The Feasibility and Acceptability of a Stand-Alone Virtual Reality Headset on Perceived Pain and Anxiety During Bone Marrow Biopsies: A Mixed Methods Study

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Abstract

Background: Virtual Reality (VR) is an emerging technology that provides an immersive user experience and has the ability to distract patients from the negative or painful experiences commonly associated with medical procedures. Bone marrow biopsies are medical procedures where a needle is inserted into the bone and a syringe is used to withdraw the liquid bone marrow. They are performed to diagnose and monitor disorders affecting the blood, often as part of care for hematology and oncology patients.

Objective: The purpose of this pilot study is to assess the feasibility of VR as an adjunctive therapy to alleviate the perception of pain and anxiety in patients receiving bone marrow biopsies.

Methods: This pilot study enrolled 60 adult participants receiving a bone marrow biopsy to assess the acceptability and feasibility of virtual reality to impact reported pain & anxiety levels compared to the subject's baseline measurements pre-operatively. They were randomly assigned into 'control'/non-VR intervention (n = 30) and 'experimental'/VR groups (n = 30). The 'experimental'/VR group utilized the Meta Quest 2 headset (Meta, Menlo Park CA) with original VR content developed for this study. Participants completed a survey adapted from a standardized verbal numerical rating score (VNRS) to rate their pain and anxiety levels before and after the bone marrow biopsy. Measurements such as procedure length, patient vitals, and experience were also gathered from both study groups.

Results: Results indicated that participants had no significant differences in their heart rate, respiration rate, and blood oxygen saturation levels between the two groups. Participants in the VR group had a significantly shorter procedure length than the control group. Participants in the VR group were significantly more likely to rate the distraction as effective and report they would repeat the procedure. Finally, participants in the VR group had significantly lower levels of anxiety before the procedure and felt significantly more comfortable after the procedure.

Conclusions: This investigation encourages the acceptability of using VR intervention for patients undergoing bone marrow biopsies. Further, the length of procedures were found to be shorter when compared to the control group - supporting the feasibility of the technology for clinical management. These novel interventions can provide distraction-based therapy that is non-inferior to standard of care and provide enjoyable user experiences which reduce the perceived pain & anxiety of non-sedated medical procedures. Clinical Trial: International Registered Report Identifier (IRRID): DERR1-10.2196/52649

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KEYWORDS
virtual reality; digital health; feasibility; acceptability; pain; anxiety; hospital; hospitalization; in-patient; observational study; bone marrow biopsy; oncology; pharmacologic pain management; pain management; topical anesthetic creams; topical cream

ABSTRACT

Background

Virtual Reality (VR) is an emerging technology that provides an immersive user experience and has the ability to distract patients from the negative or painful experiences commonly associated with medical procedures. Bone marrow biopsies are medical procedures where a needle is inserted into the bone and a syringe is used to withdraw the liquid bone marrow. They are performed to diagnose and monitor disorders affecting the blood, often as part of care for hematology and oncology patients. The purpose of this pilot study is to assess the feasibility of VR as an adjunctive therapy to alleviate the perception of pain and anxiety in patients receiving bone marrow biopsies.

Methods

This pilot study enrolled 60 adult participants receiving a bone marrow biopsy to assess the acceptability and feasibility of virtual reality to impact reported pain & anxiety levels compared to the subject's baseline measurements pre-operatively. They were randomly assigned into 'control'/non-VR intervention (n = 30) and 'experimental'/VR groups (n = 30). The 'experimental'/ VR group utilized the Meta Quest 2 headset (Meta, Menlo Park CA) with original VR content developed for this study. Participants completed a survey adapted from a standardized verbal numerical rating score (VNRS) to rate their pain and anxiety levels before and after the bone marrow biopsy. Measurements such as procedure length, patient vitals, and experience were also gathered from both study groups.

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provide enjoyable user experiences which reduce the perceived pain & anxiety of non-sedated medical procedures.

INTRODUCTION

Standard pain management protocols in adult medicine settings, hospital or clinic, typically rely on the use of pharmacotherapies such as acetaminophen, NSAIDs, analgesics and opioids to alleviate acute pain[1]. Although these forms of treatment can be effective, there are growing concerns surrounding the potential health risks associated with the use of certain pharmacotherapies, such as opioid addiction, across patient populations[2]. As a result, there is a growing interest to reduce the use of pharmacotherapy for treatment of acute pain in favor of non-pharmacologic options[3]. However, there are few alternative options for providing non-pharmacologic therapy in adults which often results in inadequate pain control[4]. There is a need to find feasible and acceptable adjunct forms of pain management and anxiety reduction in a hospital or clinic setting.

