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Repeated Use of Immersive Virtual Reality Therapy to Control Pain during Wound Dressing Changes in Pediatric and Adult Burn Patients

Albertus W. Faber, MSc¹, David R. Patterson, Ph.D., ABPP, ABPH², and Marco Bremer, MSc³

¹Department of Medical Psychology, Martini Hospital, Groningen, The Netherlands ²University of Washington, Department of Rehabilitation Medicine, Seattle, USA ³Burn Centre, Martini Hospital, Groningen, The Netherlands

Abstract

Objective—The current study explored whether immersive virtual reality continues to reduce pain (via distraction) during more than one wound care session per patient. Patients: Thirty six patients aged 8 to 57 years (mean age of 27.7 years), with an average of 8.4% total body surface area burned (range .25 to 25.5 TBSA) received bandage changes, and wound cleaning.

Methods—Each patient received one baseline wound cleaning/debridement session with no-VR (control condition) followed by one or more (up to seven) subsequent wound care sessions during VR. After each wound care session (one session per day), worst pain intensity was measured using a Visual Analogue Thermometer (VAT), the dependent variable. Using a within subjects design, worst pain intensity VAT during wound care with no-VR (baseline, Day 0) was compared to pain during wound care while using immersive virtual reality (up to seven days of wound care during VR).

Results—Compared to pain during no-VR Baseline (Day 0), pain ratings during wound debridement were statistically lower when patients were in virtual reality on Days 1, 2 and 3, and although not significant beyond day 3, the pattern of results from Days 4, 5, and 6 are consistent with the notion that VR continues to reduce pain when used repeatedly.

Conclusions—Results from the present study suggest that VR continues to be effective when used for three (or possibly more) treatments during severe burn wound debridement.

Keywords

virtual reality; burn; wound care

INTRODUCTION

One of the greatest challenges to burn care is managing the pain associated with ongoing procedures. The pain experienced by severe burn patients during medical procedures varies widely from day to day, but is often severe in intensity^{1–3}. Health care providers are faced with the challenge of helping severe burn patients cope with painful and distressing daily wound care and physical therapy/occupational therapy procedures¹ and patients' pain ratings

during the acute phase range from mild to excruciating². The control of such pain is complicated because, as patients are repeatedly subjected to painful medical procedures, patients understandably link the pain to anxiety^{1, 4}. Pain during hospitalization is a strong predictor of psychological adjustment at 1-month to 2-year follow-up⁵. Hence pain management after burn injuries is an important part of a comprehensive treatment program⁶ that involves multiple modalities, including long and short-acting opiates, anxiolytics, and non-pharmacological techniques⁷.

Opioid analgesics remain the primary treatment for acute burn pain, but pain medications have a number of negative side effects that limit use. Heavy reliance on pain medications can increase hospital stay, and pharmacologic interventions often do not eliminate all burn pain¹. Because of the repetitive, often daily nature of painful burn wound debridement/cleaning, there is also a high risk for developing a physiologic tolerance to (and possible dependence on) opioid analgesics⁸. Both the economic and psychological costs of using only pharmacologic analgesics for burn pain management contribute to the motivation to identify adjunctive non-pharmacologic analgesic treatments that can improve burn related pain management and reduce opioid analgesic drug use⁸.

Psychologically based adjuncts to pain medications are particularly attractive because they seldom have side effects. Examples of such psychological interventions include information, cognitive-behavioral interventions, distraction, and hypnosis⁹. In general, such approaches seem helpful in making burn pain more manageable, and can be used in addition to conventional pharmacologic analgesics. However, the pain associated with treating severe burn injuries is often so profound that, while such approaches are helpful, conventional adjunctive non-pharmacologic pain treatments currently still fall short of having any major effect on this problem.

