching; the system allows physicians, refresher physicians and interns to skillfully master operations' standardized procedures that need to be mastered during the operations, so as to reduce difficulty and possible risk of these complex operations. The 3D printing technology is a rapid forming technology with computer aided design, and overturns traditional teaching mode by virtue of its strong stereoscopic intuitiveness. Because it can achieve high-simulation printing of fine structures such as blood vessels, nerves, skeleton and muscles, it has important significance in undergraduate teaching: Teaching of basic medicine such as anatomy and

pathology, and teaching of clinical medicine such as surgery, orthopedics and internal medicine. In teaching link, more intuitive model display not only makes abstract knowledge points easier to master, but also greatly improves students' interest in learning. In undergraduate clinical skill operation teaching, 3D printing technology can also provide a better operation model [8]. This standardize training system is constructed by classification based on pathogenesis and clinical manifestations of various diseases, possible emergencies in an operating room, postoperative complications, etc. It includes three parts: database, a virtual 3D model and a 3D printing model. By importing a patient's medical record and a physician's diagnosis and importing image data, 3D reconstruction is performed on basis of the patient's pathological diagnosis and imaging examination result and is recorded in system database; classification includes each disease. (Figure 1a, b) This is downloaded to mixed reality equipment for use or is read and learned online. As for understanding of structure: 3D printing technology is used to print two kinds of prostheses. One is used to display organ structure to a user, and the other is used for 3D printing with materials similar to an existing teaching dummy in a medical college and is convenient for a user to operate, practice hand feeling and gain experience. As for operation skill: Operation process from an expert's perspective is inputted in database, and a diseased organ is constructed with 3D reconstruction technology; when equipment is used to view and emulate, a complex operation can be viewed and emulated at close range through change of "transparency" and other settings. Virtual reality equipment is used to project a virtual image onto a real prosthesis made by 3D printing technology to achieve 1:1 overlap, which can maximize restoration of overall process of a complete operation. For students, book knowledge may be transient—genuine knowledge comes from practice. This teaching system can help the students identify pathological tissues more quickly during an operation and understand operation process.

2.2. Analysis in teaching fields of a standardized training system:

Many diseases have complex pathology. Teaching only based on books is obviously not enough. Ultimate goal of medical students' education and training is to allow them to enter clinical work. Therefore, this system combines pathophysiology and human structure teaching with operation skill through mixed reality technology to cultivate medical talents comprehensively. In addition, although development of VR technology has been ahead of MR technology and has been put into production and can even be accessed in daily life, MR technology has an unparalleled advantage compared with VR—interaction with the real world. After this system is applied to standardize training of medical students, it can further perfect dynamic teaching system. Current traditional teaching mode of medical student practice class still adopts physical object teaching. This class mode is certainly a great improvement over an ordinary enlarge class lecture, but disadvantage is that a teacher is restricted by physical objects and confined around an operating table, and efficiency and quality of students listening to the lecture will be reduced to various degrees; moreover, when the students are grouped to simulate physical objects, they cannot timely look up books due to blood stains attached to gloves, abiding by operating room rule, etc., which takes up a considerable part of time and manpower in internship process. Using powerful interaction between MR and reality, combined with advanced technology, a teaching system is materialized and dynamized to effectively stimulate medical students' enthusiasm to learn and meanwhile save time and effort.

2.3. Cardiovascular surgery application planning

At current stage, there is no precedent for combining MR technology with 3D printing technology a nd applying it to cardiovascular surgery, but we believe that it has vast application prospect. As for application of mixed reality technology, taking great saphenous vein bypass as an example, on-the-job physicians use a head-mounted virtual reality equipment to create learning situation when listening to a

lecture, and virtual reality equipment is used to project a virtual image onto a real prosthesis made by 3D printing technology to achieve 1:1 overlap, which can maximize restoration of overall process of a complete operation. For students, this teaching system can help them identify pathological tissues more quickly during an operation and understand operation process, which can inspire the students to have more initiative, interest and 3D imagination. Mixed reality technology has great potential and broad prospect in medical teaching. Compared with traditional education way, it can improve visualization, interactivity and 3D sense in medical teaching, thereby attracting students' attention and interest. Mixed reality technology in combination with force feedback will bring revolutionary change to medical student education system, thereby having important development prospect for clinical medical students' simulation training and even being able to greatly reduce time and resource for cultivating real "general practitioners".

