Application of Virtual Reality Technology in Enhancing Thoracic Surgery Skills Training

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Abstract: With the rapid development of technology, virtual reality (VR) technology has gradually become an important branch of medical education, especially in the field of thoracic surgery skills training. This paper aims to explore the current application status of VR technology in thoracic surgery skills training, evaluate its effectiveness in surgical training, and discuss its potential impact on improving the quality of surgical education. Through a literature review, the basic principles and development history of VR technology, its specific applications in thoracic surgery education, as well as the challenges and trends it currently faces, are analyzed. This paper also discusses the role of VR technology in improving surgical training efficiency, promoting personalized learning, and potential economic benefits. Although VR technology has significant advantages in thoracic surgery training, attention needs to be paid to its practical application and effect verification in clinical practice. Finally, with the continuous advancement of technology, the future application of VR technology in thoracic surgery training is expected to be more extensive and in-depth, contributing to the cultivation of more high-quality thoracic surgeons.

Keywords: Virtual Reality Technology; Thoracic Surgery; Skills Training; Medical Education; Surgical Simulation

1. Introduction

1.1 Background

In the current medical field, the application of virtual reality (VR) technology in surgical training and education has become increasingly widespread, especially in thoracic surgery. Research by Zhang Lei, Li Xiaojun, and Tang Zhen introduced a VR-based thoracic surgery assistance control system, and the patent application demonstrates the innovative application of VR technology in surgical assistance [1]. Similarly, Huang Derong, Li Yihong, and others have developed a cardiac thoracic surgery assistance control system, further promoting the application of virtual reality technology in fine operations [2]. The combination of 3D reconstruction technology and virtual reality navigation technology has provided higher accuracy and safety for thoracoscopic surgery. Research by Zhang Yuchen and others highlighted the value of this technology in segmentectomy [3]. Li Hui considers this gradually mature technology as a new starting point for precise thoracic surgery, proposing new directions for minimally invasive era thoracic surgery [4]. The research by Dong Qing and Cui Jian discussed the application of digital medical technology in the diagnosis and treatment of non-small cell lung cancer, emphasizing the importance of technological progress in improving disease management efficiency [5][6]. Li Hui once again emphasized the importance of precise thoracic surgery in modern healthcare and proposed a new perspective on the minimally invasive era [7]. The research paper by Wu Zhili explored the progress in the application of virtual reality technology in clinical skills training, increasing the understanding of the potential of this educational tool [8]. Li Linlin, Yu Zhenkun, and others reported preliminary applications of virtual reality technology in cardiovascular surgery education and training

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[9]. Liu Shaofeng, Ma Jun, and other researchers discussed the application of virtual reality technology in otolaryngology and head and neck surgery residency training, further expanding the scope of VR in medical education [10]. Exploratory research by Gai Mingmin and others discussed the potential uses of virtual reality technology in preoperative patient education, demonstrating its value in improving patient education [11]. The patent by Tan Jinhai, Liu Siyi, and others involved a surgical teaching demonstration system based on virtual reality technology, which promoted the development of medical education from a technical perspective [12]. The research by Hao Mengfu focused on the application of virtual reality technology in thoracic surgery practice education, providing new directions for future surgical training [13]. Li Xin, Shan Wenchuan, and others discussed the specific application of virtual reality technology in thoracic and cardiovascular surgery education, further highlighting the increasing importance of virtual reality technology in medical education [14]. The research by Li Chengrun, Ma Yongfu, and others explored the three-dimensional virtual reality navigation technique for thoracoscopic pulmonary lobectomy, indicating the potential advantages of VR technology in surgical accuracy [15]. Chen Lili's research focused on the development of virtual clinical case software and its application in surgical nursing education, providing a specific case for educational practice [16]. Finally, Wang Dongfang, Kong Yuzhe, and others analyzed the development of thoracic surgery medical simulation education at home and abroad using bibliometrics, providing a broader perspective for comparison [17].

Based on the above literature, it can be seen that virtual reality technology plays an increasingly important role in thoracic surgery training and education. The development of these technologies not only enhances the safety and efficiency of surgery but also indicates the future direction of medical education. With further research and technological advancements, future healthcare professionals will be able to train and practice in unprecedented ways.

