ORIGINAL RESEARCH

Virtual reality in post-operative robotic colorectal procedures: An innovation study

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ABSTRACT

Background and objective: Three-dimensional immersive virtual reality (VR) provides the user with multiple sensory experiences involving both visual and auditory pathways. While VR-based applications have reduced procedure-associated pain in pediatric populations, there is little to no research to support the use of VR in adults. The objective of this study was to evaluate the efficacy of immersive VR for reducing pain in adult patients and to evaluate responses to the use of this technology during hospitalizations of two to four days.
Methods: This was a prospective, self-controlled pilot intervention study of the feasibility of the use of immersive VR in ten patients ages 55-68 who had undergone robotic colorectal surgery.
Results: Pain scores were positively correlated with the length of hospital stay. The use of immersive VR was also positively correlated with measures of distraction and entertainment.
Conclusions: The results of this feasibility study support the use of VR for pain management in middle-aged to early-older adults.

Key Words: Virtual Reality, Pain, Distraction, Gastrointestinal robotic surgery

1. INTRODUCTION

Virtual Reality (VR) technology first became commercially available in 1991. At this time, VR technology was used primarily by the United States Armed Forces to train fighter pilots.[1] Young gamers also began to embrace this new technology, as it provided them with a three-dimensional entertainment experience. Historically, the most common medical applications of VR include its use to create a distraction for pediatric patients undergoing outpatient procedures and to reduce pain among hospitalized pediatric cancer patients.[2,3] Beginning in 2020, the industry has focused primarily on adult gaming and has also introduced VR-based exercise/workout platforms.

Until recently, the use of VR technologies was limited and cost-prohibitive. However, alternative types of VR equipment are now available, including several very basic wearable and cellphone-based devices.[4,5] VR applications for medical care have grown and expanded from limited use for pediatric patients to wider use in the adult population. However, while VR has been established as a useful and important means to reduce procedure-associated pain and anxiety among pediatric patients, additional research will be needed to provide support for its use in the adult population to improve health care outcomes for all.

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To experience VR, an individual is provided with eyewear that provides three-dimensional, multisensory input. For medical applications, VR provides an active distraction from painful stimuli and reduces anxiety via the presentation of visually-appealing images.[6–10] Cacau et al.[11] were among the first to report the results of interventional studies designed to evaluate the responses of older adults to a VR experience. Participants in this study reported that immersive VR decreased their pain on the first postoperative day during the initiation of cardiac rehabilitation. Similarly, Teater[10] reported that VR might ultimately help to limit patient use of opioids, which frequently leads to an increased length of hospital stay and adverse effects, including severe constipation or addiction. Thus, the purpose of this study was to evaluate the efficacy of immersive VR for reducing pain and to evaluate responses to the use of this technology in a cohort of older adult patients who had undergone robotic colorectal surgery.

2. Background and literature review

A preliminary search of the literature using the terms "virtual reality AND distraction," "virtual reality AND pain," and "virtual reality AND analgesia." In subsequent searches of the CINAHL and PubMed databases, the term "distraction" was added to the search terms. The search excluded publications that focused primarily on the use of VR headsets by surgeons as part of their training to perform robotic surgery, as this was not the focus of this study.

From the results of our literature review, the term, "robotic laparoscopic surgery" refers to the use of a robotic arm to create three separate one-inch incisions in the patient's abdomen; the surgeon can then use a laparoscope to view, excise, and repair the diseased organs to restore the function of the gastrointestinal system. Robotic surgery has largely replaced incisional abdominal surgery as it decreases the incision size and reduces the time needed to complete the surgical procedure.[12]

Similarly, the results of previous studies suggest that distraction is an effective nonpharmacologic method that can be used for pain management.[7] While traditional passive distractors include television and music, active distraction can be achieved via interaction with people or video games.[1] VR provides active distraction in which the patient can control virtual movement using eye or finger controls to facilitate three-dimensional immersion with multiple sensory experiences involving the visual, auditory, and tactile pathways.[13]

Historically, opioid medications have been used for postoperative pain management. Opioid use can lead to one or more adverse effects, including a potential delay in recovery and an increased risk of permanent disability.[10] The use of opioids has been associated with increased mortality, prolonged lengths of hospital stay, and increased healthcare costs.[10] The development of alternative pain management strategies will be essential to mitigate some or all of these risks. A growing body of evidence supports the use of VR as an alternative strategy for the management of acute pain.

