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A Comparison between the Use of Patient-worn Virtual Reality in Wound Care and Hand Surgery: How Does Virtual Reality Work?

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Background: As virtual reality (VR) technology becomes smaller and more affordable, it is gaining in popularity as a tool to address the patient experience of pain and anxiety during invasive procedures. In this study, we explore the effect of VR on the patient experience in two clinical environments of different anxiety levels to propose a possible mechanism of VR on pain and anxiety reduction.
Method: Twenty-five wound care patients were randomly assigned to either a VR group or non-virtual reality (NVR) group, singly blinded. Pre-debridement, peri-debridement, and immediately postdebridement anxiety, fun, and pain scores were collected using a Likert scale (0 = least; 10 = most) from each group of patients. These measurements were compared among the VR versus NVR group in the setting of routine wound debridement procedures. The results are compared with our previously published data on patients who underwent wide awake local anesthesia no tourniquet (WALANT) hand surgery.
Results: The WALANT surgery patients using VR experienced significant reduction in anxiety and increase in fun compared with the NVR group. In the wound debridement group with VR, there was improved fun, but no statistically significant reduction in pain or anxiety when compared with the NVR group. The mean score for anxiety was higher for awake hand surgery than for wound debridement cases (3.3 versus 1.7, $P = 0.004$).
Conclusions: VR seems to be more effective in higher anxiety settings, could VR work via a neurological mechanism akin to the Melzack and Wall gate control theory of pain? VR may act primarily on the anxiety axis, providing negative feedback via cortical pathways to the amygdala. *(Plast Reconstr Surg Glob Open 2023; 11:e5185; doi: 10.1097/GOX.0000000000005185; Published online 9 August 2023.)*

INTRODUCTION

Virtual reality (VR) is defined as the use of technology to submerge a person into a computer-generated, interactive, simulated environment. The idea of VR dates back to the 1950s, but it has become more popular since the late 1980s with the PC revolution.[1] Over the past 10 years, it has become increasingly affordable due to the rapid evolution of technology enabling the smartphone industry. Because of this, surgeons and physicians may now easily offer VR to patients in their office environments, without the need for expensive equipment. At Michigan State University, we have been offering patients VR during wide awake local anesthesia no tourniquet (WALANT) hand procedures since 2016. We have elected to measure fun as one of our outcomes to reflect our belief that fun and joy act in opposition to fear and anxiety. Virtual reality can deliver an enjoyable experience, which we want to measure. The objective of this study was to use trial data from the wound clinic to explore the effect of baseline anxiety on the efficacy of VR in two very different environments, chronic wound care versus WALANT hand surgery.

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PATIENTS AND METHODS

A prospective single-blind controlled study was conducted on all previously established patients undergoing

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sharp surgical wound debridement by two providers (Dr. Chahal and Dr. Clarkson at Sparrow Hospital's wound clinic) over a 2-month period. No size of wound severity played a role in selection, and there were no exclusion criteria. Approval was given by the Michigan State University Biomedical and Health institutional review board. Twenty-five patients were randomized into a non-VR (NVR) user group and VR user group by envelope selection after obtaining informed consent. We used a Samsung (Seoul, Republic of Korea) Galaxy S7 and a Samsung Gear Virtual Reality headset with headphones, which represented readily available and inexpensive technology. The hardware was coupled with a playlist chosen by the research team of freely available 360 degree field of view media from YouTube.

For the VR cohort, the virtual reality headsets were given to the patients to wear while the patients had their wounds cleaned and prepared with topical lidocaine, by the nursing staff before the procedure. No patient received injected local anesthesia. Once they were immersed in VR, the provider would perform a sharp surgical debridement of the wound.

Pre-debridement, peri-debridement, and immediately postdebridement anxiety, fun, and pain scores were collected using a Likert scale (0 = least anxiety, pain, and fun; 10 = most anxiety, pain, and fun). After the procedure, the patient filled out a questionnaire about their VR experience and side effects. Patients were also asked to generally rate their experience.

Then we compared the data collected above in the wound clinic with those in a previous VR study conducted following a similar method (Hoxhallari et al[2]), which took place during WALANT surgery in the office setting as described by Lalonde and Wong.[3] The local anesthetic was injected, unlike the wound study, which was topical. The average score for anxiety was obtained by averaging anxiety scores among NVR patients in preoperative, perioperative, and postoperative settings from each wound and hand surgery group. The scores were then compared for statistical significance.

