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Evaluating the Impact of Virtual Reality for Pain Management in Orthopedic Trauma Patients: A Literature Review

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Abstract

Orthopedic trauma injuries frequently result in significant acute pain, requiring analgesia. If the pain is not managed effectively, patients may experience delays in mobilization, their overall recovery, and increase their use of opioid analgesia, with increased risk of opioid dependence. Opioids have traditionally been the cornerstone of pain management for orthopedic trauma with orthopedic surgeons being one of the main prescribers of opioids. The side effects and risk of dependence from opioids have sparked interest in alternative, non-pharmacological therapies. An emerging therapy is the use of virtual reality (VR), a technology that immerses a patient in an interactive simulated environment. This literature review explores the effectiveness of VR as a pain management modality in orthopedic trauma patients. This review also assesses VR's impact on pain control, opioid use, and rehabilitation outcomes in these patients. A literature search was conducted using Google Scholar, PubMed, and Scopus to identify studies that examine VR interventions in orthopedic trauma pain management. Multiple types of studies were analyzed, such as clinical trials, cohort studies, pilot studies, case reports, qualitative analyses, and surveys. Limitations included variability in study design and small sample sizes. Findings suggest that VR can significantly reduce pain and opioid use with improving rehabilitation engagement. However, barriers, such as cost, accessibility, and lack of long-term data, limits widespread integration. VR is a promising non-pharmacological adjunct to pain management in orthopedic trauma care, but large-scale studies are needed to assess the long-term efficacy, and address barriers for equitable implementation.

Keywords: orthopedic trauma, pain management, virtual reality, rehabilitation

Introduction

Orthopedic trauma injuries commonly result from motor vehicle accidents or high-impact events, but can also be due to ground level falls or seemingly minor mechanisms of injury. Orthopedic trauma injuries, such as fractures and soft tissue injuries, typically are accompanied by acute pain, making effective pain management a critical component of the patient's care and treatment. If pain is not controlled effectively, this pain can lead to admission, a prolonged hospital stay, and impede rehabilitation [1]. Historically, opioids have been the standard treatment for managing acute pain for orthopedic trauma patients due to their potency. However, opioid treatment is associated with common side effects, such as sedation, nausea, constipation, as well as the potential for tolerance, dependence, and addiction [2]. The opioid epidemic has impacted the way that orthopedic surgeons and other healthcare professionals manage acute and chronic pain. Orthopedic surgeons are notably high prescribers of opioids compared to other specialties [3]. Opioids are often prescribed to help patients manage severe pain, but it incurs the risk of opioid dependence or abuse [4]. Non-pharmacological pain management strategies have been investigated to help reduce the risk of a patient developing opioid dependence.

One promising approach is the use of virtual reality (VR). VR therapy immerses the patient in a simulated environment, which can help distract them from their pain. Initial studies in surgical and trauma patients have reported that VR sessions can significantly reduce the patient's pain intensity, anxiety, and even diminish the need for analgesic medications [5]. These findings suggest that VR could serve as a viable modality along with multimodal analgesia for orthopedic trauma patients. Barriers to remain for implementing VR, such as cost, accessibility, and patient variability remain barriers. Continued research is needed to evaluate VR's long-term efficacy, and potential role in pain management for orthopedic trauma patients.

This literature review explores the effectiveness of VR as an alternative pain management tool in orthopedic trauma patients. By investigating VR interventions for pain management, including preoperative, postoperative, and rehabilitation stages, this review analyzes VR as an adjunctive pain management tool. This review highlights how VR can be an effective pain management modality for orthopedic trauma patients with the potential to

help reduce postoperative opioid use and improve patient-reported outcomes.

Methods

A literature search was conducted using Google Scholar, PubMed, and Scopus to identify studies that examine virtual reality (VR) interventions in orthopedic trauma pain management between 1999 and 2024. Search terms included "virtual reality," "pain management," and "orthopedic trauma." Inclusion criteria included VR in the management of pain preoperatively, postoperatively, or in the rehabilitation stages of orthopedic trauma patients. Exclusion criteria consisted of studies that did not use VR as a pain-relief measure or analyses lacking clear information on pain management-related outcomes. Data was extracted from studies that met inclusion criteria including case reports, case studies, clinical trials, cohort studies, pilot studies, qualitative analysis, and surveys. Critical outcomes measuring patients' mental well-being, opioid consumption, pain intensity, and rehabilitation results were noted.