Immersive virtual reality (VR) offers a psychologically based approach to pain that appears to have unusually powerful and promising analgesic effects. VR diverts attention away from the pain during acute procedures by immersing patients in a computer generated environment¹⁰. Typically, patients use a head mounted three dimensional visual screen to interact with the computer environment in order to draw attention away from their pain. A number of studies have demonstrated that computer generated immersive virtual reality environments are effective for reducing not only laboratory induced pain^{11–17}, but preliminary studies suggest VR can also help reduce procedural pain from non-burn etiologies (dental pain^{18, 19}; urological endoscopies²⁰; cerebral palsy²¹; discomfort during treatment for cancer^{22–24}; and pruritus/itching²⁵). Most of the clinical research with VR has studied burn pain, and a number of clinical series, as well as controlled trials exploring VR distraction during medical procedures of severe burn patients have been reported, generally with good results^{26–35}. However, these studies have tended to involve small subject samples and often focus on the pain from joint range-of-motion physical/occupational therapy exercises, pain that can be significant but is not the worst that comes with burn care. Further, the results of these studies are very often limited to one medical procedure on only one day^{26, 36, 37}. To date, there are little data on the impact of VR on pain during multiple sessions of wound debridement and/or cleaning. One pilot study reported encouraging results from seven burn patients who received VR during wound cleaning³⁸. If VR only works the first time it is applied to patients during severe burn wound cleaning session, its clinical value will be limited in actual care.

The purpose of the current study was to replicate the few studies that have reported VR during burn wound care with a larger sample size. We also wished to report on the repeated use of VR analgesia with a subset of the sample. The current study addresses this issue of whether VR continues to reduce pain when the same patient receives VR during two or more

burn wound debridements. Using a within-subjects design, we compared pain during a no-distraction baseline condition (conventional treatment) to pain during one (n = 36), two (n = 30), three (n = 17) and up to seven separate VR wound care sessions per patient.

METHODS AND MATERIALS

Participants were treated with VR therapy during the first 14 days of admission, and studied using a baseline-post treatment comparison. Immersive VR was limited to the period before initial surgery. Normal analgesic regimen was continued; opioid equivalent oral doses were calculated. Data collection was quantitative using self-report rating scales.

Study population

Participants were thirty-six consecutive patients who ranged in age from 8 to 57 years old (mean age = 27.7 years old, SD = 15.2) who were hospitalized in a major regional burn unit in the Netherlands from 1-01-2005 until 1-07-2008 and met the following inclusion-criteria: ability to communicate meaningfully, Dutch speaking and reading/writing ability, and an expected hospital stay in the burn unit for at least 4 days. Patients with pre-morbid psychiatric illness, physical impairments that preclude VR therapy (e.g., facial burns), a history of seizure disorders, or the need for intensive care were excluded from this study.

During the study period, 239 burn survivors who ranged in age from 8 to 57 years were admitted to the burn unit for 4 days or longer. Patients were included in the study only if they were anticipated to have a minimum of two days of burn wound care. A total of 203 patients were excluded from the study for the following reasons: 45.3% had a physical impairment like facial-burns or other technical exclusion criteria (such as wound care limited to showers; VR systems cannot get wet); 18.7% of the patients suffered from acute or chronic psychiatric symptoms at the time of admission to the hospital (information based on intake-reports); 14.8% needed intensive care; 8.9% had poor Dutch proficiency. Eighteen persons (8.9%) refused to participate in the study; five patients (2.4%) were consented but did not complete at least one VR session or baseline pain score was not registered, and two patients (1%) were excluded because of relevant comorbidity; one patient had a history of seizure disorder and one patient was blind. Persons who were excluded from the study were on average 13.2 years older ($p < .01$). There were no statistically significant differences with regards to gender, total burned surface area, percentage full thickness skin loss, hospital stay or number of surgical procedures.

Measures

Visual Analogue Thermometer (VAT)—The VAT is a burn specific pain rating device developed by Choiniere and colleagues⁴¹ with scientifically recognized psychometric qualities⁴². The Visual Analogue Thermometer (VAT) consists of a 10-cm tall visual “thermometer” representing a continuum with the ends marked “no pain” and “unbearable pain”. Subjects were asked to mark the thermometer at a point corresponding to the worst pain intensity they experienced during wound care, and distance was evaluated to the nearest mm. The VAT is based on the measurement properties of the visual analogue scale, often used as a reliable measurement tool of pain and personal well-being^{43–45}. In the present study, worst pain VAT score during wound debridement was measured immediately after the wound dressing change procedure.