Most of the publications identified in this brief literature review reported that VR is safe and effective as adjunctive therapy for pain management. Improvements in software and design and reductions in manufacturing costs have facilitated the use of VR as a practical tool that can provide immersive, three-dimensional multisensory experiences with the potential to distract patients from anxiety and/or painful stimuli. However, there are only a few studies that address the use of VR for the relief of postoperative pain in hospitalized patients. For example, Mosadeghi[14] performed an observational cohort study and reported positive experiences among hospitalized patients; the results of this study suggested that VR could be used to reduce pain and limit anxiety. Nearly 75% of the study participants reported that their pain was reduced when using VR as a means of distraction; 43% of study participants reported that the use of VR resulted in decreased anxiety levels. In another study, Tashjian[15] recruited a cohort of study participants with various clinical diagnoses from a large, tertiary care hospital. Compared with the control group, the VR-intervention group reported clinically relevant improvements, including statistically significant reductions in pain scores.

3. Materials and methods

This study was approved by the Institutional Review Boards of the academic institutions, Sam Houston State University, and Houston Methodist Research Institute. Written informed consent was provided by each participant before enrollment in the study after a review of the inclusion and exclusion criteria.

3.1 Selection of participants

This pilot study began in the late fall of 2020, approximately eight months after the start of the Coronavirus disease-2019 (COVID-19) pandemic. Participants were recruited via printed fliers placed in physician offices and the hospital unit by physicians participating in the screening of potential laparoscopic colorectal surgery patients. The inclusion criteria were as follows: age of 18 years or older, ability to sign a consent form, postoperative pain score > 3 on a visual analog scale, no visual or hearing impairments, and no active participation in pain practice. Exclusion criteria were as follows: patients diagnosed with COVID-19, past medical history of

seizures, claustrophobia, neck injury, vertigo, chronic pain, nausea/vomiting, or inability to sign the consent form.

The study coordinator collected written consent forms from the patients at the time of their preoperative workups and provided each patient with a brief orientation to the Applied VR headset.[13] Patients were instructed on the use of the four environments, including swimming with dolphins, games, travel (e.g., walks through the Swedish Alps or the London streets), and meditation.[13] The researchers explained the various applications available and asked the patients to use the device for up to 20 minutes.

Postoperative patients with a pain score of ≥ 3 (on a scale of 0 to 10) were provided a VR headset in their hospital rooms starting on the day of surgery and again on their arrival in the postoperative unit and were encouraged to use the equipment at least three times a day for 20 minutes if desired. The patients chose the application that they felt would help them to relax and/or to be distracted from any postoperative pain. While the staff members were instructed to offer the VR headset at least three times a day, the patients could use the VR headsets on demand as often as they chose to do so. As a COVID-19 precaution, the VR headsets were not shared; each was used by one study patient only.

3.2 Data collection

Data collected included the following demographic information from each patient before the procedure: age, race, gender, diagnosis, type of surgery, admission date, and anticipated discharge date. Pain scores (on a scale of 0–10) were collected both before and after the use of immersive VR. The number of times that pain was assessed during the postoperative period was defined as the number of VR access events. The number of times the headset was used by each patient was defined as the usage rate, i. e., the number of times that VR was used divided by the number of pain score access events. Patients that utilized VR were provided with survey questions regarding their satisfaction and its effectiveness. Pain scores, adverse effects, and overall experience with VR were evaluated as outcome measures.