Distraction techniques used by hospital staff help patients cope with injuries, hospitalization, or illness, and differ based on each patient's needs and preferences[5]. Some common techniques used to distract from chronic pain include controlled breathing, guided imagery and relaxation[6]. Passive techniques like auditory distraction and television have been used to distract from acute pain resulting from routine procedures[7]. Studies for each of these different techniques over the years found some positive, but mostly mixed results[8]. Thus, there is still limited evidence demonstrating the effectiveness of distraction[9]. Moreover, there is no conclusive study suggesting that one technique supersedes others since each patient has different preferences, medical situations, behavioral needs, and developmental needs.

Virtual Reality (VR) is an emerging technology that provides an immersive user experience[10]. These immersive VR experiences show promise as a tool that can reduce perceived pain and anxiety related to acute pain in emergency rooms or other clinical settings by lessening the vividness of memories[11]. One study has even observed that immersive VR was more effective than standard care in ameliorating pain among pediatric patients undergoing venipunctures[12]. It is theorized that immersive VR draws the patient's attention away from aversive, or painful, stimuli by keeping their focus on something more engaging[13]. A study published in 2023 by Alaniz, found VR to be an underutilized intraoperative tool that enhances the overall patient experience in the emergency room[14]. Furthermore, another study by Sabinash 2023 reported positive findings with this technology are tempered by the limitations of current research, but VR still holds great potential[15]. The standalone headset's hardware offers an affordable alternative that can potentially provide a non-pharmacologic treatment for acute pain management and anxiety reduction[16]. A study published in Virtual World found that it is likely to see the widespread implementation of virtual reality in healthcare in the coming decade[17]. With recent advancements, VR technology is used in numerous settings, but limited research has been done thus far to show how effective it is[18].

The purpose of this pilot study is to evaluate the feasibility and acceptability of using VR adjunctively as a non-pharmacological distraction method for bone marrow biopsies to reduce perceived anxiety and pain in an oncology ward setting. The information gained will help to design future studies needed to ensure its efficacy and reliability of the devices.

METHODS

Design Overview

This pilot acceptability and feasibility study was performed at the University of Florida (UF) Shands Cancer Hospital to assess virtual reality (VR) as a relaxation and distraction tool for patients receiving a bone marrow biopsy procedure. We used a mixed methods design, in which trained

research assistants identified and determined eligibility of patients admitted in the UF Health Division of Hematology & Oncology Ward in coordination with medical staff. Participants were randomly assigned into the control group and experimental group. The control (or non-VR intervention) group did not receive any special distraction and patients were distracted with traditional techniques used during bone marrow biopsies. Data regarding patient vitals, procedure length, patient feelings before and after the procedure, and patient experiences with the procedure were compared between participants assigned to the VR and control group. The two groups were compared using independent t-tests with Cohen's D measure of effect size. For any measure taken before and after the procedure, the difference between the two was calculated and used to compare the groups for the t-tests.

Participants

Sixty participants were recruited between February 2021 and February 2024 from the UF Health Oncology & Hematology ward. Participants were included according to the following criteria: have a scheduled bone marrow biopsy, be aged greater than 18 years, and be able to physically wear and tolerate the VR headset. Participants were excluded if they had: nausea or vomiting upon admission, required urgent procedures or were otherwise deemed unstable by hospital staff, had a condition that prevents the use of VR technology such as epilepsy, or a facial or scalp wound, had any visual, hearing, or cognitive impairments that would limit their ability to take part in the study, or if they could not read, speak, or write in English. The demographic characteristics of the participants are shown in Table 1. The majority of participants were male, the median age was 61.5 years (IQR 53-68), the racial composition was 75% white with approximately 17% black and 8% latino enrolled, and 63% of them reported some familiarity with virtual reality.