1.2 Significance of the Study

Thoracic surgery, as a high-precision and high-difficulty surgical specialty, requires a high level of skill and experience from surgeons. Traditional surgical training often requires prolonged clinical practice, and it is difficult to ensure that each student has sufficient opportunities for surgical operations due to case limitations. With the introduction of VR technology, students can practice surgical operations in a virtual environment an unlimited number of times. This not only greatly shortens the training period but also significantly improves the proficiency of surgical skills [1][3][13].

The application of virtual reality technology is not limited to thoracic surgery training but has broad prospects in the entire field of medical education. The application of this technology can help students better understand complex medical concepts, improve the quality of clinical skills training, and provide new ideas and methods for modern medical education models [4][7][8].

2. Overview of Virtual Reality Technology

2.1 Definition and Characteristics of Virtual Reality Technology

Virtual reality technology (VR) is a computer simulation system that creates and experiences a three-dimensional virtual world. Users enter this virtual world through interactive tools such as headsets and special gloves and can observe and manipulate objects in the virtual environment in real-time [5][6].

The main characteristics of VR technology include immersion, interactivity, and imagination. Immersion allows users to feel as if they are truly present in the virtual world; interactivity enables users to interact with the virtual world through natural gestures and actions; imagination refers to the ability of VR technology to go beyond the limitations of the real world and create any imaginable scene and object [14][15].

2.2 Development History of Virtual Reality Technology

The concept of virtual reality technology can be traced back to the 1950s, but it was not until recent decades of rapid technological development that VR truly entered the public's attention. From the initial simple simulators to the highly complex VR systems today, this technology has undergone long-term

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development and evolution [10][11].

Currently, VR technology is increasingly being applied in medical education and surgical training. With the improvement of computer processing power and the refinement of interactive tools, VR systems can provide more realistic and detailed simulation effects. With further research and technological advancements, the application of VR technology in future medical education is expected to be more extensive, and its educational value and potential will be further explored and recognized [16][17].

3. Application of Virtual Reality Technology in Thoracic Surgery Training

3.1 Training Needs Analysis

Thoracic surgery involves complex anatomical structures and close spatial relationships, such as the lungs, heart, and major blood vessels. Errors in operation can lead to serious and even fatal consequences. Different surgical approaches (e.g., open surgery, thoracoscopic surgery) have their own characteristics, placing stringent demands on the skills of surgeons. Therefore, thoracic surgery training must focus on the accuracy and safety of surgical procedures to reduce intraoperative and postoperative risks.

Traditional thoracic surgery training typically relies on an apprenticeship model, where young physicians learn surgical skills through observation and supervised practice. However, this approach has limitations. Firstly, the availability of real surgical opportunities may be limited, leading to uneven training opportunities. Secondly, practicing in real surgeries during early training poses higher safety risks. Additionally, the standardization of surgical training is insufficient, and the quality of education may vary greatly depending on the experience and abilities of mentors.

3.2 Current Application Status of Virtual Reality Technology

Modern virtual reality (VR) technology provides a new solution for thoracic surgery training. By constructing highly realistic simulated surgical environments, trainees can practice operations repeatedly without risks. These simulated environments can accurately replicate the anatomical structures of the surgical area and even simulate specific patient conditions. Furthermore, VR technology can provide real-time feedback to help learners identify and correct errors in their operations.

Through virtual reality technology, trainees can learn and practice various thoracic surgical skills, from basic anatomical structure recognition to complex surgical procedures. VR systems can also record the trainees' operational processes and provide objective skill assessments. These assessments are not only based on the completion of the operations but also encompass factors such as speed and accuracy. This approach allows learners and educators to have a clear understanding of the learners' skill levels and progress.

3.3 Advantages and Limitations of Virtual Reality Technology in Teaching

The application of virtual reality in thoracic surgery training has significant advantages. Firstly, it provides a safe learning environment where learners can practice operations repeatedly until they master the required skills. Secondly, compared to traditional observational learning, VR technology offers active participation and immersive experiences, which can better facilitate skill acquisition. Furthermore, the VR educational model can be highly standardized, ensuring consistent training for every learner.

