2021

Effectiveness of Virtual Reality on Reducing Pain in Burn Patients

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EFFECTIVENESS OF VIRTUAL REALITY ON REDUCING PAIN IN BURN PATIENTS

by

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A thesis submitted in partial fulfillment of the requirements
for the Honors Undergraduate Thesis Program in Nursing
in the College of Nursing
and in the Burnett Honors College
at the University of Central Florida
Orlando, Florida

Spring Term, 2021

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Abstract

Burn patients undergo excruciating levels of pain throughout their treatment in the hospital. Pain levels increase during medical procedures, such as wound care and debridement. As a part of the treatment plan, traditional pharmacologic interventions are provided. Over time, patients become tolerant of pain medications, specifically opioids. The developed tolerance contributes to more pain felt by the patient. Medical providers limit the number of opioids prescribed to prevent addiction and other adverse effects, contributing to the challenge in treating burn pain. Virtual reality (VR) has been studied as an intervention across various settings to alleviate distressing symptoms in patients. Many studies have shown a relationship between virtual reality and a reduction in pain levels. This thesis reviewed published research when virtual reality was used as an intervention to reduce pain levels in burn patients. A total of 8 studies were analyzed to determine if there was a relationship between these variables and were included in this literature review. Multiple databases were utilized to find articles, including Applied Science and Technology, CINHAL, Cochrane Central Register of Controlled Trials, Medline, Psychinfo, University of Central Florida (UCF) libraries catalog, and Health Source Nursing/Academic edition. Search terms related to virtual reality, (VR, augmented reality, AR, and virtual environment) and burns (burn, burn patients, burn units, and burn nursing) were used, in addition to the term pain. Based on the results of this literature review, those working with burn patients can use and recommend the use of VR during painful procedures with confidence.

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Purpose

Burn patients undergo excruciating pain, especially during procedures such as wound care and debridement. Opioids are one of the main pharmacologic treatments for burn patients (Sinatra, 2010). However, tolerance of opioids unmasks the pain the burn patient feels (Sinatra, 2010). Virtual reality is being investigated as an intervention to reduce pain. The purpose of this literature review is to appraise the current literature and examine the outcomes of pain in burn patients when utilizing virtual reality during wound care. Lower pain levels would support the claim that virtual reality (VR) is an effective intervention in pain reduction in burn patients.

Introduction

Burn patients face acute and chronic pain with their injuries. Depending on the total body surface area and depth of skin burned, lasting effects can incur. Pain is defined as, "a multi-dimensional entity involving sensory, cognitive, motivational, and affective qualities" (Elavarasi, & Kumar, 2016, p. 89). Treating pain is important because it affects the psychosocial and physiological well-being of the patient. Pain that is left untreated can impair sleep, immunity, and appetite, all of which are extremely important for healing. Patients with chronic pain are more likely to experience physical disability, social isolation, and mental health disorders, such as depression and anxiety (Fraser & King, 2013).

Pain is the primary reason people decide to seek medical services (Fishman, 2007, p. 9). Burns produce a cascading physiological response causing the patient immense pain. When a burn is experienced, systemic inflammatory mediators are released activating receptors which transmit painful stimuli to the brain. Burn patients require a higher acuity level of care due to the complexities of their injuries. Severe burns cause intravascular fluid depletion and electrolyte shifts inducing cardiovascular consequences. Burns invade the layers of the skin which naturally provide defenses against microorganisms, thus increasing risk of infection. The physiological response to a burn injury predisposes the patient to developing septic shock and multiple organ dysfunction syndrome (Greenhalgh, 2017). Multiple organ dysfunction syndrome involves two or more organ systems (Marshall, 2001). It is progressive damage or failure to organ systems following the sustained injury (Greenhalgh, 2017). The complexities of managing burn patients' care may lead physicians to be more concerned about their emergent physical needs.

Fluid resuscitation is a necessary treatment for burn patients (Greenhalgh, 2017). Burn patients lose intravascular fluid when their injuries are sustained and thus, need fluids to maintain systemic volume and circulation. In addition to fluid resuscitation, procedures such as wound debridement and dressings are necessary because it removes nonviable skin which can serve as a host for microorganisms (Browning & Cindass, 2020). Patients endure pain during these procedures. Traditional pharmacologic treatments, such as opioids are used to manage burn pain. Unwanted side effects such as constipation, nausea, vomiting, and respiratory depression accompany opioid usage (Bittner et al., 2017). Tolerance can develop, where the patient needs a higher dose of the medication to achieve the same effect (Bittner et al., 2017).

Virtual reality has been gaining popularity since the release of the Oculus Rift in 2012 (Cipresso et al., 2018). The Oculus Rift is a piece of equipment that attaches around the head with a band and covers the eyes with goggles and a display screen to view the software. Virtual reality is a new tool being evaluated for use in clinical settings. Virtual reality systems can differ and can be used for different reasons. Researchers have been evaluating use in surgeries, rehabilitation, and training programs (Satava & Szekely, 1999 & Pottle, 2019). Virtual reality is flexible and can be applied to various clinical settings. Although the systems and equipment require set up by a familiar user, the equipment is often small and portable. When using virtual reality, the user is sometimes able to choose the environment in which they interact and become immersed within. Virtual reality does have disadvantages. It is expensive, can cause motion sickness, and requires training for both the patient and the provider to utilize the software (Wiederhold & Wiederhold, 2007). A challenge to utilizing virtual reality equipment for burn patients is for patients with burns to the head and neck. Much of the equipment consists of head mounted displays and goggles. Head mounted displays and virtual reality goggles are not feasible when there are burns to the head and neck due to the need to access this area for treatment. There is an increased risk of infection as the equipment is not sterile, and if the equipment touched the burned areas, it would cause pain (Al-Ghamdi et al., 2019). For this reason, patients with burns to the head, neck, and face were excluded from participating in research studies.

Background

Pain Theories

There are different theories to explain how virtual reality can impact pain. The Gate Control Theory explains how pain is relayed from the periphery into the brain. A painful stimulus is felt in the periphery. The stimulus then travels from the site of injury through the spinal cord. When it is traveling through the spinal cord, pain impulses are modulated through gates, or channels. These gates can either remain open, allowing the impulse to travel to the brain where it is processed and pain is felt, or the gate can close, blocking the impulse from being relayed, thus, little to no pain is felt (Katz & Melzack, 2004). Prior to this theory, it was generally believed pain was due to a physical injury which harmed the tissues. This theory explained how pain was impacted by psychosocial factors. The Gate Control Theory went on to explain that external factors have the potential to negate the painful stimuli from being received by the brain.

