Randomized, Crossover Study of Immersive Virtual Reality to Decrease Opioid Use During Painful Wound Care Procedures in Adults

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The objective of this study was to evaluate the effect of immersive virtual reality (IVR) distraction therapy during painful wound care procedures in adults on the amount of opioid medications required to manage pain. A convenience sample of consenting, adult inpatients requiring recurrent painful wound care procedures was studied. Using a within-subject, randomized controlled trial study design, 2 sequential wound procedures were compared, 1 with IVR distraction therapy and 1 without IVR. Total opioid medications administered before and during the wound procedures were recorded and pain and anxiety were rated before and after the 2 wound procedures. The IVR intervention included the wearing of virtual reality goggles and participation in an immersive, computer generated, interactive, 3-dimensional virtual world program. Data were analyzed with Student's *t* test and chi-square analysis, with $P < 0.05$ considered significant. A total of 18 patients were studied, with 12 completing both study wound procedures and 6 completing a single wound procedure. The amount of opioid administered before each of the 2 wound procedures was similar with and without IVR. Total opioid administration during the dressing procedures with IVR was significantly less than when no IVR was used, 17.9 ± 6.0 and 29.2 ± 4.5 mcg/kg fentanyl, respectively (t = -2.7; df = 14; $P = 0.02$). Two of 15 patients (11%) requested more than 1 opioid rescue dose with IVR and 9 of 15 patients (60%) requested more than 1 rescue dose without IVR. Seventy-five percentage of participants stated that they would want to use IVR with future dressing changes. Pain and anxiety scores were similar for the wound procedures with and without IVR ($P > 0.05$). IVR significantly reduced the amount of opioid medication administered during painful wound care procedures when IVR was used compared with no IVR. Since pain scores were similar before and after the wound procedures with IVR and without IVR, the 39% reduction in opioid medication during IVR supports its use as a pain distraction therapy during painful procedures. (J Burn Care Res 2017;XXX:00–00)

Distraction therapy has been found to be an effective method for reducing pain during painful procedures in both children and adults.[1,2] A relatively new adjunct therapy, immersive virtual reality (IVR), has been found to produce greater pain reductions than other forms of distraction, such as television, listening to music, or playing games.[3–6] With IVR, users interact with a computer-simulated, 3-dimensional environment with visual and auditory stimuli. The user performs "tasks" with a hand-held device that allows for interaction with the simulated environment of the program. This interaction with the simulated environment "distracts" the user, leaving their brain less cognitive capacity for processing pain signals.

Until recently, IVR as a pain management adjunct has been poorly studied, with the primary form of support for the therapy being case reports or

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nonexperimental studies.[3,4] Some of the earlier studies also evaluated a weak form of the technology that only provided visual and auditory stimuli and not the immersive components of blocking out environmental visual and auditory stimuli while the user interacted with the 3-dimensional program.[6]

Since 2005, several experimental studies have evaluated IVR effectiveness in a variety of painful situations or procedures with most finding significant pain reductions with IVR.[3,5,6] Generalization of these findings to painful wound debridement and cleaning procedures in adults is limited because the pain severity of these procedures is extremely high and difficult to control with analgesic medications alone.[5,7] In addition, many of the experimental studies were done in children,[8–16] normal volunteers,[12,17–20] and/or clinical procedures with limited potential to cause severe pain or discomfort (i.e., physical therapy, hand dressings, intravenous catheter insertion, port access, chemotherapy, pruritus).[5,13,15,21–25]

Only 2 experimental studies[26,27] and 1 quasi-experimental study[28] have evaluated IVR in adults during painful wound debridement and cleaning procedures (Table 1). In 1 study, the IVR intervention was studied for a 3-minute period during a painful wound care procedure in N = 11 burn patients, with another 3-minute period without IVR during the same procedure.[26] The order of the 2 treatments (IVR; no IVR) was randomly assigned. Study outcomes (patient survey of pain-related questions with rating on a 0 [no pain] to 10 [worst pain imaginable] scale) found significantly less pain during the 3-minute IVR treatment than without.