Figure 1 System flow chart

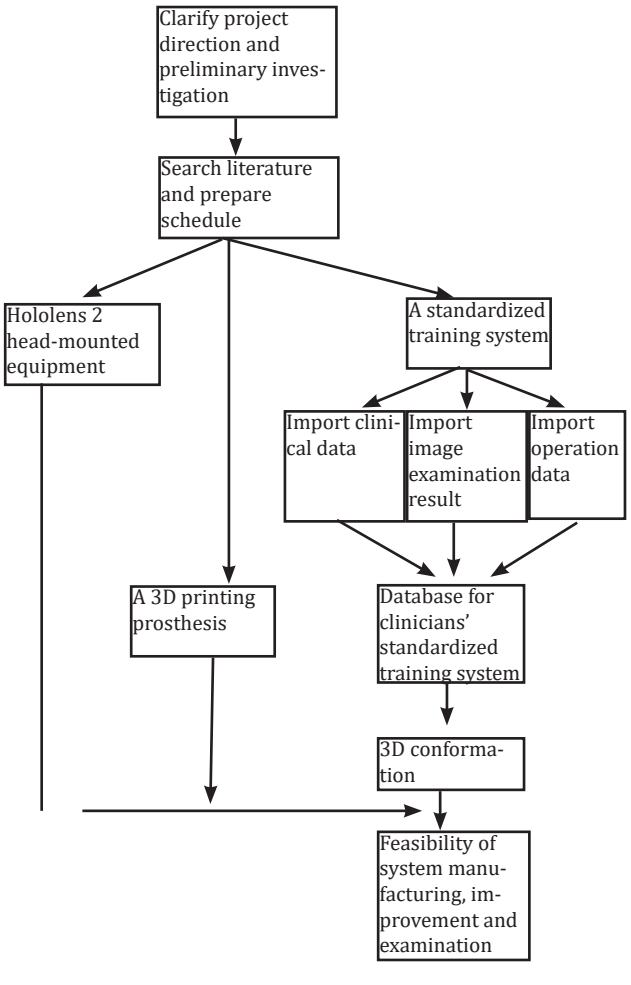
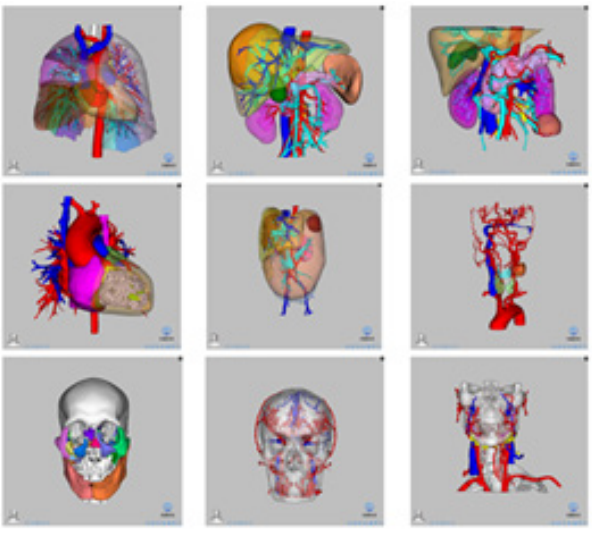


Figure 2 Human organ 3D models by 3D reconstruction



3. MR and 3D technologies

Key word of mixed reality is flexibility. It tries to combine advantages of VR and AR (augmented reality). Theoretically, mixed reality allows a user to see the real world (similar to AR), but meanwhile it can present a believable virtual object (similar to VR). Subsequently, it will fix the virtual object in the real space, thereby giving people a sense of reality.

Microsoft HoloLens 2, is the mixed reality equipment launched by Microsoft Corp. Microsoft HoloLens 2 is equipped with a Qualcomm Snapdragon 850 processor and Microsoft Corp. decides to use an ARM64 chipset without a cellular modem. Most importantly, it contains a brand-new holographic processing unit (HPU) and AI coprocessor. A brand-new display system included in HoloLens 2 allows HoloLens to achieve significant performance improvement under low power consumption. In HoloLens 2, Microsoft Corp. completely updates way that a user interacts with a holographic image. Using a new TOF depth sensor, combined with built-in AI and semantic understanding, HoloLens 2 allows a user to use the same gesture used when interacting with a physical object in the real world to directly manipulate the holographic image. Besides improvement of the display engine and more intuitive manipulation of a holographic image, HoloLens 2 also includes an eye tracking sensor, allowing a use to interact with the holographic image more naturally. You can perform Windows Hello enterprise-level login

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authentication through iris recognition, so that multiple users can share the equipment quickly and safely. A brand-new lock catch type fitting system allows a user to feel very comfortable even if the user has worn it for continual several hours. When wearing HoloLens 2, a user does not need to take off glasses, because HoloLens 2 can be adjusted by sliding above the glasses.

The 3D printing is a manufacturing method that manufactures a 3D object by fusing or depositing materials layer by layer. This technology is mainly used for individualized production and teaching in medical field, including: Producing customized jigs and fixtures, customized implants and fixation devices to exert much positive effect on operation duration, patient recovery duration and success of an operation. [10] There have already been companies that use 3D printing technology to produce living human tissues, and after cost impact is eliminated, this will greatly promote development of modern medicine.