Data were analyzed using Statistical Package for the Social Sciences (SPSS), version 28 (IBM Corporation, Armonk, New York, N.Y.). Independent sample test, such as Mann-Whitney U test, was used to compare Likert data. Pearson χ^2 was used to compare the demographics in wound debridement groups. A value of P less than or equal to 0.05 was considered significant.

Takeaways

Question: How does virtual reality (VR) influence patient's surgical experience?

Findings: Greater efficacy from VR was found in the wide awake local anesthesia no tourniquet hand environment, which was more anxiety-provoking than the chronic wound care environment. The wide awake local anesthesia no tourniquet trial also demonstrated reduced needle stick pain among VR users who were known to have an anxiety disorder.

Meaning: Analogous to the classic gate control theory of pain, VR may act primarily on the anxiety axis, providing negative feedback via cortical pathways to the amygdala.

RESULTS

Wound Clinic Data

Over the trial period, 25 patients were recruited into the study, with 10 in the NVR cohort and 15 in the VR cohort. There was no significant difference between the groups in terms of gender or ethnicity (Pearson χ^2 >0.05). The demographic of participants is described in Table 1. Debridement duration was longer in the VR group (7.4 minutes) than in the NVR group (5.1 minutes).

Supplemental Digital Content 1 demonstrates that VR patients rated their experience more fun in both stages of the procedure: peri-debridement (6.0 versus 0.6, $P < 0.01$), and postdebridement (7.0 versus 1.1, $P < 0.01$). [**See graph 1, Supplemental Digital Content 1,** which displays comparison of anxiety, fun, and pain scores between patients not using virtual reality (NVR) and those using virtual reality (VR) in wound debridement group. **http://links.lww.com/PRSGO/C711**.]

Table 1. Patient Demographics, Self-reported Prior Medical Conditions, and Procedure Type/Duration for Wound Debridement Group

	Non-VR Group	VR Group
No.	10	15
Gender	$P = 0.48$	
Masculine	60%	53%
Feminine	40%	47%
Ethnicity	$P = 0.34$	
White	80%	67%
Black	0%	13%
Hispanic	10%	20%
Other	10%	0%
Prior medical conditions, n		
Stroke/CVA	2	1
Diabetes	8	11
Anxiety disorder	1	3
Depression	2	4
Duration of procedure	2–12 min	3–16 min
Wound type and location, n		
Leg from venous stasis	6	10
Foot from diabetic ulcer	4	6
Breast from surgical complication	1	2

The average anxiety score of NVR patients during the perioperative and postoperative phase was 2.2 and 1.8 respectively, whereas VR patients had average score of 1.9 and 1.0. The average pain score of NVR patients during perioperative was 2.2, and postoperatively, it was 2.4. The VR patients had an average score of 2.5 in perioperative phase and 2.3 in postoperative phase. No significant difference was noted for anxiety and pain criteria.

Postoperative survey revealed that all of the patients who received VR agreed that they had a good experience, and that VR helped them relax and they would recommend it to a friend. One patient complained of dizziness, and two complained of nausea.

Wound Clinic versus Hand Clinic Data

Supplemental Digital Content 2 shows that VR hand surgery patients had significantly more fun than the NVR group in both stages of the procedure: peri-debridement (6.9 versus 1.5, $P < 0.01$), and postdebridement (8.0 versus 2.5, $P < 0.01$). **[See graph 2, Supplemental Digital Content 2,** which displays comparison of anxiety, fun, and pain scores between patients not using virtual reality (NVR) and those using virtual reality (VR) in hand surgery group (created using data from Hoxhallari et al[2]). **http://links.lww.com/PRSGO/C712**]. There was also a reduction in anxiety in the group receiving VR in both stages of the procedure: peri-debridement (1.9 versus 3.5, $P < 0.05$), and postdebridement (0.6 versus 2.1, $P < 0.05$).

Supplemental Digital Content 3 demonstrated that when comparing the wound care versus the hand surgery experience, greater overall anxiety scores were reported by patients undergoing hand procedures (3.3 versus 1.7, $P < 0.004$). [**See graph 3, Supplemental Digital Content 3,** which displays comparison of mean anxiety score between wound debridement group and hand surgery group derived from patients not using VR (hand data from Hoxhallari et al[2]). **http://links.lww.com/PRSGO/C713**.]