In the second experimental study, 12 military trauma patients with burns were studied during 2, randomly assigned 6-minute periods with or without IVR, no IVR during a single wound debridement and cleaning procedure.[27] Pain outcomes were measured as described above, with significantly less pain during the 6-minute IVR treatment than without.

In a nonexperimental, within-subjects study design, 19 patients were studied during painful wound care.[28] IVR was used for the entire dressing procedure and then compared with no IVR on the day before the IVR treatment. Pain, measured with a visual analog scale (0–10, 0 = no pain; 10 = worst pain imaginable), was significantly lower when IVR was used during the dressing change procedure. While the study attempted to evaluate anxiety before and after treatments, missing data in a number of the participants make interpretation of the data difficult. Since descriptive studies have found anxiety levels to be extremely high during burn dressing changes,[7] it is possible that IVR therapy may also decrease anxiety if pain is better managed with IVR.

None of the studies of IVR to date have evaluated the effect of IVR on opioid administration during the treatments. Given the high level of pain with wound debridement and cleansing, particularly with burn injuries, finding ways to decrease the large levels of opioid required to effectively manage pain is important. If IVR administered during painful wound care procedures could reduce opioid requirements, the risk of tolerance to opioids and the need to increase doses with continued use and physical dependence on opioids could be minimized. While prior studies have shown IVR during painful procedures to decrease pain compared with no IVR, it is not clear if this pain reduction decreases the amount of opioids administered during highly painful procedures.

The primary purpose of this within-subject, randomized controlled trial was to evaluate the effect of IVR distraction therapy during painful wound care procedures in adults on the amount of opioid

Table 1. Summary of key information from studies of IVR distraction therapy in adults during burn wound care

Study	N	Subject Age	IVR Program	Treatment Length	Outcomes	Miscellaneous Comments
Hoffman et al[26]	11	4–40 yr (mean = 27 yr)	Snow World®	3 min with IVR 3 min without IVR	Significant decrease in pain with IVR	Treatment order randomly assigned, done in the same dressing procedure
Maani et al[27]	12	20–27 yr (mean = 22 yr)	Snow World®	6 min with IVR 6 min without IVR	Significant decrease in pain with IVR	Treatment order randomly assigned, done in the same dressing procedure
van Twillert et al[28]	19	8–65 yr (mean = 30 yr)	Snow World®	Entire burn procedure with IVR Entire burn procedure without IVR	Significant decrease in pain with IVR; no change in anxiety	Treatments on sequential days (not randomized); study done in the Netherlands

IVR, immersive virtual reality.

medications required to manage pain. Secondary outcomes included levels of pain and anxiety.

METHODS

This study was conducted in a 427 bed community-based hospital in the Pacific Northwest region of the United States with a 16-bed American Burn Association–verified regional inpatient burn center. Study approval was obtained from the institution's investigational review board before data collection. Data collection occurred from October 2013 to March 2015.

Study Design

A within-subject, randomized controlled trial study design was used to evaluate the effectiveness of an IVR intervention to decrease opioid administration, pain, and/or anxiety in patients undergoing painful wound care. The primary dependent variable for this study was the amount and frequency of opioid medication administration before and during the painful wound care procedure. Participants were random assigned by a computer algorithm to receive IVR with the first or second sequential wound procedure, with no IVR for the other wound procedure. Investigators were blinded to treatment order until before the first dressing procedure was to begin.

Sample Selection

Subjects for this study were adult patients undergoing painful wound care procedures for deep or partial thickness burns of ≥ 5% or complex non-burn wounds, such as necrotizing fasciitis or large decubitus ulcers. Inclusion criteria were prior completion of at least 2 prior painful wound care procedures, need for at least 2 sequential painful wound care procedures before anticipated surgical management, pain level ≥ 5 during the previous wound procedure, and fully sensate in the area requiring painful wound care. Exclusion criteria included medical diagnosis of dementia and/or cognitive impairment, inability to use the computer mouse, and/or physical impediments about the face and neck that would prevent application of the IVR headgear.