The Neuromatrix Theory was released after the Gate Control theory but served as an extension to it (Melzack, 1999). The Neuromatrix Theory elaborates on aspects that contribute to pain. This includes the neuromatrix, which is a group of neurons that process nerve impulses. This theory explains the neuromatrix as multi-dimensional and develops as a result of someone's experiences, genetics, memory, and emotions. All of these aspects of the neuromatrix contributes to how the pain is interpreted and felt. In summary, the Neuromatrix Theory describes pain as being a result from physiological and psychological factors.

The Multiple Resource Theory explains attentional and multi-tasking capacity. It states there are multiple resources which process attentional stimuli in the brain, but can be separate from one another, enabling people to pay attention to many different stimuli at once. However, these attentional resources are limited. A task increases in difficulty when it utilizes multiple resources (visual, auditory, and tactile, for example). When a person is completing a demanding task utilizing multiple resources, it limits the ability to complete an additional task or process additional stimuli without the initial task being disrupted (Chen et al., 2011). In summary, a person has a limited number of resources to pay attention to stimuli. As tasks occupy these resources, it limits the amount of sensory information a person can process. Since VR occupies various sensory information, it is theorized it can limit the pain a person can feel.

Pathophysiology of Burn Pain

Burns trigger a massive inflammatory response. Inflammatory mediators are released, causing vasodilation and permeability of blood vessels. Inflammatory mediators cause pain by activating the nociceptors and increasing their sensitivity (Kidd & Urban, 2001). Burn pain is also generated by nociceptors when they react to heat, mechanical, and chemical stimulation. Depending on the depth and extent of the burn injury, nerve endings may be exposed which contribute to initial and chronic pain. A loss of a nerve ending can lose all sensations in that particular area. An open or damaged nerve ending is what contributes to chronic pain (Judkins & Norman, 2004). Primary and secondary hyperalgesia further exacerbate pain the patient feels throughout their treatment. Primary hyperalgesia is pain due to inflammatory mediators at the initial site of injury. This happens immediately, but it also sensitizes the nociceptors to touch, causing pain during dressing changes and debridement. Secondary hyperalgesia is pain surrounding the injury, due to increased stimulation and receptiveness of pain receptors and nerve fibers. This contributes to chronic pain, but is also felt during tactile stimulation, as in dressing changes and debridement (Judkins & Norman, 2004).

Sequelae of Burn Pain

Untreated pain has negative consequences for the patient and can contribute to negative health outcomes (Sinatra, 2010). The consequences of untreated pain include disturbed sleep, impaired physical movement, and a reduced quality of life, all of which are contributing factors to the negative health outcome of impaired healing. Impaired healing in turn increases susceptibility to infections (Sinatra, 2010). Burn patients lose massive amounts of fluids, reducing their overall cardiac output and potentially compromising circulation to all of the organs in their body. Burns destroy the skin and breaks down the natural protections the skin produces to fight against infections. The fragility and decreased defenses of their skin places them at high risk for invasive microorganisms to infect. Additionally, psychological distress is the most common consequence of a burn injury (Agarwal et al., 2010). Both physiological and psychosocial stress increases patients' risk of infection. Due to these complexities of their care, providers may focus on emergent physiological needs as opposed to pain and could cause pain to remain undertreated. In a study conducted on pain management and relation to length of hospitalization, it was found that untreated pain contributed to a longer length of stay (Abbasi et al., 2015). Depending on the size and location of the injury, burn patients are complex patients due to the physiological toll burns have on the body.

Additionally, untreated and undertreated acute pain can cause chronic pain (Judkins & Norman, 2004). Destruction and damage to nerves can cause neuropathic pain, which becomes chronic (Judkins & Norman, 2004). In addition to physiological effects of untreated pain, they also impact the psychosocial wellbeing of the patient. According to Agarwal et al., studies showed consequences from burn pain included “acute stress disorder, depression, suicidal ideation, and post-traumatic stress disorder for as long as 2 years after the initial burn injury” (2010, p. 136). In addition to feeling pain, burns are extremely disfiguring and damaging to the skin. According to Agarwal et al., it is common for burn patients to feel dissatisfied with their appearance post-burn (2010). Disfigurement can contribute to PTSD and stress disorders in burn patients. Psychological distress promotes a sensitive and vulnerable state for burn patients.

Pharmacological Therapy

Analgesics, specifically opioids have been the main treatment to manage pain in burn patients (Ainsworth et al., 2019). However, opioids have unpleasant side effects. These include respiratory depression, constipation, and nausea (Ainsworth et al., 2019). An expected consequence of opioid usage is tolerance. Tolerance indicates the patient needs higher levels of opioids to achieve the same effect. Since burn patients have pain throughout their hospitalization, tolerance makes it difficult to adequately manage pain. As patients progress in their care and opioids are discontinued, they also experience unpleasant symptoms such as nausea, anxiety, and headaches (Joseph et al., 2009). This occurs because of physical dependence on the opioid throughout their hospitalization. Due to the history of opioid misuse, providers may be less willing to prescribe them and more skeptical (Ainsworth et al., 2019). Additional therapies are being sought to reduce opioid usage while still providing optimal pain management. These therapies include hypnosis, music, massage, and aromatherapy (Ainsworth et al., 2019).

Methods

A literature review was conducted analyzing articles published in peer reviewed journals. These articles were found utilizing the following databases: Applied Science and Technology, CINHAL, Cochrane Central Register of Controlled Trials, Medline, Psychinfo, UCF libraries catalog, and Health Source Nursing/Academic edition. The inclusion criteria for the search included the adult population (ages 18 and older) and articles published in English within the past ten years. While characteristics of the participants varied, generally participants had to have a burn or burn stimulus, sufficient visual acuity and physical ability to utilize the software. Studies did have exclusion criteria which generally consisted of no cognitive impairments since it has the potential to impact the ability to use the software and communicate outcomes, no preexisting pain conditions other than the thermal injury, and no burns to the head or neck since it impacts the ability to utilize the equipment. The search criteria included pain, terms related to virtual reality (augmented reality (AR), virtual environment, or virtual reality (VR)) and terms related to burns (burn units, burn patients, burn nursing, or burn). The initial search resulted 32 articles. Twenty-six articles were removed upon analyzing the abstracts. The reasons for exclusion included not being related to the topic, using the pediatric population, or being literature reviews themselves. Six articles remained. Two additional articles were integrated into this literature review upon analyzing the references of a literature review regarding this topic. A total of eight research articles were reviewed.