Table 1: Demographic Information & Familiarity with VR

	Median Age (IQR)	**Gender**	**Race**	**VR Familiarity**
Total Population (n = 60)	61.5 (53 - 68)	60% M 40% F	75% W 17% B 8% L	63%
Control (n=30)	65 (58.5 - 69.5)	53% M 47% F	77% W 13% B 10% L	63%
VR (n=30)	58 (48 - 64)	63% M 37% F	73% W 17% B 10% L	63%

Index: W = White / B = Black / L = Latino / M = Male / F = Female / yr = Year

Distraction-Based Virtual Reality Intervention

The ‘HealthPointXR’ app (Gainesville, Florida), developed for this study was used to provide distraction and relaxation for participants enrolled in the experimental group. This study utilized a retrofitted Meta Quest 2 headset (Meta, Menlo Park, CA) with plastic straps and easily sanitizable materials. The Meta Quest 2 fit most head shapes and sizes, tablets were connected to the headsets for research assistants to control and supervise the virtual reality content in real time utilizing an intuitive interface. The tablet and the VR headset were connected through a bluetooth pairing and did not require internet or Wi-Fi connectivity. ‘HealthPointXR’ virtual reality game included:

1. An experience of a tranquil walking path through a natural environment where the user snaps photographs of wildlife passing by while being transported in a cart along a track. The user must take these different photographs when prompted to advance their journey. Users are also incentivized to follow the track closely through minimal head movements in order to receive points on the trip across the natural environment to further immerse the user. Soothing music and different sounding notifications provide auditory cues to engage the user.

For participants randomly selected to the experimental group, research assistants provided a standardized 5 minute tutorial for participants on wearing the VR headset and fitting it properly for optimal user experience. The length of time required to fit the VR headset on participants was not factored in the total length of the procedure as it was done during normally occurring time intervals prior to the bone marrow biopsy procedure. Figure 1 shows an example of the virtual reality experience.

Figure 1: ‘HealthPointXR’ Virtual Reality Experience

Patient Vitals and Procedure

Patients in both the VR and control group had their vitals, including: heart rate, respiration rate, and blood oxygen saturation recorded through a pulse oximeter during and after the procedure. These vitals were taken by the healthcare staff present at the time of the procedure and research assistants collected this data from the healthcare staff after completion of the intervention. Procedure length was recorded on a stopwatch by the research assistants, who began measuring the procedure length as soon as the VR headset was placed on the patients. Timing concluded at the end of the medical procedure once the clinician completed the last component of the procedure.

Patient Feelings and Experience

Patients in both the VR and control group were asked the same questions regarding their feelings and experience with the procedure. Patients’ feelings regarding the procedure was assessed by pain before and after the procedure, worry before and after the procedure, anxiety before and after the procedure, and comfort after the procedure. Feelings of pain were recorded using a verbal numerical rating scale from 1-10 before and after the procedure with higher values indicating higher feelings of pain. Feelings of worry were measured before and after the procedure using a scale from 1 to 5 with a 1 indicating not worried at all and 5 indicating extremely worried. Feelings of anxiety during the procedure were recorded on a verbal numerical rating scale from 1-5 with higher values indicating higher feelings of anxiety. Feelings of comfort after the procedure were evaluated using a 5 point scale from strongly disagree to strongly agree for the statement “I felt comfortable with the distraction”.

Patients' experiences with the procedure were all assessed on a 5 point scale from strongly disagree to strongly agree. To measure awareness, patient’s were asked their agreement with the following statement “I was very aware of the procedure I was receiving”. To measure distraction effectiveness,

patients were asked their agreement with “Using the distraction made me feel less worried about getting the procedure”. Finally, for likelihood to repeat, patients were asked their agreement with “I would want to use the same distraction on medical procedures in the future”.

RESULTS

Patient and Procedure Summary Information

Figure 2 summarizes the patient's vitals and procedure duration between the VR and control group. Patient’s heart rate, respiration rate, and blood oxygen saturation were taken before and after the procedure. There were no significant differences in the change in vitals pre and post procedure between the VR and control group. The average procedure duration was significantly shorter in the VR group (M = 23.94, SD = 9.72) compared to the control group (M = 31.94, SD = 15.34), $t(51) = -2.45$, $P = .018$, $d = 0.62$.