A minimum sample size was determined by power analysis to be N = 14 participants, with a total of 28 interventions studied.[29] Power was set at 0.8, alpha at 0.05, and effect size at 0.7. Effect size was calculated to identify at least a 20% difference in opioid administration between the 2 treatments.

IVR Intervention

The IVR system consisted of 4 parts, a laptop computer with video card with the video program (Lenovo T 510 ThinkPad with Intel Core i7 processor and Intel HD Graphics, Leveno, Morrisville, NC), virtual reality goggles (NVISINC MX 90, NVISINC, Reston, VA), earphones (Logitech Wireless Gaming Headset G930, Logitech, Freemont, CA), and background music. Patients looked into the virtual reality goggles that substituted the real world environment with a synthetic, computer-generated image, making the hospital room and personnel invisible (Fig. 1). Patients also wore noise-cancelling earphones to replace the hospital room noise with music and sound effects. The goal is for the patient to become immersed in the virtual world as they interact with the computer program by throwing snowballs at objects in the virtual world by clicking a computer mouse button (SnowWorld, www.vrpain.com., Seattle, WA).

Study Outcome Variables

The amount of intravenous opioid (fentanyl) medication administered before and during the painful wound care procedure was recorded as mcg/kg. A standardized medication regimen was used for all patients and was based on their ideal body weight. All participants received 1.0 mcg/kg of intravenous fentanyl 20 minutes before the start of the wound procedure. During the dressing change, 0.25 mcg/kg of intravenous fentanyl was administered whenever patients request pain medication for breakthrough pain. The number of times the participant requested pain medication during the wound procedure was also recorded.

Pain intensity was measured with a patient verbal report of pain on a 0 to 10 verbal numeric scale (VNS). Zero represented "no pain" and 10 represented "worst possible pain." Numeric pain scales are commonly used rating scales for patient report of symptoms in research involving acutely ill patients because they are easy to understand and do not require manual skills to complete.[30,31] Anxiety severity was measured with a patient report of anxiety on a 0 to 10 VNS. Zero represented "no anxiety" and 10 represented "worst possible anxiety." Validity and reliability are high with numeric rating scales.[29,30]

Participants were asked to complete an investigator developed survey of 6 yes/no questions about the IVR experience. Questions related to the participant's perception of whether the use of IVR during the painful wound care procedure decreased their pain and/or anxiety, was stressful or helpful to use,

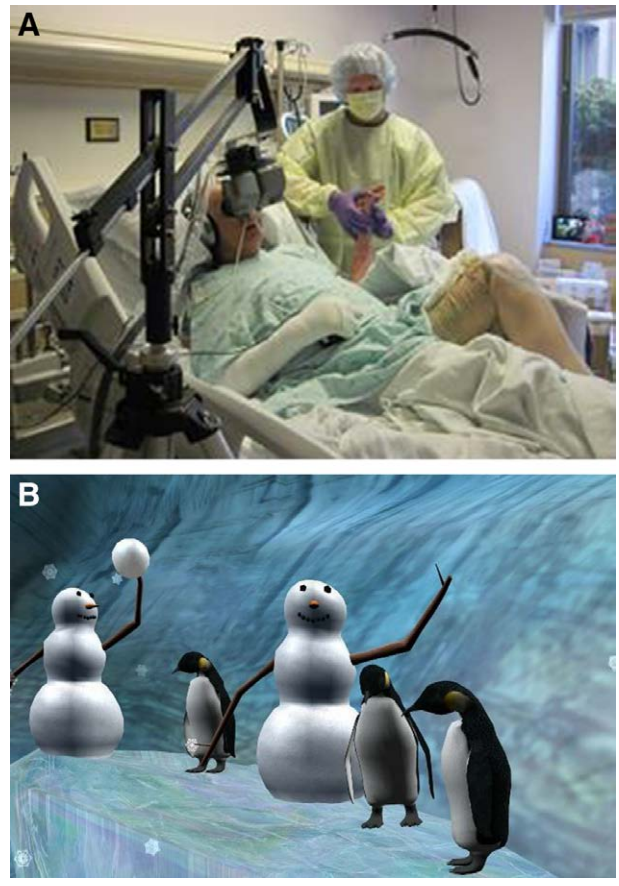

Figure 1. A, Virtual reality goggles and headset being used by a patient during a wound care procedure. B, Image observed by patient when using virtual reality device during the Snow World program designed by Hoffman and Patterson (www.vrpain.com, University of Washington, Seattle WA; used with permission from Hunter Hoffman).

was better than when no IVR was used, and was something they would want to use for future wound procedures. No validity or reliability testing of the investigator developed survey was done.

