International Journal of Studies in Nursing; Vol. 6, No. 3; 2021
ISSN 2424-9653 E-ISSN 2529-7317
Published by July Press

Current Status and Challenge for Implementation in Clinical Application of Augmented Reality in Orthopedics Department at a Medical Center

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Received: August 17, 2021 Accepted: September 11, 2021 Online Published: September 22, 2021

doi:10.20849/ijsn.v6i3.923 URL: https://doi.org/10.20849/ijsn.v6i3.923

Abstract

With technical development, artificial intelligence (AI) has been actively involving in the healthcare industry. Augmented reality (AR) is an interactive experience with the combination of virtual objects and a real-world environment, and the objects reside in the environment of the real world through computer-generated images for the purpose to enhance perceptual effects, which can be applied in the fields of medical education and clinical practice. Researchers have found that learning motives and interests may be raised by AR. At a medical center, the inter-specialty team from the Teaching Department and Rehabilitation Department jointly developed an AR Medical Education App, which involves 44 muscle strength and walking exercises, including 6 upper limb movements, 28 lower limb exercises, and 10 cardiorespiratory exercises. Various exercise packages can be designed by health caregivers based on patient's needs in exercise. The Orthopedics Ward applied it in the respiration training for patients who underwent spinal surgery, preventing respiratory comorbidities. The improved postoperative pulmonary function has been found when compared with that before surgery, with statistical significance. Respiration, upper and lower limbs exercises were persistently performed in patients who underwent spinal surgery, which also has been incorporated in routine nursing care to add diverse options of patient education materials for nursing personnel. In the future, aspects that required further efforts include: expanded software equipment, simplified operation mode, increased user-friendly features for equipment, and expended plentifulness of contents.

Keywords: augmented reality, orthopedics, spinal surgery

1. Introduction

1.1 AR

AR is an interactive experience with the combination of virtual objects and real-world environment, and the objects reside in the environment of real world through computer-generated images for purpose to enhance perceptual effects. The definition in Wikipedia (2021) shows: the technology enabling combination and interaction between virtual world in the screen and real-world scenario, through the precise calculation for position and angle of camera images involving image analysis techniques. Azuma (Azuma, 1997), professor for the University of North Carolina indicated AR as systems that have the following three characteristics: 1) Combines real and virtual. 2) Interactive in real time. 3) Registered in 3-D AR can be applied in various circumstances such as entertainment, healthcare, education, and sales industry. With the progress in technology, smart healthcare has been the trend for future development.

1.2 The Medical Application and Dilemmas of AR

The diverse presentation tools of AR may include smartphone, tablet, etc. It can be used in the development for surgical techniques, increasing interaction and visual excitement in education field when compared with conventional educational practice.

A systematic literature analysis related to 36 articles in medical education was conducted by Tang et al. (2020), the use aspects included 23 articles in surgery, 9 article in anatomy, and 4 articles for others. Among these, 7 articles involved use of ProMIS emulator in surgery for student training in performing laparoscopic surgery, which indicated significant improvement in technical performance and experience; moreover, in the field of anatomy, interactive learning was conducted by connection of anatomy image cards in the monitor, 76.9% of respondents considered AR as effective in learning, 75% believed the increased motive and interest, 67.3% believed their performance might be higher if the professor used such a technique. In medical students using "MagicBook" AR, 100% of them indicated facilitating the participation in learning. Furthermore, in mode comparison of App mobile devices with papers, it was found that App AR increased respondents' knowledge memory, decreasing cognitive fatigue. For contents of AR's future design, teaching experience shall be reinforced, education courses are to provide user-oriented feedback mechanism. In the future, cost for utilizing and effectiveness of use remain as important factors to be considered.

Tait et al. (2020) analyzed 91 parents and children, it was found that there was no any difference in children's understanding between paper brochures and AR, but compared with brochures, AR was shown to be more helpful with its plentiful interactive games and expression measures. Moreover, the correct use of feedback mechanism increased children's understanding of information, the easy-to-read and visual attraction features provide effects in message transduction. Both parents and children considered AR operation as very easy to use, and 71.2% of these believed that for future participation in research, they would prefer AR modes.

Parekh et al. (2020) proposed that AR was the first technique applied by surgeons for enhancement of surgery and patient experience, with the advancement in tools, becoming a trend for future development. Use of AR monitors enables easy performing medical training and surgical treatment, AR's application in healthcare may change surgical methodology. Nevertheless, the possible challenges may include surgeons are required to acquire information about how to use the technique, lacking of design standards for AR development and application, compatibility issues in hardware, and consideration for case security and privacy. Moreover, battery lifespan, huge equipment and bulky cables are also limitations of such a technique.