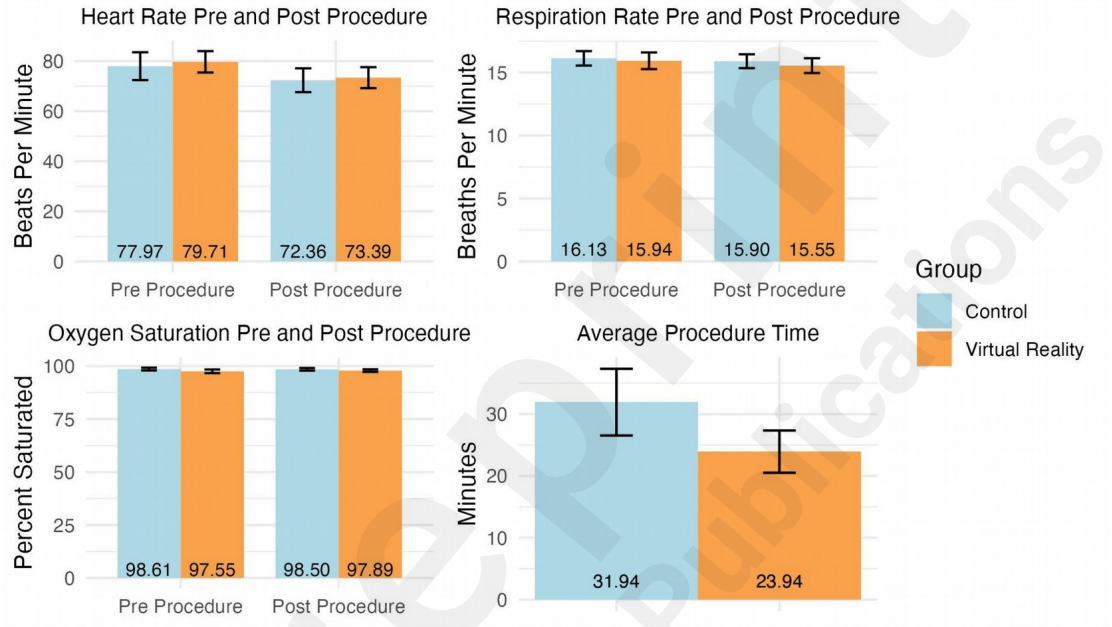

Figure 2: Summary of Patient’s Vitals and Procedure Length

Patient’s Feelings

Figure 3 summarizes patients' feelings before, during, and after the procedure between the VR and control group. Patients were asked to indicate their feelings as explained in the methods with higher scores indicating higher levels of pain, worry, anxiety, and comfort. The error bars represent 95% confidence intervals and the mean for each group is labeled at the bottom. Participants in the VR group (M = 2.13, SD = 1.26) had significantly lower feelings of anxiety during the procedure compared to the control group (M = 3.42, SD = 1.46), $t(57) = -3.73$, $P < .001$, $d = 0.95$. Participants in the VR group (M = 4.45, SD = 1.12) had significantly higher feelings of comfort with the distraction compared to the control group (M = 2.10, SD = 1.27), $t(59) = 7.73$, $P < .001$, $d = 1.96$. There were no significant differences between the VR and control groups for pain and worry either before or after the procedure. Additionally, there was no significant difference within either the VR or control group for the difference in pain or worry perception before and after the procedure.