Clinical Implications and Outcomes

Opioid Reduction

Virtual reality (VR) has emerged as a promising tool to help reduce the use of opioids in orthopedic trauma patients. VR has demonstrated clinical efficacy as a non-pharmacological method of pain management [5]. Through an immersive and interactive environment, VR could distract patients from pain sensations, and activate different cognitive pathways that modulate pain and perception [5]. There are a growing number of clinical trials and meta-analyses that support this approach. Pandragi et al. conducted a randomized control trial, which demonstrated that postoperative patients who did VR therapy experienced lower pain scores and utilized fewer opioids compared to postoperative patients who received the standard care [6]. This study highlights the potential of VR as an adjunct in pain management, which could prioritize patient comfort, while reducing opioid utilization. Firoozabadi et al. found that VR for postoperative pain management in orthopedic trauma patients reduced the pain intensity, as well as the amount of opioids patients used to manage their pain [7]. The patients in this study also reported greater satisfaction with their pain control experience [7]. This study suggests that even short-term relief from pain could possibly reduce the utilization of opioids, especially during the early stages of healing. While some additional studies have shown mixed results in overall measurable reduction in opioid prescription reductions, trends still show that VR has the potential to contribute to more balanced pain management strategies [8]. This makes VR a potentially important tool that could offer a multidisciplinary approach to a patient's pain control.

Recovery and Rehabilitation

There are a variety of orthopedic trauma injuries ranging from fractures that are amenable to nonoperative treatment to a mangled extremity. Managing these different injuries, especially in the setting of a patient with multiple traumatic injuries, is variable depending on the injury etiology, patient mobility goals, patient comorbidities, and social factors. It is also important to consider how similar injuries may present with differing pain perceptions. Therefore, multimodal and individualized pain management goals for orthopedic trauma patients is typically recommended. Virtual reality (VR) has become more frequently tested due to promising results in reducing the need for opioids to help manage pain. Multiple studies have identified potential for VR to accelerate recovery times and improve rehabilitation outcomes [5,9]. With the increasing evidence of the efficacy of VR as an adjunct in pain treatment, coupled with the restrictions on opioid prescription in the context of the opioid public health issues in the United States, VR has arisen as an appealing option to complement standard pain treatment modalities. A large part of this can be attributed to VR's ability to personalize therapy depending on the exact nature of the trauma and treatments performed. While standardized postoperative protocols are crucial in minimizing complications and ensuring proper recovery, patients can often feel overwhelmed in the complexities and tedious nature of these protocols, leading to poor adherence and increased risk for complications, preventing optimal recovery. This issue can be further exacerbated in patients with low health literacy. For example, only 66% of patients were correctly able to identify their appropriate weight bearing instructions after an orthopedic injury, indicating a significant lack of health literacy in orthopedic trauma patients [10]. Patients from low-income households, often correlated with low health literacy, often have increased complications and worse outcomes after orthopedic trauma [11]. Recent studies have indicated that patients of lower socioeconomic status were more likely to undergo complications intraoperatively or postoperatively and were associated with worse prolonged recovery periods [11]. Patients of lower socioeconomic status may find it difficult to understand medication regimen, follow rehabilitation protocols, or may have mistrust of the healthcare system, all which can lead to worse outcomes after trauma.

These worse outcomes can exacerbate their poverty by affecting employment. Patients that underwent orthopedic trauma were reported to have a 13% unemployment rate one year after trauma, as well as a $14,621 mean income loss at 24 months post-trauma [12]. These findings indicate that establishing an inexpensive, accessible pain regimen for the treatment of patients is paramount to allow them to return to full activity and prevent income loss and further poverty. VR can allow for a personalized, accessible adjunct to traditional pain management. A VR-based exercise therapy regimen can allow providers to constantly adjust the frequency, duration, and intensity of exercises depending on the exact trauma [13]. Utilizing this approach has proven to be effective with a study reporting that 41% of patients had improvement in pain, 31% had improved functional ability, and 24% increased muscular strength when using VR-based therapies in many different orthopedic trauma scenarios [14]. Another study performed at Mass General Brigham Health, reported similar global improvements in pain (40-70%) and physical function (30-70%) across multiple traumatic injuries and surgeries [15]. These global improvements in VR use translate to the speed of recovery as well, with studies reporting as much as 30% acceleration in recovery time [13, 16]. While studies are limited, there is evidence for utilizing VR in improving postoperative recovery.