Findings

Aballay et al. (2018) conducted a study on ten participants where all participants experienced VR during burn wound care. Eight VR applications were offered. Prior to the procedure, the participants were able to explore the eight applications and familiarize themselves with the equipment to ensure a timely start of wound care. During the start of the procedure, the research staff briefly helped the participants with the VR equipment, and the provider explained the wound care process. Research staff told the participants the VR system could be removed at any time per participant preference. Participants used a renovated iPod Touch placed inside of a Sunnypeak VR headset. Headphones were optional and based on participant preference. This equipment was chosen because of its lower cost in comparison with other VR equipment (approximately $200 U.S. dollars). Research staff collected notes on how long VR was utilized, whether the participant asked to remove the VR system, and whether the participants wanted to change the application to a different one. After the procedure, the participants completed a survey and a semi-structured interview. The survey consisted of the participant self-reporting demographics and five questions on a 4-point Likert-type scale to measure the satisfaction of their wound care. The semi-structured interview assessed whether the participant believed VR was feasible and effective, the advantages and disadvantages of utilizing VR, and improvements that could be made with VR. Many participants reported that VR decreased their pain some or a lot, and they were likely or very likely to recommend VR. Four qualitative themes were derived from the semi-structured interviews: tolerance of procedure, medical provider interactions, logistical concerns, and potential VR applications. All participants found the procedure to be beneficial, well-tolerated, and able to reduce pain. The participants believed too many providers were present in the room during wound care and thought communication between research staff and medical providers could have been improved to optimize VR's effectiveness. A participant reported their glasses moved around frequently under the headset, disrupting VR. Participants reported the sounds from VR while using headphones helped them feel more immersed, however some had trouble hearing the provider. Participants also mentioned the applications were short and should have lasted longer. The participants reported VR could be beneficial to children and that VR should be kept in all rooms as an option for patients.

A qualitative within-subjects study conducted by Babiker et al. (2019), consisted of five participants who experienced three dressing changes, one with active VR, one with passive VR, and one without VR. The order of these conditions varied between participants. This study also collected data regarding staff perceptions of VR, and thus consisted of three nurses who completed a post-study discussion to assess the feasibility of VR. An Oculus Rift CV1 headset and a PC were used among participants to provide a feeling of immersion during the VR experience. Two active VR scenarios were used, named Basket and Flocker, both of which were developed by burn survivors and researchers. Additionally, these scenarios were tested under experimental conditions and shown to be pleasant and able to reduce pain. Passive VR included watching videos from the Oculus video application. Dressing times varied widely, from twelve to seventy minutes. Patients were interviewed at the end of the two VR sessions, and at the end of the other three sessions. Questions evaluated pain during the procedures, satisfaction with the procedures, effectiveness of VR, and which VR experience was preferred. A digital recorder was used to record the staff members conversations post-conference. They discussed their experiences and how it impacted the dressing changes, the impact it had on patients, and the challenges to using VR technology. Themes were derived from the data collected from both the participants and nurses. These themes included: caution replaced by contentment, distractions and its implications for pain and wound care, anxiety, control and enjoyment, and preparation and communication concerns. The participants noted they were afraid and suspicious of using VR but realized upon using it that it helped their pain, and they were looking forward to using it again. Nurses noted that the VR seemed to have a positive impact on participants and wished to be a part of future VR research. Participants noted during wound care when they were in the active VR group it helped distract themselves from pain. They also commented when using headphones and goggles, they could not see or hear the nurses performing the wound care so they could not focus on what was happening to themselves. Nurses found themselves being able to remove more dead tissue and perform higher amounts of wound care because the patient's pain tolerance when using active VR allowed them to do so. Participants described the VR scenarios as fun and enjoyable. They noticed when they had the opportunity to familiarize themselves with it before wound care, it decreased their anxiety level before the procedure. Nurses also noticed participants seemed less anxious. Participants did note the nurses were not familiar with VR and could not explain how it worked. Participants and nurses believed better preparation and training would amend this problem. Nurses also struggled with wanting to talk the patient through what was happening during the wound care, but simultaneously did not want to distract the patient and inflict pain from the VR.

A randomized controlled study conducted by Atterbury et al. (2018), measured pain on burn patients undergoing wound care. The study had a within-subjects design, where the participants experienced burn care with and without VR. Eighteen participants were recruited, but only 12 were a part of both groups. The VR equipment for this study included a gaming laptop, VR goggles, headphones, and background music. SnowWorld was utilized as the virtual environment. The researchers included headphones with background music to diminish the hospital environment and fully immerse the patient. Fentanyl was administered intravenously (IV) before wound care. The medication was standardized based on ideal body weight. Prior to the dressing change, participants received one microgram per kilogram of body weight, while during the dressing change, participants were administered 0.25 micrograms per kilogram of body weight for breakthrough pain. Pain was measured using the verbal numeric scale from 0-10, with 0 representing no pain, and 10 representing worst pain. Anxiety was also measured on the verbal numeric scale from 0-10. Participants were also asked to complete six yes or no questions about their experience with VR burn care. The results showed fentanyl administration was significantly higher with no VR in comparison with VR. Nonsignificant differences in pain and anxiety were found between the VR and no VR groups.

A randomized controlled trial by Ebrahimi et al. (2018), measured the effects of virtual reality on burn patients' pain during dressing changes in comparison with a multimedia system in a burn unit in Iran. The researchers used convenience sampling to pick their participants from a burn unit. Sixty burn patients participated in the study, with twenty patients randomly selected for each group (control, VR, and multimedia system). Demographic data was collected and analyzed using Chi-square test to ensure each group had similar characteristics. The VR system consisted of images and waterfall sounds being played through a VR specific headset. The same images and sounds were played to the multimedia group, with the difference being they were played through a TV screen. The participants had the same intervention they were assigned to for five consecutive days with one dressing change each day. Pain during dressing changes was measured utilizing the visual analog scale. There was no significant difference between the virtual reality and control groups. The multimedia group significantly reduced pain in comparison with the control group on the second, third, fourth, and fifth days. The multimedia system showed a significant decrease in pain levels in comparison with the VR group.