However, virtual reality technology also has limitations in educational applications. The main issue is the high cost, which includes not only hardware investments but also the expenses of developing and maintaining high-quality educational content. Additionally, the rapid advancement of technology requires continuous updates of equipment and software to maintain the modernity and relevance of teaching. Moreover, virtual reality cannot fully replicate the tactile and other non-visual sensations of real surgeries, which may affect the complete mastery of surgical skills.

4. Strategies to Improve Thoracic Surgery Skills Education

4.1 Education Model Based on Virtual Reality Technology

The design of an education model based on virtual reality (VR) technology aims to provide an interactive and immersive learning environment through simulated surgical

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scenarios, thereby improving learners' surgical skills. Firstly, the model needs to set clear learning objectives, including mastering specific surgical techniques, understanding complex surgical procedures, and how to handle complicated situations during surgeries. Based on these learning objectives, corresponding virtual surgical scenarios should be developed, covering a comprehensive range of skill training from basic surgical operations to advanced complex procedures.

Furthermore, the education model design should include a mechanism for providing real-time feedback to learners. Through data tracking and analysis functions in VR systems, learners can receive instant feedback on the correctness, speed, and efficiency of their operations, enabling them to adjust their learning methods and strategies promptly. Lastly, to enhance learning efficiency, the education model should allow for personalized learning paths, enabling learners to choose suitable training content and difficulty levels based on their needs and progress.

Implementing an education model based on VR technology requires ensuring sufficient understanding of VR devices and educational content by all participants, including learners and teachers. Therefore, training prior to implementation is essential. Subsequently, based on the design of the education model, a reasonable learning plan and schedule should be set to ensure the orderly progress of learning activities. During the implementation process, regular evaluation of learning outcomes, along with collecting feedback from learners and instructors, should be conducted to make timely adjustments and optimizations to the educational content and methods.

To maintain the vitality and attractiveness of the education model, the implementation process should continuously introduce new surgical scenarios and teaching elements to ensure the cutting-edge nature and practicality of the educational content. Additionally, considering the differences in learning abilities and speeds among learners, the implementation process should allow for flexible adjustment of learning paths and difficulty levels to ensure that each learner can study and progress in the most suitable environment.

4.2 Evaluation of Education Effectiveness

To comprehensively evaluate the effectiveness of the education model based on virtual reality technology, a set of scientifically reasonable evaluation standards should be established. These standards should cover various aspects, such as improvements in learners' surgical skills, depth of understanding of thoracic surgical knowledge, and problem-solving abilities. Specifically, the improvement of surgical skills can be assessed based on indicators such as the quality of simulated surgeries, time required, and error rates. Additionally, theoretical tests and scenario-based simulations can be used to assess learners' mastery of thoracic surgical knowledge and their ability to handle complex surgical situations.

To objectively evaluate the education effectiveness, various methods and tools can be employed. On the one hand, the data analysis functions provided by VR systems can provide learners' operational data in simulated surgeries, intuitively reflecting their skill levels and progress. On the other hand, subjective evaluations of the education model's effectiveness and satisfaction can be collected through questionnaires, interviews, and other means to gather learners' and instructors' feedback.

5. Future Impacts of Virtual Reality Technology on Thoracic Surgery Training

In modern medical education, the increasing application of virtual reality (VR) technology, especially in high-risk and technologically intensive fields like thoracic surgery training, indicates its significant potential. Not only does this technology drive educational model transformations, but it also paves the way for personalized and refined education. The discussion below attempts to provide a more in-depth exploration of this topic.

5.1 Technological Advancements Driving Educational Model Changes

With the advancement of VR and other digital technologies, their integration into medical education has become a trend. VR technology provides a safe and risk-free environment for practicing surgical skills, allowing students to practice operations repeatedly until they become proficient. The introduction of this technology goes beyond traditional observational and textbook learning methods,

providing students with more intuitive and practical learning experiences. Furthermore, the integration of VR technology enables interdisciplinary learning, such as the combination of computer science and medicine, bringing unprecedented technological support and educational resources to thoracic surgery training.