4. Advantages and disadvantages of a medical standardized training system compared with traditional education

4.1 Advantages

1) Education system optimization and reform supported by brand-new technologies

It is very obvious that only virtual reality and/or augmented reality equipment is not enough to meet needs of surgeons. Solution may lie in a hybrid technology called mixed reality, which combines many functions of virtual reality and augmented reality. Microsoft HoloLens is the first commercially available mixed reality equipment that provides surgeons with hands-free access to complex data, real environment and two-way communication during an operation. This report has introduced use of HoloLens in an operating room to improve decision-making and operation processes. [4] Young doctors often have characteristics of being unable to perform an operation in face of complex human structures and individual variations. Correct diagnosis and clinical operations require experienced clinical surgeons to perform. A user can use this system for training and accumulates operation experience through dealing with different events preset in the system, thereby improving operation success rate and timeliness of handling an emergency. Different from traditional education way in the past, emerging education system with combined MR and 3D printing technologies has obvious and prominent advantage, which directly solves the following problems: Distance issue, inability to operate in person, limited perspective, and excessive training duration.

2) Breaking through distance limitation and training multi-disciplinary talents at the same time

In traditional teaching mode, students mostly learn an organ's structure and relationship with the surrounding organs by observing a teacher's operation or video. Disadvantage is that students must abide by principle of an aseptic operation in an operating room and cannot approach the operating table, but far distance is difficult to guarantee learning efficiency. Even so, number of students who can enter the operating room each time is strictly controlled and even a very large part of students never enter an operating room to learn. Therefore, we try to apply MR to operation perspective sharing, input operation process of an expert's perspective, construct a diseased organ through 3D reconstruction technology, and change "transparency" and other settings when equipment is used for view and simulation, so as to view and simulate a complex operation at close range. Virtual reality equipment is used to project a virtual image onto a real prosthesis made by 3D printing technology to achieve 1:1 overlap, which can maximize restoration of overall process of a complete operation by every student with his/her hands. Clinical medical college can use this system to train young doctors and clinical medical students, thereby promoting progress of the existing operation teaching under technical support of multi-perspective sharing. Meanwhile, this will also shorten training duration of a student. Students can obtain knowledge of different departments through teachers in different departments, thereby training the students to become true "general practitioners" who were unable to do what they hoped to do in the past traditional education.

Students' interests and needs:

We used "www.wjx.cn" to conduct a market survey. As for selection of users, we mainly selected sophomore students to conduct the questionnaire survey. Vast majority of them had expectation and optimism about an emerging education system and all believed that the emerging education system could resolve defect of traditional education mode. We believe that when this system is put on the market, it will bring revolutionary change. Many problems are still involved in current teaching system:

First, with promotion and large-scale application of minimally invasive surgery, relevant technologies have developed rapidly, but there are still relevant technical problems in field of sharing an operator's perspective.

Second, number of students who view and simulate each operation is limited. Although there will be a substantial increase in number of students compared with traditional education mode, it is still impossible to guarantee coverage of similar number of students in enlarged class in a short time.

Third, although there is real-time presentation by a teacher and students have hands-on opportunity, there is no guarantee that the teacher will give real-time guidance to each student because there is no enough time.

Using combination of this system and 3D printing technology and using educational means combining a 3D printing prosthesis and mixed reality (MR), a teaching mode of online learning and offline practice is constructed, effectively solving a problem of lack of practical experience for young doctors.

4.2 Limitations

Increased preliminary fund requirement: After Hololens 2 head-mounted virtual reality equipment is purchased, fund is needed to support writing a virtual operation system that can run and partial fund is required to purchase 3D printing materials that simulate the human body; then, after obtaining consents of the hospital and patients, import of imaging data of cases also requires a lot of cost, which also requires funding.

The existing technology cannot completely simulate human body environment (such as blood flow), there is still certain difference with actual human body situation, and an operation hand feeling problem needs to be solved urgently. Since emergencies are controlled by a system and occur in MR equipment, it is impossible to completely replicate actual emergencies during an operation. In view of patient privacy and hospital agreement issues, it is necessary to obtain consents of a patient and relevant hospital before medical record can be used in clinical operation simulation and teaching.

5. Future outlook about a standardized training system

Mixed reality technology has vast application prospect. Especially in medical field, modern mixed reality technology will bring revolutionary change in medical basic research, practical skill training, doctor-patient communication and clinical treatment aspects to promote optimization of clinical medical system, thereby driving further development of medicine. By building a standardized training platform with mixed reality technology, in the future, we can design a virtual operation system to set out to solve a hemodynamic problem and build an almost real human body environment to perform preoperative simulation and postoperative reflection in the virtual environment. After obtaining a classic operation model, learning training will be repeatedly carried out. Individualized operation training is based on an individual's image data, and after the individual's operation model is obtained, research training will be repeatedly carried out before the operation.

With deep overlap of 3D printing technology, a constructed virtual organ and a 3D printing organ achieve 1:1 overlap, which effectively solves a force feedback problem. In teaching, every student can set out to operate, the existing teaching mode is changed and students can quickly master learning content and keep up with a teacher's thinking, thereby helping cultivate every student's own clinical thinking. A teacher can also explain change in an organ with anatomic details to students, and explanation will also be clearer and be easier to understand.

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