A study conducted by Babiker et al. (2018) analyzed VR under experimental conditions. This study utilized a cold-pressor test and tested four VR scenarios on fifteen healthy college participants. Participants with preexisting health conditions, including mental health diagnoses, migraines, fibromyalgia, and injuries were excluded because the researchers did not want pain from any underlying conditions to impact the results of the study. The cold-pressor test was used because both heat and cold can create a burn injury to the skin. The equipment for the cold-pressor test consisted of an iced water tank that maintained a temperature of 4 degrees Celsius monitored with a thermometer. Researchers utilized the temperature of 4 degrees Celsius to create an unpleasant experience but to not cause actual tissue damage. Two of the scenarios were active (named Flocker and Basket) and two were passive (named Henry and Blindness). These scenarios were developed by game designers and psychologists who focus on burn research. The active scenarios involved aspects that engaged the participant. The scenario Flocker had the participant round and herd sheep around obstacles. The scenario Basket had the participant shoot basketballs through a basketball hoop. Passive scenarios did not aim to engage the participant, instead it told stories while incorporating picture and video content. The passive scenario Henry showed a hedgehog celebrating his birthday. The passive scenario Blindness shared a blind person’s story with the participant. Participants experienced all four scenarios, but the order of them was randomized. An Oculus Rift Headset and computer were used to deliver the scenarios. An initial pain score was measured. Researchers did this by having the participant place their hand in the iced water for as long as the participant could tolerate. The threshold was recorded when the participant first reported pain, and their tolerance level was measured based on the time the participant first reported pain but left their hand in the water until it became unbearable and they had to remove their hand. Pain scores were recorded for the initial test and after each scenario. The participants' hand was placed into the water 30 seconds after the scenario started. The scenario ran for the entire time (approximately five minutes) or until the participant removed their hand. Participants also ranked each scenario. Pain was measured using the visual analog scale. Participants were interviewed after each scenario to gauge the advantages and disadvantages to using the scenarios and VR equipment. The results showed the pain threshold to be significantly different between the scenarios Flocker, Blindness, and Basket, in comparison to the baseline. The median baseline score was 26 seconds until pain was felt, while in Flocker it was 55 seconds, in Blindness it was 33 seconds, and in Basket it was 59 seconds. There were also significant differences among pain tolerance. Participants tolerated significantly more pain in the Henry, Flocker, and Basket scenarios (median for all three scenarios was 300 seconds) in comparison with the baseline (median was 57 seconds). Both immersion and enjoyment scores were higher in the Henry, Flocker, and Basket scenarios.

A study by DeSocio et al. (2011) was conducted on 12 U.S. soldiers burned in attacks involving explosive devices. The participants utilized VR, specifically the software SnowWorld, during their wound care and their pain was measured to evaluate VR's efficacy. Participants were excluded if they had a history of motion sickness, open wounds that could not be covered during the procedure resulting in an ability to operate the equipment, and if they had anxiety when utilizing the equipment. Participants had to have a thermal injury that was described as excessively painful during the dressing change on the previous day and be 18 years or older to be included in the study. All patients were male. A within-subjects design was used to compare pain from VR to the control (pharmacological treatment). The order of the groups was randomized. The pharmacological treatment administered in the control group were analgesics which were individualized for each patient, depending on the physicians' orders. These medications were administered twenty minutes prior to the start of wound care. Each participant received six minutes of wound care in each condition, for a total of twelve minutes total. The equipment to deliver VR consisted of a laptop, SnowWorld, and Rockwell Collins Sr-80A VR goggles held in place by a robot-like arm. The graphic rating scale on a 0-10-centimeter line was used to measure participants' pain twice, once after each treatment condition. The graphic rating scale measured the time spent thinking about pain, the worst pain experienced, and how unpleasant the pain was. The results showed a significant reduction in all three pain measurements during VR in comparison with the control group.

Another study was a case study by DeSocio et al. (2011) which studied ketamine and virtual reality during burn care on two participants. One participant was a U.S. Solider who had 13% of his body burned in an electrical fire, while the other one was a civilian who had 50% of his body burned in a building fire. Both participants were premedicated with 40 milligrams of ketamine IV roughly 20 minutes before wound care occurred. The procedure was ten minutes but divided into two five-minute portions. One part was with no VR (only the ketamine was used) while the other part utilized VR. After each part, the participant was asked to utilize the graphic rating scale to indicate the time spent thinking about their pain, worst pain felt, and how unpleasant the pain felt. Participants were also asked if they enjoyed the experience and if they experienced nausea. The VR system included a laptop, Rockwell Collins SR-80 goggles held with a robot-like arm, and the SnowWorld software. Both participants reported pain reduction on all three measures when utilizing VR. One patient reported no nausea, while the other patient reported mild nausea.

A study conducted by Al-Ghamdi et al. (2019) aimed to study pain relieved by virtual reality using an eye-tracking system. This study delivered brief painful thermal stimuli to 48 healthy female college students. The study was a within-subjects design consisting of an active VR group, a passive VR group, and a group which did not use VR. The order of the groups the participants received were randomized. The VR system consisted of a gaming laptop, a head mounted VR helmet with built in SMI eye-tracking, and SnowCanyon, which is similar to SnowWorld, except it has more updates. The SMI eye-tracking was used in this study because the researchers wanted to provide a stronger feeling of immersion. The eye-tracking software eliminates the need for a computer mouse and allows the participants to create an action (in this case throwing a snowball) with their eye movements. The passive VR consisted of SnowCanyon software, except it was not interactive, meaning it did not have eye tracking, and the participant could not interact by throwing snowballs. The thermal pain stimuli were delivered using a Medoc thermal pain stimulator. Medoc is a machine developed for research purposes, including pain research. A thermode, which is a device which delivers the thermal stimulus, was attached to the participant's forearm. Participants were able to choose the temperature (within a range of 44-48.5 degrees Celsius) for the first part of the study. The stimuli were delivered for ten seconds. Following the stimulus, the participant was asked to rate their pain using a graphic rating scale, which measured time spent thinking about pain, worst pain levels, and pain unpleasantness. The temperature was increased by one degree Celsius and the same process was repeated (unless the participant reached the maximum temperature which was 48.5 degrees Celsius). This continued until the participant described the stimulus as “painful but tolerable.” The graphic rating scale was used to assess pain and the researchers asked participants about the extent of which they went into the virtual world and the reality of the virtual world to assess for feelings of immersion. Researchers also assessed for entertainment of VR and nausea experienced during VR. It was found that the interactive eye tracked VR significantly reduced worst pain levels in comparison with no VR and with passive VR. Pain unpleasantness was also significantly reduced during the eye-tracked VR in comparison to the no VR and passive VR groups. Eye-tracked VR did significantly reduce the time spent thinking about pain, but only when compared to the group with no virtual reality. Interactive eye-tracked VR was also found to significantly increase the feeling of enjoyment and realness of the environment.