3.3 Study protocol

Following surgery, once the patient reported a need for pain medication with a pain score > 3, the researcher approached the patient and implemented the use of the VR device. Pain assessment and administration of pain medications continued as ordered; VR was used as an adjunct intervention, or for entertainment. Once the patient selected the VR video, the researcher carefully fitted the device, launched the video, and placed the device on the patient's head. Before the start of each VR session, the patient was asked to rate their pain using a 0–10 numerical rating scale. The patient engaged in the VR experience for 15–20 minutes. The patient was then asked to rate the pain experienced during the VR experience using the same numerical rating scale. Participants were then asked two questions about the VR experience: (1) On a scale of 0–5, to what extent did you feel like you went inside the virtual world? Five was 'I went completely inside the virtual world,' and zero was 'I did not feel like I went inside it at all,' and (2) On a scale of 0–5, how real did the objects seem to you? Five was 'indistinguishable from the real world' and zero is 'completely fake'. Participants were also asked three questions designed to address any adverse effects: (1) On a scale of 0–5 how much dizziness did you feel while you were in the virtual world? Five was 'feel faint' and zero was 'no dizziness at all,' (2) On a scale of 0–5 how bad a headache did you feel while you were in the virtual world? Five was 'worst headache possible' and 0 was 'no headache at all,' and (3) On a scale of 0–5 how much nausea did you feel while you were in the virtual world? Five was 'vomited' and 0 was 'no nausea at all.' Once the session was complete, the device was removed from the patient's head, wiped down with Clorox-hydrogen peroxide wipes, and returned to the storage case.

3.4 Data analysis

Statistical analysis and visualization were conducted with Python 3.8.10[16] on a convenience sample recruited at a single community hospital associated with a hospital system in Texas. Because this was a pilot/feasibility study, data analysis was focused on descriptive and exploratory parameters. The analysis was de-identified by assigning study ID numbers to each patient. Data were aggregated and the multiple records collected from each patient were combined into a patient-level summary that included age, sex, race, pain scores, and VR usage, as well as admission and discharge dates. Descriptive statistics (mean, standard deviation, median, quantiles, and frequencies) were calculated for each variable, and correlations between collected variables were determined. Pearson correlation coefficients were reported between each pair of variables.

4. RESULTS

The study participants (N = 10) reported an average age of 61.9 ($\pm$10.6) years. Five participants were males and five were females, and 80% of the patients were white. The patients had a median length of stay of three days (IQR = 2 –7 days). On a scale of 0–10, the average pain score was 3.89. VR equipment was provided at a median of three of those times (Q1-Q3, 2–3.75 times).

On a scale of 0–5, the patients reported an average score

of 4.08 (somewhat satisfied) to the question "How satisfied were you with the VR experience?", an average score of 4.29 (somewhat effective) to the question "How effective was VR in relieving your pain or anxiety?", and an average score of 4.19 to the question "On a scale of 0–5 to what extent did you feel like you went inside the virtual world?" (see Table 1).

Table 1. Demographics

Characteristics	All patients	Patients who only used VR for entertainment	Patients who used VR for pain (could also use it for entertainment)
	N = 10	N = 5	N = 5
Age			
Mean (Std Dev.)	61.90 (10.57)	59.40 (10.21)	64.40 (11.46)
Median (Q1-Q3)	63.50 (53.00 - 70.25)	59.00 (52.00 - 68.00)	68.00 (56.00 - 74.00)
Sex			
Female	5 (50.0)	1 (20.0)	4 (80.0)
Male	5 (50.0)	4 (80.0)	1 (20.0)
Race			
White	8 (80.0)	1 (20.0)	5 (100.0)
Black	1 (10.0)	1 (20.0)	0
Hispanic	1 (10.0)	3 (60.0)	0
Length of Stay			
Mean (Std Dev.)	5.20 (5.79)	2.80 (2.95)	7.60 (7.23)
Median (Q1-Q3)	3.00 (2.00 - 7.00)	2.00 (1.00 - 2.00)	4.00 (3.00 - 8.00)
Pain			
Mean (Std Dev.)	3.89 (1.40)	2.99 (1.33)	4.80 (0.78)
Median (Q1-Q3)	4.00 (2.68 - 5.06)	2.33 (2.00 - 3.71)	5.08 (4.09 - 5.16)
Number of Access			
Mean (Std Dev.)	13.50 (8.77)	7.20 (2.68)	19.80 (8.17)
Median (Q1-Q3)	11.00 (7.50 - 17.50)	7.00 (7.00 - 9.00)	19.00 (13.00 - 23.00)
Number of VR			
Mean (Std Dev.)	3.50 (2.42)	3.20 (0.84)	3.80 (3.49)
Median (Q1-Q3)	3.00 (2.00 - 3.75)	3.00 (3.00 - 4.00)	2.00 (2.00 - 3.00)
VR usage rate (# of VR/ # of all events)			
Mean (Std Dev.)	0.35 (0.27)	0.52 (0.29)	0.18 (0.09)
Median (Q1-Q3)	0.30 (0.18 - 0.38)	0.40 (0.33 - 0.57)	0.17 (0.11 - 0.23)
How satisfied were you with the VR experience? (1 – 5, 5 is Very Satisfied)			
Mean (Std Dev.)	4.08 (0.60)	4.15 (0.55)	4.00 (0.71)
How effective was VR in relieving your patient's pain or anxiety? (1 – 5, 5 is Very Effective)			
Mean (Std Dev.)	4.29 (0.40)	4.33 (0.47)	4.26 (0.36)
To what extent did you feel like you went inside the virtual world? (1-5, 5 is Very Effective)			
Mean (Std Dev.)	4.19 (0.63)	4.50 (0.50)	3.89 (0.64)