Procedure

After informed consent of the patient and, when the patient was younger than 18 years, also the informed consent of the parent(s), the patient could participate in the study. All subjects received some type of pharmacologic analgesics including opioid analgesics using the

normal burn unit regimen. To determine the presence of adverse effects due to the VR, after each trial the subjects were asked whether or not they felt any nausea during the VR administration, and responses were recorded for analysis. Pre-treatment nausea was not assessed; only nausea that was perceived by the patient to be a side effect of VR treatment.

Using a within subjects design, worst pain intensity VAT during wound care with no-VR (baseline, Day 0) was compared to pain during wound care while using immersive virtual reality (up to seven days of wound care during VR). Other data relevant to predicting patients' response to treatment were collected (e.g., personality traits); however, these data will be reported in a subsequent study.

VR Technology

In this study the Cybermind Hi-Res900_{ST}TM -3D Head Mounted Display with a field of view of (Low-tech) 31.2° diagonal degree was used with an integrated audio system and controlled by a FasTrak® control-box: the Polhemus FasTrak 6 DOF motion tracking system and StarTech 4 port VGA/Video splitter, connected with a Dell® 650 Precision Workstation with Pentium IV processor, 2.392 Ghz (2 processors: HyperThreading Technology); Physical Memory: 2047 MB, Free memory: 1829 MB; Operating System: Windows 2000, SP 3 + Virtools® Web Player Network Configuration; Display Mode: 1024 × 768 (32 bit); NVIDIA Quadro FX 1000 (126/128 MB) graphic card; IVR-software, SnowWorld version 2.1 (2003) was used (www.vrpain.com).

Pain medications—Patients were medicated for pain with paracetamol during hospital stay from admission to discharge and dosing was determined by age. The mean dose recorded in the patient sample was 32.8 mg/kg per 24 hours (min-max: 16.7–62.0; SD 10.7; Median 31.5). For background, breakthrough and procedural pain, patients also used opioid analgesics including enteral morphine, transdermal fentanyl, intramuscular piritramide, and/or oral tramadol. To calculate total opioid analgesic usage, doses were standardized by calculating the oral morphine equivalent dose (OME) dose per 24 hours. The following formula was used: morphine suppository mg/24 hours multiplied by 1.0, transdermal fentanyl mcg/hour multiplied by 3.6, intramuscular piritramide mg/24 hours multiplied by 0.8, and oral tramadol mg/24 hour divided by 3.0. In addition to the several opioid and non-opioid analgesic medications administered regularly for background pain, enteral morphine and piritramide were administered on a PRN (as needed) basis to address procedural pain. The mean opioid analgesic usage for *background* pain in our sample per kilogram body weight per 24 hours was 1.60 mg (min-max: 1.05 – 2.57; SD 0.5; Median 1.42). The mean *procedural* opioid analgesic usage in our sample per kilogram body weight was 0.16 mg (min-max: 0.11 – 0.42; SD 0.1; Median 0.13).

Statistical analyses

Differences between pain intensity during no-VR (baseline) and pain intensity during VR was tested using within-subjects paired t-tests. All patients were compared to a baseline of wound care with medication only and no VR. However, this baseline often did not occur on the first day of hospitalization, and patients often had several wound care sessions before their baseline day (i.e., before the first study day). The baseline wound care occurred within the first two weeks of hospitalization and was based on factors such as when patients were out of intensive care and stable and alert enough to participate in the study. All effects are reported as significant at $p < .05$. All analyses were executed using SPSS Statistics version 20 (release 20.0.1).

RESULTS

Thirty six patients participated in the study (i.e., completed at least one “no VR” baseline and one VR treatment). These patients were predominantly male (83.8%) and were, on average, 27.9 years old ($SD = 14.8$). Patients had an average length of hospital stay of 23.2 days (5–63; $SD = 11.8$), had undergone, between admission and discharge, but after the VR study period, on average 0.78 (0–2; $SD = 0.75$) surgical procedures, and their TBSA ranged from 0.25 to 25.5% ($M = 8.4$, $SD = 6.6$). The percentage full-thickness skin loss ranged from 0–16% ($M = 2.8$; $SD = 4.1$). Participants used VR on at least one and up to seven consecutive days ($M = 2.8$; $SD = 1.4$) during wound dressing procedures. Thirty-six patients (100%) completed at least one wound care session in VR, 30 patients (83%) used VR during two or more wound care sessions and 17 patients (47%) used VR for three or more VR wound care sessions (see Table 1). None of the patients reported side effects of VR intervention (e.g., nausea). Although not formally assessed, some patients reported mild pre-treatment nausea that was thought to be associated with opioid analgesic use. In no cases did patients report a worsening of nausea or attribute it to VR use. No correlations were found between the reduction in pain ratings and demographic variables such as age, sex, duration of hospital stay, or percentage of (deep) burns.