Virtual Reality Equipment

This literature review uses Cipresso et al. (2018) definition's of VR, "a newer technological system in which virtual objects are added to the real world in real time during the user's experience" (p. 2086). Various equipment was utilized throughout the articles. All studies utilized virtual reality headgear, including items such as a headset or goggles. This equipment consisted of various types of straps and bands to hold the devices in place. These securement devices had to be placed on the head and neck. Patients with burns to the head or neck presented a challenge to using the virtual reality equipment since it would press on the skin, creating discomfort, posing an infection risk, and impeding wound care. Two articles utilized a technology that allowed a robot-like arm to hold the virtual reality goggles in place during the session. One study looked at the quality of virtual reality helmets and effects on analgesia. The high-tech virtual reality helmet was found to significantly decrease worst pain levels and the time spent thinking about pain (Furness et al., 2006). It was found that approximately 30% of participants in the low-tech helmet group reported a reduced amount of intense pain. However, 65% of participants in the high-tech helmet group reported a significant reduction in intense pain (Furness et al., 2006). Research has provided support for the use of head mounted virtual reality displays in providing a greater feeling of immersion in the virtual world (Hoffman et al., 2008). Another aspect of the virtual reality equipment was sound. Some of the studies did use sound, while others did not. The use of sound was arguable because there was a potential for the patient to be unable to hear directions.

The software, Snow World was present in four studies. Created by researchers at the University of Washington specifically for burn patients, Snow World is the software patients focus on during burn care. Patients cruise around through a snow filled and icy landscape, throwing snowballs at penguins. Since the environment is filled with snow and cold, it negates the burn experience. Additionally, due to its interactive nature, it is intended to distract burn patients from their pain. A study conducted on nine patients who were using virtual reality and being administered opioids measured a magnetic resonance imaging (MRI) of their brain and analyzed the areas that tend to show a higher level of activity when undergoing a painful thermal stimulus. They compared subjective reports of pain and the MRI scans. They found both pain ratings and brain activity to be reduced the greatest under the combined virtual reality and opioid condition (Blough et al., 2007).

An advantage to virtual reality is it has little side effects. Motion sickness is currently being studied as a disadvantage of virtual reality. In a study conducted on older adults using virtual reality, it was found that the group using virtual reality had a lower score on the motion sickness susceptibility questionnaire, with the average score being 21.63 (Burd & Smith, 2019). In another study that analyzed and tested the motion sickness susceptibility questionnaire (MSSQ), the mean score was 45.5 (Golding, 1998). This score was utilized as a standardized reference for comparison (Burd & Smith, 2019).

Since virtual reality includes technology close to the patient's eyes, when the patient uses it for an extensive amount of time, eye strain and headaches are seen (Ayyoubzadeh et al., 2020). There are other disadvantages to virtual reality, such as education and training. To maximize benefits received from virtual reality, both the patient and the person implementing the technology needs sufficient training and education (Ayyoubzadeh et al., 2020). Another disadvantage is cost. In a study conducted by Chaudhury et al., they estimated the cost of implementing virtual reality to be “substantial” (2015). In another study, it was found that the average cost to implement one virtual reality system was approximated to be $2,500 (Cordingley et al., 2018).

Pain Measurement

The articles included different methods to measure pain. Three articles utilized the graphic rating scale. The graphic rating scale was a 0-10 cm line which included verbal descriptive measures, depending on the variable measured. Variables included time spent thinking about pain, pain unpleasantness, and the worst pain the participant felt. As the scale increases, the severity of the variable being measured increases. One study utilized the visual analogue scale, which was a 10-centimeter line. It included “no pain” to “worst pain” as anchors on each end (Ebrahimi et al., 2018). Two studies utilized a numeric rating scale. One study utilized the numbers 0-100 to describe pain, while another study utilized 0-10. Another study utilized a Likert-type scale. This scale included ratings of “not at all”, “a little bit”, “some”, and “a lot” (Aballay et al., 2018). The visual analogue scale and the numeric rating scale are the most commonly used pain assessment tools and have demonstrated validity and reliability (Alghadir et al., 2018). In another study done regarding validity and reliability of the graphic rating scales across cultures, it was found that for both groups of patients (Dutch and Egyptian), the graphic rating scale demonstrated adequate test-retest ability. The intraclass correlation coefficient is a statistic used to measure reliability. In the study, the intraclass correlation coefficient was found to be 0.78 and 0.83 for the two groups. These numbers represent a good measure of reliability (El-Garf et al., 2006). In one study, it was found that the Likert-type scale showed “strong internal consistency” (Croasmun & Ostrom, 2011).

Results

Overall, a majority of the eight studies were reviewed and showed a positive impact of virtual reality and the reduction of pain. Some studies were mixed, showing some support for virtual reality while the findings were inconclusive. While not all of these studies were statistically significant, it does provide insight into virtual reality as an intervention and indicates further research is needed.

Discussion

Seven of the articles did provide positive support for virtual reality. The study designs varied, and many articles utilized a within-subjects design to measure the participants pain in a controlled setting and then with virtual reality. A within-subjects design helped researchers see a change from the baseline pain rating, to the measured pain with virtual reality and determine its significance. Another study randomly assigned participants to a group, and those participants stayed in the same group for subsequent dressing changes (Ebrahimi et al., 2018).