The patients' overall pain scores and frequency of VR use are shown in Figure 1. For each patient, hours of hospital stay are shown on the x-axis (black lines) together with each pain score assessment. Red symbols indicate that VR was provided, green symbols indicate that medication was provided, and blue symbols indicate that neither VR nor medication was provided. Note that patient #4 remained in the hospital for 504 hours (21 days); we truncated the line on the right

for scaling considerations. All patients experienced at least three pain score access events. Most patients used the VR headset within the first 24 hours after the surgical procedure.

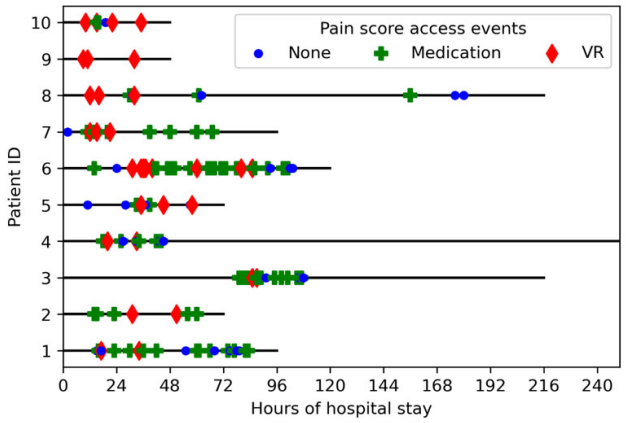

Figure 1. Pain access events in entire hospital stay*

**Hours in the hospital (black lines) and each pain score accessing events. Red marks mean VR was given, green marks mean medication was given, while blue marks mean that neither VR nor medication was given. Note that patient 4 stayed 504 hours; we truncated on the right for scaling considerations. We see all patients had at least 3 pain scores accessing events and at least 2 events were given VR. Most patients received VR within the first 24 hours.*

The female gender was strongly positively correlated with a longer length of stay (r = 0.62, p = .05) and moderately negatively correlated with the usage rate of VR (r = -0.54, p = .106). Age was positively correlated with scores 1 – 5 provided in answer to question 2 (r = 0.52, p = .126). Pain score was positively correlated with length of stay and with negatively correlated with VR usage rate (r = -0.55, p = .111). Scores on the patient satisfaction survey questions were strongly positively correlated with one another (r = 0.68–0.77, p < .05 for all pairs). For reducing pain, the correlations were only moderate potentially because of the small sample size (see Figure 2).

5. Discussion

The study findings suggest that VR may be a feasible and effective means of providing distraction and pain relief to older adults. The findings revealed that the patients who used VR for entertainment were younger adult males who experienced shorter lengths of hospital stay and less pain following robotic colorectal procedures. Males used VR more frequently and reported greater satisfaction with this modality.