DISCUSSION

By measuring fun, we are exploring the more entertaining and distracting qualities of VR. It is our supposition that fun, as an emotional state, will act in opposition to the emotions of fear and anxiety.

VR is known to augment the patient environmental experience in the form of visual and audio modalities for distraction during many types of procedures, such as bone marrow biopsies, needle sticks, and burn wound care.[4–10] Similarly, for children, VR has been shown to decrease pain and anxiety associated with needle sticks, intravenous cannulation, wound care, and dental procedures.[10–13] In a study on patients who had ambulatory surgical lipoma removal under local anesthetic, use of VR significantly decreased pain ratings during and after the procedure.[14] VR has significantly reduced the need for the use of sedation or anesthesia for children by allowing transnasal endoscopic procedures and reducing healthcare costs and time in office for families.[15]

In our previous trial,[2] patients undergoing hand surgery while wearing VR experienced increased fun and reduced anxiety during their surgical procedure. Subgroup analysis for hand patients who reported preexisting anxiety disorder also demonstrated reduced pain during the injection of local anesthesia for patients with preexisting anxiety disorder, suggesting that VR seems to have greater effect the greater the anxiety state.

By comparing the previously published WALANT VR trial versus this wound VR trial, we found that the WALANT hand environment is more anxiety-provoking than the chronic wound care environment, yet we saw greater efficacy from VR in the more anxiety prone WALANT environment. Subsequently, we have also published a larger patient-reported outcome study of carpal tunnel WALANT procedures, demonstrating that patients with an anxiety disorder were more likely to choose VR during WALANT surgery when given the option and that the effects of VR on anxiety and joy were greatest in this population.[16] Thus, it may be observed that the more stressful the perceived environment, the greater the effect VR may have in reducing anxiety and anxiety driven pain. We hypothesize that VR has the property of emotionally dissociating the patient from their experience of pain and anxiety, and it hints at a neurological mechanism akin to the Melzack and Wall gate control theory of pain.[17] Their theory postulates that within the dorsal horn, counter stimulation from A-beta fibers in the same region as the painful stimulus may close the gate to nociceptive inputs. In addition, there may be an interplay between the emotional environment and the patient's perception of pain.[18] Figure 1 illustrates this concept. Figure 2 illustrates our hypothesis that VR may compete for our attention to anxiety by a similar mechanism to the gate control theory, by placing the patients experience in a new context. We have modified the gate control theory with the model described by LeDoux, who demonstrated how emotional stimuli are transmitted from thalamus to the amygdala via a fast direct pathway and a slow moderating cortical pathway.[19] In this model, the negative feedback gateway would be achieved via the cortical pathway under the influence of the VR environment, analogous to A-beta fibers from the original gate control theory in the dorsal horn. One limitation of this study is that we do not have the same patients in both the WALANT and wound environments, which may also be a factor in their differing response to VR. We can only speculate why there is a different baseline anxiety score between these groups, which is not the objective of this study.

The wound results demonstrate that VR provides an opportunity to enhance the patient experience by producing more joy. The Center for Medicare and Medicaid has developed The Meaningful Measures initiative with a high priority focused on patient-reported outcome measures.[20,21] As a result, clinics must now compete against one another, based on their consumer satisfaction rating using the Outpatient and Ambulatory Surgery Consumer Assessment of Healthcare Providers and Systems (OAS CAHPS). Our study has shown that VR can provide fun entertainment to the patients in both types of procedures and may consequently yield a higher rating of their office experience.

CONCLUSIONS

VR seems to improve the patients' experience of wound care by increasing their level of fun, which has the potential to impact satisfaction scores. Our comparative analysis between the environments of wound and hand care demonstrated that VR appears to provide a greater magnitude of effect the greater the patient's anxiety, and hence, we hypothesize that VR primarily works on the anxiety axis. The mechanism of cortical negative feedback on the anxiety axis between the hypothalamus and the amygdala mirrors the mechanism described in the gate control theory of pain found in the dorsal horn of the