Researchers collected both qualitative and quantitative data. Quantitative data collects statistics and measurements while qualitative research captures themes and human experiences. Qualitative data was collected interviewing the patients and recording their feedback. In one study, patients completed surveys and semi-structed interviews. A few themes were synthesized from the data collected. These themes included the tolerance of the procedure, interactions with the providers, logistical concerns, and how virtual reality can be applied in the future. It was found that patients felt as though virtual reality distracted them from their wound care. Participants mentioned they appreciated how the medical providers did not force virtual reality and allowed them to proceed at their own pace. Participants mentioned their concerns regarding virtual reality. These were about the make of the equipment, such as the feeling of heaviness, having many wires, and how it was uncomfortable to use in patients who had glasses. Participants thought that virtual reality could be helpful, especially in children (Aballay et al., 2018). The majority of patients felt as though virtual reality decreased their pain “some” or “a lot” (Aballay et al., 2018). They felt as though they were “likely” or “very likely” to use virtual reality again in their next burn care treatment (Aballay et al., 2018). Nearly all patients reported being satisfied with their burn care. In another study which collected qualitative data, four themes were synthesized. In summary, participants described themselves as being surprisingly content as opposed to their initial suspicions. Participants felt as though virtual reality produced a positive experience, as it reduced their pain and decreased their anxiety. However, they explained how nurses were not knowledgeable about virtual reality, and thus could not explain it or discuss it with participants (Babiker et al., 2019). In a study that gave fentanyl during wound care, it was found that fentanyl was administered significantly more frequently when no immersive virtual reality was used (Atterbury et al., 2018). However, there were small, insignificant changes between immersive virtual reality, and the group without the immersive virtual reality intervention (Atterbury et al., 2018). In a case study with two participants, researchers conducted information about the time spent thinking about pain, the worst pain felt and the pain unpleasantness during the previous five minutes. Both participants reported less pain on all measures (DeSocio et al., 2011). Another study individualized pain medications per each patient (n = 12) before wound care. Participants were able to participate in wound care both with and without virtual reality. Three pain ratings were taken throughout the wound care. The results concluded that the mean pain ratings were significantly lower during virtual reality (DeSocio et al., 2011).

Limitations

Despite the positive support demonstrated for virtual reality, multiple limitations were discovered upon analyzing the articles. Virtual reality is a newer intervention in medicine and as a result, there is a lack of research on this topic. Upon doing an initial search, virtual reality was being studied in a breadth of areas and it was difficult to find articles relating to burn patients and their pain, particularly during wound care. There were many studies about this topic that focused on the pediatric population instead of adults and on burn patients' pain during physiotherapy. In order to properly determine its effectiveness in clinical settings, further research needs to be conducted.

While virtual reality was studied utilizing a similar set up, different companies produced the equipment, creating natural variations which may have impacted results. Many studies used SnowWorld, a software created specifically for burn patients. One study had the participant chose between eight different virtual reality scenarios. Creating many different environments can cause varying outcomes.

Varying pain medication was used in each study. It is standard practice to premedicate burn patients with an analgesic before their wound care (Ainsworth et al., 2019). The articles utilized various pain medications and sedatives, such as ketamine, fentanyl, and morphine. The dosages of those medications also varied. Analgesics directly reduce the outcome being measured. This practice is a limitation because the influence of pain medications could have impacted the results.

Another limitation includes variation in the total body surface area of the burns. In one study, they issued random thermal stimuli and measured pain outcomes. Some studies included a varying amount of TBSA burn and burn depth. TBSA stands for total body surface area. TBSA is used to assess the extent of burns. A percentage is assigned to portions of the body. The percentages are then added together, and the total body surface area of burns is determined (Choudhry et al., 2020). Another study required the thickness of the burn to be greater than or equal to 5% (Al-Ghamdi et al., 2019).

Other limitations include the methods of the studies, including sample size and data collection. A few studies collected more qualitative data as opposed to quantitative. Both qualitative and quantitative data have advantages and disadvantages. An advantage to quantitative data is that it is factual and can be interpreted to determine interventions in clinical settings. The largest sample size was 60 participants, and the majority of studies reviewed had between two to eighteen participants. It is important to have a larger sample size to accurately reflect the population to be able to generalize the results to the target group, in this case being adult burn patients. A small sample size increases the risk for errors. Said errors can attribute the intervention as ineffective because such a small sample size cannot detect significance accurately (Atkinson & Columb, 2016). A small sample size increases the margin of error. This was a limitation because it can skew the data and the results can become misinterpreted.

Nursing Implications

There are many implications of this literature review on nursing practice. As nurses, it is crucial to assess and treat pain. An inadequate pain assessment remains one of the main reasons for the lack of treatment for patients' pain (McCaffery et al., 2008). Untreated pain contributes to an increased length of stay and impaired quality of life for patients. It is important to alleviate patients' pain and make them as comfortable as possible. Virtual reality has shown a positive impact on patients' pain. It has few side effects, none of which are harmful or long lasting to the patient.

A nurse implements evidence-based practice and recommends interventions accordingly. Feasibility is important to consider when establishing something new. Feasibility examines the level of difficulty to implement a system and the process of doing so (Bond et al., 2016). As a nurse, time management is essential. When implementing a new technology, it takes time to become adjusted and efficient. However, the new system should be beneficial and easy to use. A study conducted at a regional burn center implemented virtual reality for the care of ten burn patients and studied its feasibility. It was found that implementing virtual reality during burn care was extremely time consuming (Faucher et al., 2009). Researchers recorded the time it took to set up the equipment, provide directions to the patient, have the patient undergo therapy using VR, and clean the equipment afterwards (Faucher et al., 2009). The average time was approximately one hour. The most time-consuming aspect was the set-up, which accounted for about 25 minutes. Researchers did mention this decreased over time, but there were many technical issues with the equipment overall (Faucher et al., 2009). However, one of the studies assessed the practicality of virtual reality and found that it was not challenging to implement (Aballay et al., 2018).