To the best of our knowledge, this is the first study designed to elucidate the postoperative impact of VR in patients undergoing robotic colorectal surgery. Our findings were similar to those reported by Jones[17] who found that VR supported reductions in pain and anxiety in older adults undergoing physical rehabilitation and distracting patients during procedures. Sahin and Baskak[18] reported that the use of VR during knee-arthroscopic operations resulted in decreased preoperative and postoperative anxiety when compared to the control group. Similarly, a health education intervention VR simulation resulted in a significant impact on older adults who had undergone hernia surgery compared with results from the control group.[19] In another study, patients with newly-diagnosed cancer who were initiating chemotherapy and provided with VR-based education exhibited decreased heart rates, blood pressure, and anxiety scores, with heart rate positively correlated with anxiety scores before the first session.[20] The findings from this study suggest that the use of VR in conjunction with pain medication will provide amplified relief to patients with postoperative pain. Of note, this study was conducted during the COVID-19 pandemic when family visits to patients in the hospital were not permitted.

While the costs of VR equipment have diminished considerably along with increases in overall quality,[4] the Applied VR device currently lists at $1500 at a minimum; thus, this intervention may still be cost-prohibitive for smaller hospitals and hospital centers. Another important factor is the risk of loss or theft, as these devices may be lost among the patient's personal belongings when transferring between rooms. Our research staff experienced some anxiety when asked to leave the devices in the patient rooms, although this was essential for COVID-19 precautions. In our hospital only one VR device was purchased at the beginning of the study; this limited the number of patients that could be recruited to one to two per week. Another device was purchased later to facilitate the expansion of this study.

Although the results of this study revealed only moderate correlations associated with the use of VR for distraction and entertainment, middle-aged and early-older adults enjoyed using VR. Therefore, this subject might be studied further; the impact of VR on pain management might ultimately be evaluated in a larger patient cohort with a randomized controlled trial study design.

VR use for entertainment among younger adults in the cohort were typically males who experienced a shorter length of hospital stay and less pain. These individuals used VR more frequently and reported greater satisfaction with this modality. Pain scores correlated positively with length of stay and negatively with VR usage and with answers to the survey questions that addressed one's satisfaction with VR. Thus, the conclusion is that VR might be effective at treating postoperative pain in patients undergoing robotic colorectal

surgeries. Patient-reported complaints about the use of the VR headset included eye strain, headache, claustrophobia, and nausea. Seven percent of patients reported adverse responses to VR, including nausea (5%), headache (1%), and vertigo (1%). Only one patient discontinued the use of VR due to an adverse response.

Limitations

This study includes several limitations. The small sample size did not provide the statistical power that would be needed to perform hypothesis testing and investigation of the impact of VR on important clinical outcomes (i.e., pain score and length of hospital stay). However, the results did show a moderate negative correlation between the rate of VR usage, length of hospital stay, and reductions in pain scores. Nonetheless, analyses stratified by age, sex, or race could not be performed. Likewise, the patient group was quite heterogeneous. For example, among the 10 study participants, two patients required significantly longer stays in the intensive care unit. This variation makes the interpretation of the results somewhat challenging. Furthermore, the study was not randomized or blinded, which limits our interpretations regarding the unique impact of VR. Confounding variables also include the treatment provided by the individual clinicians and the extent of the colorectal surgery. The research was limited to patients who could provide self-reported pain scores and was not controlled for use of other pharmacologic interventions, including pain medications that were ordered on an "as needed" basis. Finally, it was noted that the VR device was at times left to power down and would need to be recharged before use, thus delaying patient access to this device at the time desired.

In summary, VR is receiving more attention as a means to provide distraction and decrease pain and anxiety in both outpatient and inpatient perioperative settings. Pilot studies are essential as they provide insight into unforeseen inconsistencies as well as methods that might be used to facilitate study procedures so that they align with patient flow. As but one example, the pain management practices of each hospital and physician differ from one another. It is thus critical to find ways to align anesthesia regimens and postoperative pain management with the use of VR strategies and devices. The use of an interprofessional approach will be essential to maintain the consistent timing of research interventions and to control for confounding variables, including pain medication protocols. The results of this study suggest that VR may be used successfully as a nonpharmacologic intervention that reduces pain and limits the length of hospital stay. The findings also reveal positive perceptions of the use of VR following post-operative robotic procedures among members of the older adult population.

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CONFLICTS OF INTEREST DISCLOSURE

The authors declare that there is no conflict of interest.

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