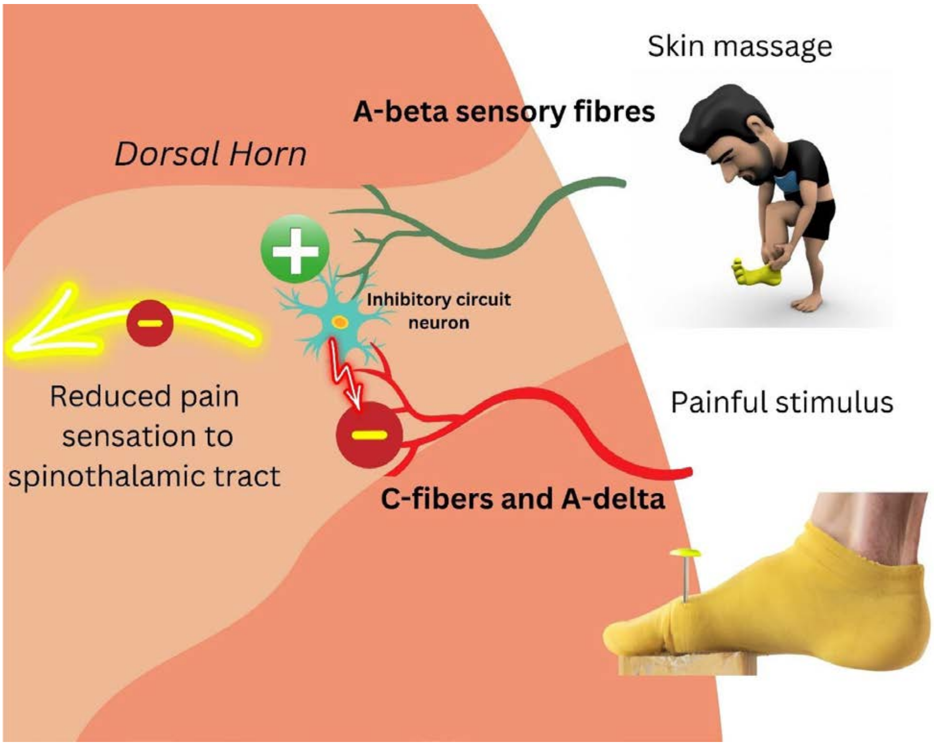

Fig. 1. Illustration of the Melzack and Wall gate control theory: nonpainful sensation can override or reduce painful sensation.[17]

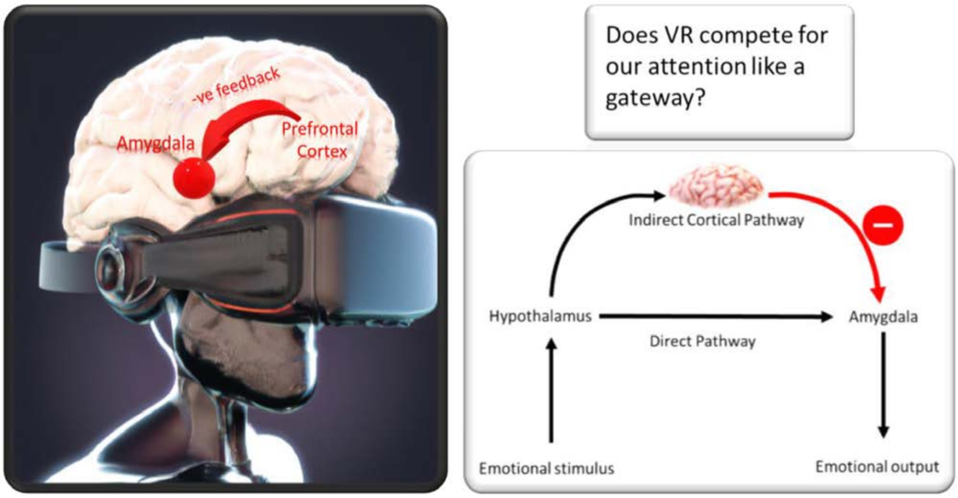

Fig. 2. Similar to the gate control theory, VR may have an inhibitory effect on anxiety at the level of amygdala by placing the experience in a new context, via the indirect pathway. Original illustration modified from *The Emotional Brain: The Mysterious Underpinnings of Emotional Life*. Simon & Schuster; 1996.

spinal cord.[17] It is our position that patients should ideally have the opportunity to experience joy during their care, creating a better climate for information retention and postoperative recovery.

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DISCLOSURES

Dr. Clarkson is the Chief Medical Officer and co-founder for a Virtual Reality Company, "Wide Awake VR." All the other authors have no conflicts of interest to declare in relation to the contents of the article.

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