Berton et al. (2020) screened 24 articles with 2,472 patients enrolled between 2015 and 2020 regarding studies on virtual telerehabilitation for knee joint and hip joint replacement. Of these, 28% used AR, patients aged 40 to 60 were in the majority, mostly with university degrees. The application was used for orthopedic patients with postoperative artificial joint replacement and bone fracture, compared with the effect from face-to-face rehabilitation, significant improvement was found in all aspects including patient's pain, joint movement indicators, and overall functionality, with decreased time consumed in hospital transportation, costs, and hospital stays, etc. The number of patients simultaneously underwent treatment was also increased, with patients' facilitated motive resulted from the direct and ongoing interaction between patients and healthcare personnel, which may improve treatment compliance; nevertheless, obstacles to be overcome include elderly patients are in the majority of orthopedic patients, the restricted availability of gamification and telerehabilitation in elderly patients because such patients face difficulty in use of new techniques, with relatively poor adaptation to novel techniques. For future research, specific and objective measures are also required to be developed for evaluation of clinical quality of such a technique.

Murali et al. (2021) conducted a questionnaire survey on the authors of 27 articles using AR in healthcare field between 2019 and 2020 to investigate using status and obstacles for AR. A total of 65% respondents were aged 40 and above, 91% used it due to clinical interest, 9% of them used it in simulating clinical circumstances. Objectives of use included 27% as expanded aspects of medical care, 18% as increased clinical efficiency, 9% as expanded working capability. Implementation settings included 55% in surgery, 27% was used in outpatient clinics or hospitalization settings, as well as endoscopic or imaging examinations. Obstacles for implementation included cost for equipment and battery consumption, case security and privacy, etc.

In summary, use of AR may increase learning motive and extent of understanding. The obstacles in using AR include cost for equipment, case security and privacy. More objective assessment indicators shall be necessary for evaluation of AR benefits.

2. The Purpose of AR's Development in Orthopaedics Wards

In the orthopaedics ward, the traditional way of teaching is to use paper-based health care single. It's single and not attractive. We investigated orthopaedics nurses, 75.0% believed that "the current teaching aids were not sufficient", and 80.0% considered that the current paper-based teachings were "incorrect in the respiratory movements of clinical patients". Following the progress of science and technology, the development of attractive, improved correctness of rehabilitation exercises, compliance with the needs of health teaching aids.

2.1 Existing Problems

a) The unitaryization of health education teaching aids, the lack of different forms of teaching aids.

b) Health education aids are not attractive.

c) The correctness of the patient's rehabilitation exercise is not enough.

2.2 The Purpose of Developing

a) Develop different types of teaching aids.

b) Increase the attractiveness of teaching aids.

c) Improve the correctness of patients' rehab exercises.

3. Features of Orthopedics Healthcare AR App

At a medical center, the inter-specialty team from the Teaching Department and Rehabilitation Department jointly developed an AR Medical Education App, which involves muscle strength and walking exercises, including 6 upper limb movements, 28 lower limb exercises, and 10 cardiorespiratory exercises. Various exercise packages can be designed by health caregivers based on patient's needs in exercise, including movement items, daily frequency of implementation, and implementation frequency for each movement at one time. Patients are able to watch the complete picture of their exercise implementation by means of the carriers with rear cameras such as smartphone. With the precise movement and vocal explanation demonstrated by AR healthcare instructor in the same screen, exercise injuries or soreness due to improper movements can be avoided. After relevant trainings have been completed by the patients as scheduled, AR system will present various figures based on patient's achievement, expressing five corresponding growth phases from infant to adult. The processes of growth bring patients with surprising encouragement, the encouragement may turn into patient's motive force in ongoing endeavors. As for health caregivers, the completeness for patient's training can be timely learned in AR medical education App to provide concerns and guidance at an appropriate time, increasing satisfaction of clinical services.

3.1 Pulmonary Rehabilitation Exercise for Orthopedic Spinal Surgery

Yin et al. (2018) indicated that postoperative pulmonary complications were found in 14.9% of patients with congenital scoliosis, including 10.9% with pleural effusion, 6.9% with pneumonia, and 6.3% with hypoxemia, etc. The predictive factors for postoperative pulmonary complication include age > 18.1 years ($P = 0.039$), Cobb angle > 77 °($P = 0.011$), duration of surgery > 430 min ($P = 0.032$), and blood transfusion > 1500 ml ($P = 0.015$). Wu et al. (2019) analyzed 323 patients with congenital scoliosis and found that 13.9% of them were with postoperative pulmonary complications, among these, 75.6% with pleural effusion were in the majority. The independent risk factors for incident pulmonary complications include age, repeat surgery, preoperative pulmonary diseases, and correction rate. Lao et al. (2013) conducted preoperative forced vital capacity (FVC) measurement in 60 patients with extremely severe scoliosis, results of respiratory impairment indicated 18.3% of severe, 21.7% of moderate, and 36.7% of mild conditions. With the underlying pulmonary diseases in spinal deformity, patients with severe scoliosis are believed to be high risk group for respiratory comorbidities of surgical treatment. Studies have found a higher incidence of postoperative pulmonary complications in patients with severe restrictive pulmonary impairment, which is a predictive risk factor for postoperative pulmonary complications.