By utilizing VR technology, educational models can be innovated, especially in simulated surgical environments for surgical training. VR technology provides a controllable learning environment where students can practice in simulated surgical scenarios, learning surgical techniques and understanding complex surgical processes without concerns about harming real patients. This simulated environment can also be adjusted based on learners' learning progress and abilities, ensuring that each student learns at their most suitable pace, which is difficult to achieve in traditional educational models.

5.2 Prospects for Personalized and Refined Education

With the development of VR technology, the design of personalized learning paths becomes a possibility. Each student has different learning abilities, progress, and needs, and VR technology can provide customized learning plans to cater to specific student needs. For example, for students who have difficulties mastering a specific surgical step, the VR system can provide additional practice for that step or even offer more detailed guidance until the student becomes proficient. This personalized learning path not only improves learning efficiency but also increases students' motivation to learn.

The application of VR technology also facilitates the development of refined educational content. Through high-quality 3D images and simulated environments, students can gain in-depth understanding of anatomical structures and surgical procedures in every detail. Furthermore, educational content can be continuously updated based on the latest medical research, ensuring that students learn the most cutting-edge knowledge. Refined educational content not only helps students build a solid theoretical foundation but also enhances their comprehension and mastery of complex surgical procedures.

From the above discussion, it is evident that virtual reality technology has a profound future impact on thoracic surgery training. It not only drives educational model innovations but also opens up new directions for personalized and refined education. With the continuous progress of technology and further applications, the role of VR technology in thoracic surgery training will become increasingly significant, contributing to the improvement of medical education quality and effectiveness.

6. Discussion

6.1 Comprehensive Analysis of the Current Impact on Thoracic Surgery Training

The widespread application of virtual reality (VR) technology in thoracic surgery training has demonstrated its great potential in optimizing technical aspects. The ability of VR technology to provide a highly realistic simulated surgical environment offers surgeons an unprecedented operational experience, helping beginners establish surgical intuition and providing a platform for experienced doctors to improve their skills. Technical optimization is not only reflected in the renewal of hardware devices but also in the enrichment and precision of software content, such as detailed anatomical characterization, realistic feedback on surgical tools and operations, and simulation of surgical complications.

The application of VR technology also promotes the optimization and distribution of educational resources worldwide. Traditional thoracic surgery training is often limited by the geographical distribution of high-quality educational resources, while the introduction of VR technology breaks through this limitation. The possibility of remote teaching allows students from around the world to receive guidance from top experts without expensive travel costs and time commitment, greatly improving the efficiency and fairness of resource utilization in education.

6.2 Outlook on Future Research Directions

Future research needs to further explore how to enhance the application effectiveness of VR technology in medical education, including improving the realism of simulated surgeries, reducing the cost of VR devices, and refining assessment systems for surgical operations. Additionally, research should focus on the

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combination of VR technology with emerging technologies such as artificial intelligence and machine learning to develop intelligent personalized learning systems, providing learners with more precise and effective learning support.

Innovation in teaching models is also needed, integrating VR technology with traditional teaching methods such as face-to-face courses and physical models to form a blended learning mode. This mode allows students to not only acquire knowledge but also better apply it in practice, cultivating their clinical thinking ability and problem-solving skills.

7. Conclusion

7.1 The Importance of Virtual Reality Technology in Thoracic Surgery Skills Training

Through in-depth analysis, the importance of virtual reality technology in thoracic surgery skills training has been confirmed. It not only provides a safe and controllable environment for surgical practice but also promotes rapid skill acquisition and refinement through highly realistic simulation experiences.

7.2 Inspirations for Medical Education Field

Virtual reality technology offers multidimensional inspirations for the field of medical education. It not only changes teaching methods but also promotes resource sharing, contributing to the development of critical thinking and decision-making abilities among physicians. The widespread adoption of this technology indicates a period of more efficient, equitable, and personalized development in the field of medical education.

7.3 Future Research Directions and Application Prospects

Looking ahead, the prospects for the application of VR technology in thoracic surgery training are broad. Future research directions include continuous optimization and deepening of technological aspects, as well as constant innovation in educational content and models. With advancing technology and the deepening application of VR, it is expected that VR technology will play a more important role in the global medical education field, with significant implications for improving the quality and effectiveness of medical education.

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