Study Procedure

Before data collection, investigators (all of whom were experienced burn unit nurses) were trained in the proper use of the IVR equipment and study procedures. Two investigators were present at each painful wound care procedure, 1 operated the IVR equipment and gathered study data and the other conducted the wound care procedure.

Eligible patients were consented by a study investigator. Twenty minutes before each of the 2 wound procedures, consenting participants were given the standardized, preprocedure opioid medication. Pain and anxiety levels were rated by study participants immediately before beginning the wound care procedure. The wound care procedure was then done by a study investigator including removal of the old dressing, wound hygiene, and redressing according to departmental standards for the specific wound type. During the wound procedure, whenever the patient requested pain medication, a study investigator administered additional opioid medication based on a standardized dose. At the conclusion of each wound care procedure, a study investigator had participants rate their pain and anxiety. Following completion of the second wound procedure, the participant was asked to respond verbally to 6 questions about the IVR experience.

For the wound procedure done with IVR therapy, a study investigator instructed the participant in the use of the IVR equipment after preprocedure medication administration. Participants were allowed to practice operation for a few minutes before the initiation of the wound procedure. During the wound procedure, a study investigator stayed at the participant's side to assist with IVR use, if needed, and removed the equipment at the end of the procedure or during the procedure if requested by the participant.

Data Analysis

Data were summarized using descriptive statistics. Changes in pain and anxiety scores before and after the interventions were calculated before data analysis. Student's *t* test was used to determine if the amount of opioid medication administered before and during the wound procedure and/or change in pain and anxiety scores were different for the wound procedures done with or without the IVR intervention. Chi-square analysis was used to compare the number of patient requests for pain medication during the wound procedure with and without the IVR intervention. The level of significance for all tests was $P < 0.05$.

RESULTS

A total of 18 participants were studied over an 18-month period, with 83% of the subjects having a deep or partial thickness burn wound and 17% a nonburn wound (necrotizing fasciitis or decubitus ulcers). Twelve patients (67%) completed both study dressing procedure treatments (with IVR; without IVR) and 6 patients (33%) received only 1 of the 2 study dressing procedure treatments (Table 2).

Table 2. Demographic information and participant characteristics

Demographic Information	Participants (N = 18)
Patient age (yr)*	38.4 ± 15.5
Body weight (kg)*	71.5 ± 8.2
Gender, n (%)	
Male	13 (72)
Female	5 (28)
Type of wound, n (%)	
Partial or full thickness burn wound	15 (83)
Nonburn wound	3 (17)
History of opioid abuse, n (%)	
Yes	12 (67)
No	6 (33)
Treatment order, n (%)	
IVR treatment with first dressing change	10 (56)
IVR treatment with second dressing change	8 (44)
Number of study dressing changes completed	
IVR and no IVR dressings	12 (67)
IVR only	3 (16.5)
No IVR only	3 (16.5)
Minutes for dressing changes*	
IVR	29.9 ± 12.9 (range of 10–55)
No IVR	30.7 ± 15.1 (range of 10–68)

IVR, immersive virtual reality.
*Mean ± SD.

Reasons for not receiving a study dressing procedure were varied (IVR procedure: N = 2, due to inability to operate equipment; N = 1, due to equipment problems; no IVR procedure: N = 1, due to no further need for the dressing procedure; N = 1, due to caregiver miscommunication; N = 1, no explanation provided). Ages ranged from 20 to 73 years, averaging (± SD) 38.4 ± 15.5 years. The majority of participants were male (N = 18; 72%) and 12 of the 18 (66%) participants had a history of prior substance abuse. Treatment lengths were similar for the IVR and no IVR dressing procedure treatments ($P > 0.05$) and treatment order (IVR with first or second study dressing procedure) was not found to be a significant factor in study outcomes ($P > 0.05$).