Condon et al. (2020) analyzed 22 articles and found that in respiratory rehabilitation for patients with chronic respiratory diseases such as chronic obstructive pulmonary disease, patients' exercise endurance, and level of blood oxygen saturation were both increased with use of AR or virtual reality (VR), that were entertaining too. Compared with conventional rehabilitation measures, 42%-96% of patients may maintain exercise compliance six weeks after initiation of AR or VR rehabilitation.

Valkenet et al. (2011) proposed that preoperative correction of risk factors may decrease the incidence of postoperative respiratory comorbidities, for instance, preoperative respiratory rehabilitation and respiratory muscle training were found to be effective in decreasing postoperative pulmonary complications. Items for preoperative respiratory training primarily include thoracic expansion, diaphragmatic breathing, respiratory muscle (muscles of expiration, muscles of inspiration, diaphragm muscle) training and use of incentive spirometer.

In summary, results indicate that for prevention of respiratory comorbidities in patients underwent spinal surgery, preoperative respiratory rehabilitation and respiratory muscle training are found to be effective in decreasing postoperative pulmonary complications.

Therefore, for patients underwent long-rod spinal surgery with general anesthesia, 7 preoperative respiratory exercises were designed by the Orthopedics Department, including diaphragmatic deep breathing, chest expansion, expiration exercise, pursed-lip expiration, chest fly with stretched back, side arms up, and arms stretched back. Each movement was performed 5 cycles, four sessions a day, preoperative and postoperative extents of pulmonary expansion were compared to affirm the effectiveness of chest exercises. Results indicated increased FVC in respiratory training using AR before discharge when compared with that before surgery, with statistically significant difference ($p = 0.001$), also without any respiratory comorbidities (Chen, et al., 2021).

3.2 Upper and Lower Limb Exercise for Orthopedic Spinal Surgery

Survey of 20 nursing personnel for the extent of endorsement in AR use, results found that 75% believed AR has convenient, interesting, and interactive features. Therefore, AR exercise program has been persistently implemented in Orthopedics Ward. In addition to the originally designed 6 respiratory exercises, 6 upper limb exercises were added, including hand grasp, stretched arm grasp, forearm pronation and supination, elbow joint flexion, shoulder joint abduction, and shoulder joint limb flexion; 7 lower limb exercises include 3 bedridden exercises such as ankle pumping, stretched and raised legs up, and ankle water-skiing, with 4 exercises getting out of bed including supine knee bent hip raised, wall sit, stepping exercise, and half squat. It is expected to be established as a routine measure for nursing health education, providing an alternative health education mode besides conventional printed-material health education.

4. Future Challenge and Adaptive Measures in Promotion of Orthopedics AR

With the persistent implementation of AR rehabilitation exercises in Orthopedics Ward since August 2020, the dilemmas encountered in clinical practice include 1) limitations of software equipment: the system is required to be operated under Android, it will be unable to operate without such a software, restricting the subjects enrolled. In the future, it is to develop systems that can be downloaded using different software to increase generality. 2) The establishment of personalized-design exercise packages is a time-consuming task, which prolongs the working hours of nursing personnel. Nevertheless, with ongoing real-world practice and difficulty solving, improvement has been found both in time consumed and techniques. In the future, with the user-friendly operational interface and directly-downloaded package modes available, the inclination of use by staff can be facilitated. 3) All limitations including elderly patients, acceptance to technical devices, lacking of smartphone, or smaller screen size of smartphone, etc. are factors to be considered in promotion of AR health education measure. Selecting appropriate subjects or increasing the friendly features of the devices are suggested to be persistently improved in the future. 4) There are a variety of rehabilitation items, and the number of currently established basic exercises have been limited. In the future, it is expected to further expand exercise items based on patients' needs to benefit various patients for their individual uses.

5. Conclusion

With the technical progress, novel intelligent products weed through the old to bring forth the new, AR use in medical education or clinical practice would be an inevitable trend in the future. The effectiveness has been recognized for the first-phase implementation in the Orthopedics Department of a medical center. For further practical application, convenient and friendly operational interfaces will be crucial factors for persistent implementation. Moreover, assessment indicators shall be established for evaluation of its benefits in clinical use.

Acknowledgments

This study was supported by grants Clinical Innovation Center No.AACIC017.

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