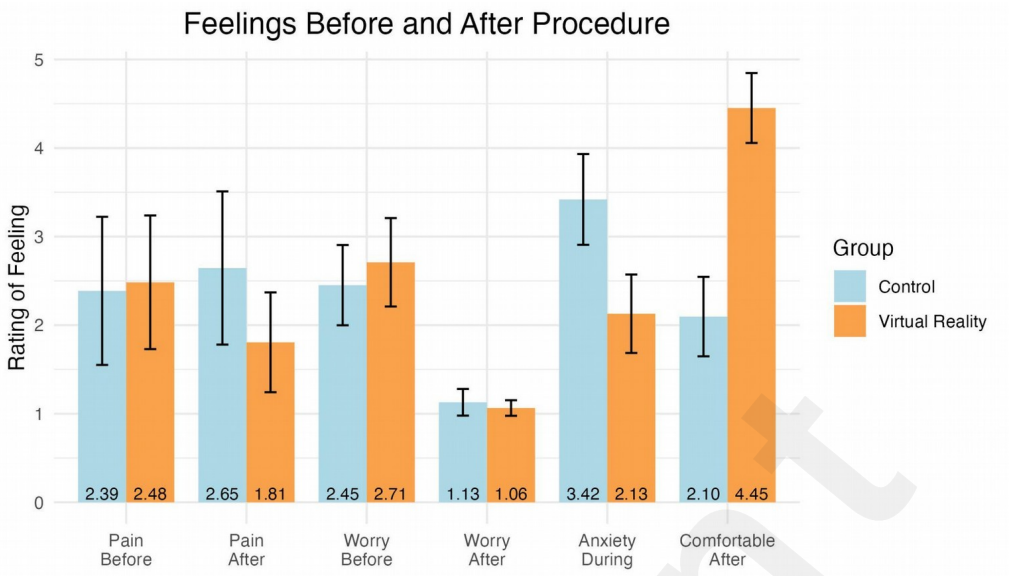

Figure 3: Differences in Patient Feelings Before and After Procedure

Patient's Experience

Figure 4 summarizes differences in patient experience during the procedure between the VR and control group. Patients were asked to rate the statements on a scale of 1 to 5 with higher scores indicating a larger awareness of the procedure occurring, higher effectiveness of the distraction, and a greater likelihood to repeat the procedure. The error bars represent 95% confidence intervals and the mean for each group is labeled at the bottom. Participants in the VR group (M = 4.29, SD = 1.19) were significantly more likely compared to the control group (M = 1.55, SD = 0.93) to rate the distraction as effective $t(57) = 10.14$, $P < .001$, $d = 2.57$. Participants in the VR group (M = 4.32, SD = 1.05) were also significantly more likely compared to the control group (M = 1.81, SD = 1.25) to indicate they would repeat the experience $t(58) = 8.60$, $P < .001$, $d = 2.18$. However there were no significant differences between participants in the VR group (M = 4.45, SD = 0.96) and the control group (M = 4.52, SD = 0.85) of how aware participants were of the procedure occuring $t(57) = -0.28$, $P = .781$, $d = 0.07$.

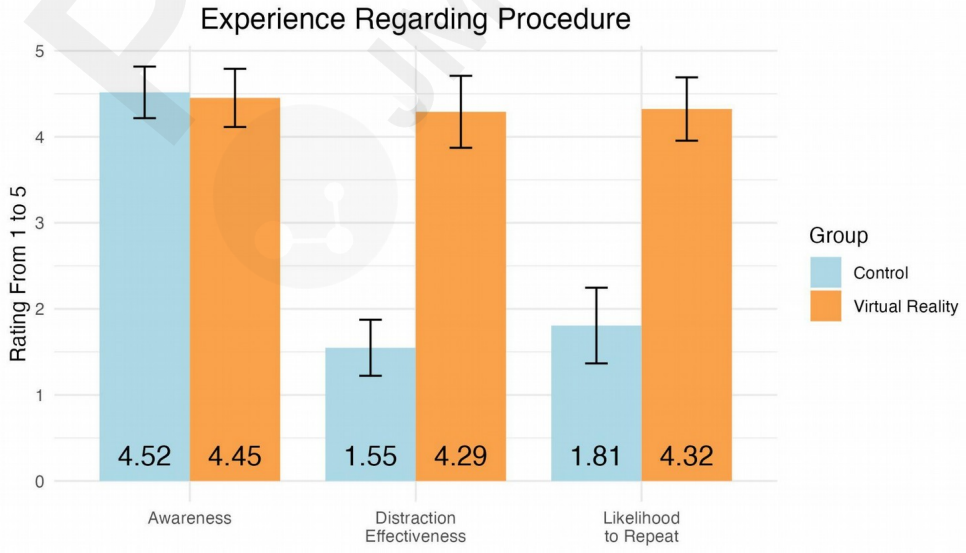

Figure 4: Differences in Patient Experience During Procedure

DISCUSSION

The results of this pilot study suggest that virtual reality (VR) has a role in reducing anxiety and perceived pain in adult patients receiving bone marrow biopsy. Although this study is not designed to be statistically powered, a notable reduction in perceived pain was measured in the VR group with a reduction of 0.7 in reported pain levels postoperatively compared to the control group's increase of 0.2 reported pain postoperatively on a 10-point scale. These findings paralleled those reported by Wong 2023, when assessing patient perceptions of virtual reality for pain relief in labor[19].

Anxiety levels before and after bone marrow biopsies were not significantly different in the VR group compared to the control group. Anxiety in oncology patients can be triggered from a multitude of factors as well as anticipation of pain associated with medical procedures[20]. VR might be slightly effective in reducing reported anxiety levels, although the complex combination of factors associated with the care of cancer patients require caution when interpreting the results of a tool used in an acute care application. This differs from similar studies that have reported marked changes in reported anxiety levels. A study by Fabi 2022 reported that among 22 patients who used VR during chemotherapy, there was a significant decrease in perceived anxiety and duration of procedure compared to the control group[21].