The amount of fentanyl administered before the wound procedures with and without IVR was similar ($P > 0.05$; Table 3). Total fentanyl administration during the wound procedures with IVR were significantly less than when no IVR was used, 17.9 ± 6.0 and 29.2 ± 4.5 mcg/kg, respectively (t

Table 3. Summary of outcome variables before, during, and after a painful wound care procedure with and without IVR treatment

Outcome Variables	IVR Treatment, N = 15	No IRV Treatment, N = 15
Pain level (0–10)*		
Range	0–10	0–9
Before dressing change	6.9 ± 2.4	6.3 ± 2.6
After dressing change	5.8 ± 2.9	5.7 ± 2.6
Difference (after - before)*	-1.2 ± 2.9	-0.3 ± 1.7
Anxiety level (0–10)		
Range	0–10	0–9
Before dressing change	4.8 ± 2.9	4.1 ± 2.4
After dressing change	3.5 ± 3.0	3.5 ± 2.6
Difference (after - before)*	-1.3 ± 4.4	-0.4 ± 2.7
Amount of IV opioid administered (mcg/kg)		
Before dressing change	71.5 ± 8.2	72.2 ± 7.9
During dressing change	17.9 ± 6.0	29.2 ± 4.5
Total (before + during)†	91.7 ± 10.1	103.1 ± 16.1
Number of requests for opioid administration during the wound procedure		
Average‡	1.0 ± 0.7	1.5 ± 1.0
0§	3	0
1	13	6
2	1	5
3	1	4

IVR, immersive virtual reality.
*$P > 0.05$.
†t = -2.7; df = 14; $P = 0.02$.
‡t = -2.8; df = 14; $P = 0.02$.
§$\chi^2 = 9.9$; df = 3; $P = 0.02$.

= -2.7; df = 14; $P = 0.02$). The number of patient requests for opioid administration during the wound procedure was found to be significantly less in the wound procedures with IVR than without IVR ($\chi^2 = 9.9$; df = 3; $P = 0.02$). Only 11% of the participants requested opioid administration during the wound procedure 2 or 3 times during the IVR procedures, but 60% of participants requested opioid administration during the wound procedure 2 or 3 times when no IVR was used.

Changes in pain and anxiety levels before and after the dressing change procedure are summarized in Table 3. Small, nonsignificant differences in pain and anxiety levels were found between the IVR and no IVR wound procedures ($P > 0.05$).

Overall, the majority of participants thought IRV decreased their pain during the dressing procedure (Table 4). Similar numbers of participants thought anxiety was decreased by IVR. More than 75% of participants found IVR to be helpful and made the dressing procedure better for them. Only 3 of 12 (25%) participants stated that they would not want to use IVR for future dressing changes.

DISCUSSION

This study evaluated the effect of IVR therapy on amount of opioid administration in adult patients undergoing painful wound care procedures in a civilian burn center. During wound care procedures, 39% less opioids were administered when IVR therapy used compared with wound procedures when IVR was not used. Furthermore, 11% of patients requested more than 1 opioid rescue dose with IVR, and 60% of patients requested more than 1 rescue dose without IVR. Changes in pain and anxiety after the wound procedure were similar for both treatments. A majority (> 75%) of patients found IVR helpful, preferred it to no IVR, and stated they wished to use IVR for future dressing changes.

Table 4. Patient responses to questions about IVR after a painful wound care procedure in N = 11 participants

Patient Responses	Yes	No	Do Not Know
Do you think the IVR decreased your pain?	8	4	2
Do you think IVR decreased your anxiety?	7	7	
Did you find the IVR helpful?	10	5	
Did you find the IVR stressful?	6	9	
Which dressing change was better?			
IVR	10		
No IVR	3		
Do you want to use IVR for future dressing changes?	12	3	

IVR, immersive virtual reality.