VR and burn Pain

Procedural VAT pain scores—Using within-subjects paired t-tests, each patient’s pain during wound care with no VR (baseline, day zero) was compared to the same patient’s pain ratings during wound care during VR on up to seven treatment days (see Figure 1).

DISCUSSION

Results of the current study show that VR reduced the amount of pain reported on more than one dressing change/wound debridement session per patient. To our knowledge, this is the first large multi-patient study to test whether VR analgesia remains effective for reducing pain during burn wound care, when VR is used more than once per burn patient.

Although the current study provides encouraging preliminary evidence, additional research is needed. The within-subjects design used in the present study generally has more statistical power than a between-groups design. However, future studies using a between groups experimental design are still needed. The declines reported in the present study could be potentially partially due to historical factors (e.g., due to natural healing) and might lead to overestimation of the amount of VR analgesia. A between-groups design could isolate the influences of VR more carefully. Although we were able to report that pain ratings went down with repeated use of VR, only 83% received VR for two or more treatments, and only 47% of the sample received VR three or more sessions. However, this is the largest sample VR wound care study to date.

The software used in this study (SnowWorld 2003) appears to be powerful in its ability to capture attention and is particularly appropriate for patients with burn injuries (given the illusion of coolness that is encouraged); however, this is one of the early worlds that has been created for medical and pain applications in general, (a more recent version of this software is now available; www.vrpain.com). The VR helmet used in the present study is an earlier “low tech” model, and has a relatively narrow field of view (31 degrees diagonal). This limits the amount of peripheral vision stimulated, and patients can see the hospital room out of their peripheral vision. Future studies using a higher quality (e.g., wider field of view) VR helmet now available (e.g., the MX90 with 90 degrees diagonal field of view, from www.nvisinc.com) will likely show even stronger analgesic effects¹⁴. As hardware and

software technology improves, the ability to reduce pain using immersive virtual reality is likely to increase in the future (see review⁴⁶).

To date, the current study is the largest sample of hospitalized burn patients to receive VR distraction while undergoing bandage changes/wound debridement. The present findings are encouraging regarding the potential for developing VR into a powerful analgesic technique that does not have pharmacological side effects. Research to date suggests VR has few if any side effects (there is the potential of motion sickness which has thus far been avoided⁴⁶).

The size of the analgesic effects in the current study and the finding that VR continued to reduce pain when used repeatedly (i.e., over multiple debridement sessions) represent an encouraging advance in the field. Future studies further exploring how effectively VR reduces pain when used for multiple debridement sessions are justified and needed. For example, a patient with a large burn may require 30 or more wound care sessions lasting 30 minutes or more per day and in addition, may require 30–60 or more physical/occupational therapy range-of-motion sessions. Whether VR continues to be effective under those conditions is an important topic for future research.

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Figure 1.
Virtual Reality distraction remained effective over multiple treatments.

Table 1

Paired t-test results of Baseline VAT pain scores/Opioid-usage (OME/kg/day) compared with VR VAT pain score/Procedural Opioid-usage of the 1st-7th day VR

	VAT pain scores				Procedural Opioid usage			
	<i>On</i>	<i>df (n-1)</i>	<i>t</i>	<i>p</i>	<i>SD diff.</i>	<i>t</i>	<i>p</i>	<i>SD diff.</i>
Day 1		35	2.939	.006	2.23	0.793	.433	0.05
Day 2		29	2.145	.040	2.17	0.792	.435	0.05
Day 3		16	2.262	.038	2.22	-1.444	.168	0.05
Day 4		6	-0.034	.974	2.22	-1.508	.175	0.07
Day 5		2	4.214	.052	0.81	*	1.000	0.00
Day 6		2	4.105	.055	1.21	*	1.000	0.00
Day 7		0	*	*	*	*	*	*

* Scores are equal or not analyzable (n=1)