Research Implications

While these studies provided positive support for virtual reality as an intervention, there are research implications which should be considered. There is a lack of research on this topic, and further research needs to be conducted to be able to determine its effectiveness. In addition to conducting more research, virtual reality needs to be studied with standardized methods, equipment and software. Although the goal to deliver a virtual reality experience while reducing pain was consistent with each study, utilizing varying equipment can impact the results. Pain medication also varied throughout the articles. Due to the excruciating nature of wound care on burn patients, it is unethical to hold pain medicine to measure the effectiveness of virtual reality. However, pain medications should be standardized as much as possible to avoid impacting the results. Perhaps medications could be standardized per kilogram of body weight or administered based on set parameters of a pain scale. While pain medicine is difficult to standardize as participants have allergies, tolerance, and/ or a history of substance abuse, it should be standardized in order to properly measure the dependent variable.

Data collection included both qualitative and quantitative studies. Qualitative data could have been beneficial initially to determine the participants thoughts and opinions on implementing virtual reality in their wound care. However, this indicates the need for quantitative data to be collected because both qualitative and quantitative data have advantages and disadvantages. Both types of data should be considered when analyzing an intervention to assess its efficacy.

Sample sizes need to be greater in order to provide the most meaningful results. As previously mentioned, small sample sizes can increase the risk for errors pertaining to the significance of the results of a study. A larger sample size is needed in future studies to provide more accuracy and to easily identify outliers in the data.

Conclusion

Burn patients undergo excruciating pain. Opioids are the main treatment, however there are unpleasant side effects, including tolerance and physical dependence. Managing pain is desired, as leaving pain untreated produces side effects which can negatively impact the patient's health. The effectiveness of nonpharmacological therapies are being investigated in their ability to reduce pain. Virtual reality is one which has been increasingly measured in clinical settings. Multiple theories can explain how virtual reality is effective. This literature review analyzed eight articles and determined its effectiveness and feasibility. This literature review concludes virtual reality as an intervention with positive support, but suggests further research be conducted. Nursing implications were derived and analyzed. Limitations related to the methods and structure of the studies were found, and suggestions were made for future research and clinical implementation of virtual reality.

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Appendix: Tables of Evidence

Author(s) and date	Title	Sample size	Data Collection Method/ Procedure	Participants characteristic	Equipment Used	Key Findings
Aballay, A. M., Duncan, C. L., Ford, C. G., Manegold, E. M., & Randall, C. L./ 2017	Assessing the feasibility of implementing low-cost virtual reality therapy during routine burn care	N = 10	• Participants were introduced to and familiarized themselves with the VR equipment and selected which simulation they wanted to use based on a picture of the simulation • VR and burn care began • Participants completed surveys and semi-structured interviews	• Adults (18 years or older) • Undergoing burn dressing change and/ or debridement of a burn injury below the shoulders • English speaking • Had sufficient visual acuity • They defined most of the participants as being male, high school educated from low-income families • Wide range of TBSA and burn depth	• 5th generation Ipod touch • Participants chose between 8 different VR simulations • Sunnypeak VR headset • Sentey Flow LS 422 headphones (optional to listen to the simulation)	Quantitative data • Majority of pts reported that VR distracted them and decreased their pain some or a lot • Reported they were likely or very likely to use VR in their next burn care and recommend to another pt • Providers reported it was not difficult to implement VR while performing wound care procedure • Providers reported VR provided some relief from pain and distraction for the pt and that they would consider using VR again for a pt Qualitative data • 4 themes • Tolerance of procedure→ all pts described vr

Author(s) and date	Title	Sample size	Data Collection Method/ Procedure	Participants characteristic	Equipment Used	Key Findings
						as having some positive impact on their burn care • 8 participants mentioned that VR distracted them from their procedure • Medical provider interactions→ participants liked the medical staff was not "pushy" about using VR • Participants liked the choices and liked being able to remove it when needed • Staff needs education about VR • Logistical concerns→ mask was a little bulky and uncomfortable; too many wires; one participant wore glasses and that was uncomfortable for the VR experience • Wanted more choices of different VR scenarios; reported that

Author(s) and date	Title	Sample size	Data Collection Method/ Procedure	Participants characteristic	Equipment Used	Key Findings
						some VR videos were too brief and wanted them to be longer • Participants were mixed if using the headphones and audio was helpful • Potential VR applications→ some participants were enthusiastic about it and thought it would work well with children
Babiker, N. T., Fehily, O., Furness, P. J., Lindley, S. A., Phelan, I., & Thompson, A. R./2019	Reducing pain during wound dressings in burn care using vr: study of perceived impact and usability w/ patients and nurses	N = 5	• Qualitative • Participants got to choose between two active VR scenarios that were tested under experimental conditions • Passive VR experience, participants were offered a choice of videos & got to pick which one they would watch • Patients took part in all three dressing groups • Patients were asked questions at the end	Exclusion criteria: • Head & neck burns • Wound infection • PTSD • Active psychotic symptoms • High levels of distress	• Oculus rift CV1 headset, PC, and digital recorder	4 key themes • Caution replaced by contentment • Distraction and its implications for pain and wound care distracting effects • Anxiety, control, and enjoyment • Preparation and communication concerns

Author(s) and date	Title	Sample size	Data Collection Method/ Procedure	Participants characteristic	Equipment Used	Key Findings
Atterbury, M., Gartner, S., Helmold, E., McSherry, T., Schulman, C., & Searles, D. M./2018	Randomized crossover study of immersive VR to decrease opioid use during painful wound care procedures in adults	N = 18	• Within subject • Randomized controlled trial • All pts received 1 mcg/kg of fentanyl 20 mins before wound care • During wound care, for breakthrough pain, 0.25 mcg/kg of iv fentanyl was administered when pt requested it & the times they requested it was recorded • Pain intensity measured w/ verbal numeric scale (0-10) • Anxiety also measured w/ same scale • Answered 6 yes/no questions about the VR (no validity/ reliability testing was done regarding these questions)	Exclusion criteria: • Cognitive impairments • Dementia • Inability to use computer mouse • Physical impediments of face/neck to use headgear Inclusion: • Thickness burn of greater than or equal to 5% • Completion of at least 2 prior painful wound care • greater than or equal to 5 during previous procedure	• A laptop computer w/ video card w/ video program • Virtual reality goggles • Earphones • Background music • Pt utilized googles and noise cancelling headphones to be fully engaged w/ the equipment • Used snowworld software	• Administration of fentanyl occurred significantly more when no ivr as used • Pain and anxiety levels before and after the dressing change procedure found small nonsignificant differences between ivr and no ivr wound procedures • Majority of pts thought that ivr decreased their pain and anxiety