To our knowledge, our study is the first to standardize the amount of opioid administration during the study procedures and to quantify the amount of opioids administrated before and during the wound care procedures. We believe this is an important component of research studies testing IVR as a pain management adjunct.

Prior studies in adults with very painful procedures found pain to be decreased with IVR compared with no IVR,[26–28] whereas we found no difference in pain with the 2 treatments. Because other studies did not attempt to standardize drug administration, it is difficult to compare those studies with ours with regard to pain levels. Our study had similar pain score changes before and after wound procedures with and without IVR, but the number of participant requests for opioid medication during the procedure was significantly reduced with IVR. These findings likely indicate that either pain levels were not as high during the wound procedure with IVR and/or the use of IVR distracted participants from perceiving their pain during the wound procedure. Another possibility for the lack of pain score differences between groups could be related to the high incidence of substance abuse history observed in our participants. It is possible that their perception of pain is different from nonabusing individuals.

Many prior studies were related to procedural pain for procedures with limited potential to cause severe pain or discomfort (i.e., physical therapy, hand dressings, intravenous catheter insertion, port access, chemotherapy, and pruritus).[5,13,15,21–25]

Two studies reported on anxiety as an outcome measure during wound care. In 1 of these studies,[28] a large number of anxiety scores were missing, making interpretation of the anxiety scores difficult. In a second, small study with only 2 patients, significant anxiety reduction was observed when IVR was used in conjunction with pharmacologic analgesics compared with when pharmacologic analgesics were used alone.[32] While anxiety has been proposed by experts to be high with very painful procedures, the short duration of the anxiety associated with the painful wound care procedure may create difficulties in measuring the phenomenon in a clinical setting.

The majority of patients in our study believed that IVR was helpful during their painful procedure and wished to use it during subsequent dressing changes. Two studies evaluated patient experiences while using IVR. Healthy human volunteers subjected to cold pressor exposure for 1 to 2 minutes stated that

IVR gave them a sense of control over their pain but did not address whether they "liked it" or would prefer it during subsequent cold exposures.[20] A case study report of 2 subjects undergoing combat-related wound care states the experience as "more fun" when IVR was used vs when it was not.[33] We believe our study was unique in that it evaluated the patient's subjective impressions about IVR and their willingness to include it as a consistent component of their wound care regimen.

Limitations

The demographics and characteristics of the participants of this study may limit generalization of findings of this study to other populations. Of interest is that 67% had a prior history of opioid abuse, which may have influenced their preprocedure pain scores both with and without IVR. This may also have made their overall response to IVR distraction therapy different from those without an opioid abuse history. The findings of this study are also limited by the particular type of IVR equipment available at the time the study was conducted. Newer models are less cumbersome and may be easier and more practical to use in clinical settings. Another limitation of the study is that the use of a VNS to measure anxiety may not have been sensitive enough to detect small changes in anxiety associated with IVR. Future studies should consider measuring anxiety with a more extensive anxiety survey, such as Spielberger's State Anxiety survey.[34,35]

Clinical Implications

IVR as distraction therapy during extremely painful procedures should be considered as an adjunct to analgesic administration for painful wound care procedures. A reduction in total opioid administration similar to that found in this study could be especially beneficial in situations where the painful procedure needs to be done on more than 1 occasion. The risk of tolerance to opioids and the need to increase doses with continued use due to physical dependence on opioids could potentially be minimized. Patients liked the use of this technology and preferred it to wound procedures without it. Given that a top clinical and patient satisfaction priority is to minimize patient pain and anxiety, IVR should be added to the list of nonpharmacologic strategies for improving the patient experience.

CONCLUSIONS

IVR during painful wound care procedures significantly reduced the amount of opioid medication administered during the procedure compared with no IVR. Despite receiving 39% less opioid medication during wound procedures with IVR, changes in pain and anxiety levels before and after the dressing change were similar to no IVR dressing changes. The majority of participants in this study thought IRV was easy to use and wanted to use it on future wound procedures.

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