Acceptability of VR in the hospital setting was supported by the patient experience findings and reinforced by the anxiety and perceived pain data collected during this study. The results of the surveys suggest a 2-3 point higher score in level of immersion, likelihood to use intervention again and comfort level in the VR group compared to the control group using a 5-point scale. The majority of patients expressed a willingness to use VR as a distraction-based tool during their bone marrow biopsy. Furthermore, a study published by the Journal of Internet Medical Research in 2022, found VR beneficial for breaking up the monotony of treatment, providing an additional choice of activity and in some instances as a distraction from the treatment itself[22].

Measurements of feasibility for VR focused on the usability and comfort of the technology as well as its impact on length of time for the medical procedure to be completed. Notably, there was an 8 minute faster completion or 25% time reduction for completion of the bone marrow biopsy procedure among the VR intervention group (n=30) compared to the control group (n=30). The faster completion of the procedure occurred without any report of compromised quality of care and this data provides a valuable clinical benchmark for the use of VR in the hospital setting as it appears to improve efficiency of providers while performing routine procedures. The same size remains a limitation on these findings to differentiate them from being anecdotal opposed from powered warranting the need for further investigation regarding time efficiencies and cost-effectiveness regarding the use of VR in minimally invasive procedures like bone marrow biopsies.

Furthermore, clinical staff reported a positive outlook on VR as a distraction-based therapy although they did question how easy it is to set up the technology. The opinion of hospital staff was that 8/10 found VR to be a useful tool for distraction in clinical practice however 6/10 questioned how easy it would be to learn how to properly operate the device. It must be noted that additional time was designated for clinical staff to learn administration of VR as this must be considered when translating research findings into practice. This finding is consistent with a review conducted in 2023 that factored in hospital staff opinions of virtual reality use in the hospital[23].

The existing evidence to support the implementation of distraction-based virtual reality therapy is still limited amongst oncology patients receiving bone marrow biopsies[24]. This study provided insight into the novel application of a standalone virtual reality headset. The results from this study indicate the use of virtual reality as a non-inferior adjunct tool that is acceptable and feasible for

providing distraction and relaxation in adult patient populations undergoing bone marrow biopsy. Furthermore, the data adds to building the evidence-base for VR in medicine as part of innovative clinical practice involving digital therapeutics.

This study has several limitations, as the study was not designed to measure for the impact of potential moderators on the outcomes the data cannot provide reliable information on the potential impact of age, gender, pain tolerance of participants enrolled in the study. The study design, sample size, and inability to double blind the participants are also notable limitations that impacted the quality of data reported in this research. A review by Kouijzer 2023 supports these considerations as a lack of time and expertise on how to use VR in treatment, a lack of personalization of some VR applications to patient needs and treatment goals, or the gap in knowledge on the added value of VR in a specific setting were noted as limitations[25]. Additionally, the enrollment strategy could not control for the utilization of additional pain medication prior to the bone marrow biopsy that was self-prescribed by the patient prior to being approached regarding participation in the study. Furthermore, the study did not factor in medications that the patients are on or the full past medical history of participants to consider the impact of those factors on how the participant's vital signs.

CONCLUSION

In conclusion, this pilot study's findings suggest that the utilization of an Oculus Quest 2 Headset with the 'HealthPointXR' virtual reality (VR) program can serve as a non-inferior adjunct distraction-based therapy option for patients who are distressed when undergoing a bone marrow biopsy. Based on the parameters accessed, it is reasonable to determine that the implementation of VR improved anxiety levels, perceived pain, and did not prolong clinical workflow on average. Further studies that are statistically powered can provide more robust evidence to support the routine application of this emerging technology to impact patient's experience during non-sedated, minimally invasive procedures.

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AUTHOR CONTRIBUTIONS

A.M. and J.W. conceptualized and planned out the methodology of the study. A.M. and J.W. worked on the programming and software development of the virtual reality game. T.W. supervised the project. A.M. and S.H. carried out the investigation and A.M., S.H., and K.K. wrote and edited the manuscript. K.K. analyzed the data and A.M. and J.W. contributed to the interpretation of the results. All authors provided critical feedback throughout the study and helped shape the research and manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

FUNDING STATEMENT

This research received no external funding.

INSTITUTIONAL REVIEW BOARD STATEMENT

This study was conducted according to the guidelines of the University of Florida Institutional Review Board, approved by the ethics board on January 27th, 2021.

DATA AVAILABILITY STATEMENT

Not applicable.

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