Author(s) and date	Title	Sample size	Data Collection Method/ Procedure	Participants characteristic	Equipment Used	Key Findings
DeSocio, P. A., Fowler, M., Gaylord, K. M., Hoffman, H. G., Maani, C. V., & Maiers, A. J./2011	Combining Ketamine and Virtual Reality Pain Control During Severe Burn Wound Care: One Military and One Civilian patient	N = 2	• Within subject design • Both pts received 40 mg of ketamine IV for wound care • ½ of wound care was without VR and the other ½ was with immersive VR (5 minutes each session) • Graphic pain rating scale	• 21 y/o male US army soldier who suffered electrical burns • 41 y/o civilian male burned in building fire	• Voodoo envy laptop w/ nvidia gforce go 7900 GTX video card • Snow world software • Audio background music • Rockwell Collins VR goggles • Goggles held in place by robot-arm	• Time spent thinking about pain • Rate worst pain during past 5 minutes • How unpleasant was your pain during the past 5 minutes • Both patients reported less pain on all 3 measures
Ebrahimi, H., Ghafourifard, M., Ghahramanpour, M., Musavi, S., & Namdar, H./2018	Effect of virtual reality method and multimedia system on burn patients' pain during dressings	N = 60 (20 per each group)	• Randomized clinical trial • Randomly allocated per each group • Compared VR to multimedia system • Dressing pain intensity was examined by VAS (visual analog scale) • The same intervention was done once a day for 5 days for each dressing change	• Convenient sampling Inclusion criteria • Hospitalization into the burn ward • No history of burns • 18 or older • Conscious and oriented • No drug addiction • No eyesight or hearing problem • Below 25% of their body and second-degree burns, being in acute phase (42-72 hrs)	• Virtual images were played through a virtual-reality-specific headset • A screen to display the multimedia system	• None of the three groups had differences in terms of demographic considerations • No significant difference between the virtual reality and control groups • Multimedia group pain score was significantly different from the control group for all sessions • VR pain score was higher than multimedia group on fourth day only

Author(s) and date	Title	Sample size	Data Collection Method/ Procedure	Participants characteristic	Equipment Used	Key Findings
				Exclusion criteria • Absences in sessions • Receiving sedatives without a prescription • Receiving skin graft		
DeSocio, P. A., Gaylord, K. M., Hoffman, H. G., Maani, C. V., Maiers, A. J., McGhee, L. L., & Morrow, M./2011	Virtual reality pain control during burn wound debridement of combat-related burn injuries using robot-like arm mounted VR goggles	N = 12	• Order of interventions were randomized • Received individualized pain medicine 20 minutes before wound care • Within subjects design	• 18 years old at least • Pain was documented as excessively painful during the previous days wound care session • All were soldiers with combat related injuries in the burn center	• Voodoo envy laptop w/ NVIDIA Gforce go 7900 video card • Snow world software • Rockwell Collins VR goggles • Robot arm held goggles in place	• Three subjective pain ratings throughout the wound care • Used GRS to rate the questions • Mean pain ratings were lower during VR than the control condition for all 3 pain measures, and the differences were all statistically significant
Babiker, N. T., Fehily, O., Furness, P. J., Lamb, M. A., Lindley, S. A., Phelan, I., & Thompson, A. R./2018	A Mixed-Methods Investigation Into the Acceptability, Usability, and Perceived Effectiveness of Active and Passive Virtual Reality Scenarios in Managing Pain Under Experimental Conditions	N = 15	• Four different scenarios • Measured pain using visual analog scales • Participants pain threshold and pain tolerance were recorded by placing their hand in iced water for as long as possible	• Adults; English speaking • Students • Excluded those with preexisting pain conditions, such as migraines, mental health	• Oculus rift CV1 headset and PC • Head tracking & simple remote device • Experimental pain was administered via a cold	• Statistically significant pain threshold times depending on VR scenarios: blindness had a lower time threshold, flocker and basket had significantly longer

Author(s) and date	Title	Sample size	Data Collection Method/ Procedure	Participants characteristic	Equipment Used	Key Findings
			• Threshold was the first point at which pain was reported and tolerance was the duration before pain became unbearable and the participant removed their hand from the water • Nondominant hand in water and dominant hand to control VR • Participants asked to rate their maximum pain on a pain scale, providing a baseline value • Scenario ran until complete (5 minutes) or if participant asked to stop • The next trial started when participants hands returned to pretest temperature	diagnoses, nausea, fibromyalgia, sports/hand injuries	pressor test using an iced water tank, with water circulated to maintain a temp of 4C, monitored using a thermometer • Creates discomfort without causing tissue damage (4 degrees Celsius) – monitored using thermometer • 2 passive VR scenarios and 2 active	• Statistically significant difference in tolerance times depending upon vr scenario that a participant was exposed to • Feelings of immersion were significantly higher in henry, flocker, and basket scenarios
Al-Ghamdi, N., Alhalabi, W., Atzori, B., Hoffman, H. G., Meyer, W. J., Seibel, C. C., & Ullman, D./2019	Virtual reality analgesia with interactive tracking during brief thermal pain stimuli: randomized controlled trial	N = 48	• Graphic rating scale to measure pain (0-10) • Within subjects design	• Healthy volunteers • 18 years or older	• Immersive VR equipment placed on the head	• Compared to passive VR, worst pain and pain unpleasantness were significantly lower during

Author(s) and date	Title	Sample size	Data Collection Method/ Procedure	Participants characteristic	Equipment Used	Key Findings
			• Order of groups were randomized • Pain stimuli between 44-48.5 (participant picked during 1st phase of the study) for 10 second stimulus • Temperature kept getting increased by 1 degree Celsius and participants kept rating their pain		• Medoc thermal pain stimulator • Snowcanyon software • Gaming laptop • VR helmet with a field of view 110 • Head mounted VR integrated with eye tracking	interactive eye tracked vr • Time spent thinking about pain was significantly lower during interactive VR, but only when compared to no VR • Fun was significantly higher during interactive eye tracked VR • Realness and immersion were significantly higher in interactive VR