VR-based exercise therapy is also demonstrating utility in addressing trauma-related anxiety and improving emotional recovery. In many cases, postoperative recovery and rehabilitation is a significant barrier for the patient with more than 50% of these patients developing psychological distress lasting decades following their initial trauma [17]. This psychological distress can manifest itself in many ways and can lead to depression. Orthopedic trauma patients were also found to have a 30% rate of depression after trauma with a quadrupled rate of depression in open fractures [9]. With the significant relationship between how mental, psychological, and emotional components of recovery contribute to a patient's physical recovery following trauma, it is crucial to address all aspects of care to help maximize patient outcomes [18]. A way all these could be addressed is through VR's incorporation of a more interactive, game-like recovery regimen, specifically tailored to the individual needs of each patient. Engaging patients in a more immersive and interactive therapy program can help motivate patients during their recovery [15]. For example, Ryan et al. found a 40-60% improvement in emotional wellbeing for participants who used VR. Besides improving engagement, the ability to customize VR-based therapy to a young athlete who needs to quickly return to playing football, versus a low-demand geriatric patient, can help activate goal-oriented behaviors, further motivating recovery. Chen et al. found that task-oriented VR scenarios consistently provided at least a two standard deviation improvement in shoulder range of motion when compared against imitation-oriented tasks [19]. Therefore, VR's ability to adjust each session based on the individual needs and recovery stage of the patient can help address both physical and psychological aspects of healing.

Challenges & Limitations

Although the use of virtual reality (VR) in pain management for orthopedic trauma patients provides promising avenues to combat the cycle of opioid utilization, it does have challenges. The limitations in implementing VR range from insurance coverage, resource availability, training of those implementing VR, patient comfort, and time needed to implement a program. The costs of purchasing VR material, such as immersive headsets and motion tracking software, can often lead to substantial initial costs. According to a survey by Vincent et al., the most common reason that providers declined to implement VR in their practices was due to cost [20]. The significant initial investment can often drive potential users away from VR for orthopedic trauma patients. With each VR headset and installation costing anywhere from $200 - $500, supplying multiple VR headsets requires an investment [21]. This will likely limit smaller practices and hospitals that may not have the capital to initially fund the purchase or maintenance of VR equipment. Funding may become dependent on limited research grants. Mallari et al. reported that these challenges are particularly pronounced in safety-net hospitals serving marginalized communities, further contributing to healthcare disparities in the United States [22]. Given that these institutions already face reduced reimbursement due to a high proportion of uninsured patients, the limited adoption of advanced pain management modalities, such as VR may exacerbate disparities in care. In contrast, hospitals in urban areas or areas with greater financial resources are better positioned to implement these emerging technologies, potentially widening the gap in pain management accessibility.

Another barrier for the implementation of VR for orthopedic trauma pain management is the discomfort that it can potentially cause patients. A systematic review performed by Smith et al. found that adverse effects from VR pain intervention, such as dizziness or nausea, were found in 0.5% to 8% of patients that utilized VR for acute pain management [9]. Increased side effects were found in patients that had previous traumatic brain injury or vestibular dysfunction [9]. While the side effects are relatively uncommon, their prevalence, especially in patients with other comorbidities, may cause providers to refrain from the use of VR. Additionally, the potential for these side effects to disrupt the patient experience, and decrease treatment adherence, underscores the importance of personalized VR therapy approaches. These limitations highlight the need for continued research into mitigating the potential side effects or risks of VR.

A further complicating factor in the implementation of VR for pain management in orthopedic trauma patients is the disjointed literature surrounding VR, its sustained effectiveness, and applicability in varying populations. Despite racial minorities often portraying higher pain levels than white patients, there has been a significant gap in literature regarding utilizing VR in heterogeneous patient populations [23,24]. Many of these studies have been performed in larger hospitals in urban areas with more access to research funding, which may lead to biases in results, and difficulty establishing generalizability. This discrepancy may be due to the difficulty for rural hospitals or facilities serving marginalized communities to purchase and utilize VR technology. More research is warranted to determine the effects of VR for pain management on diverse patient populations. Possible studies could focus on non-English speakers or patient populations stratified by race or socioeconomic status.

Technical and bureaucratic barriers can also lead to challenges implementing VR for pain management of orthopedic trauma patients. As the growing field of VR adapts, new technological guidelines and instructions are needed to better serve patients. However, these constantly changing landscapes can often lead to technology issues, such as hardware compatibility discrepancies, frequent software updates, and reliance on technology support, adding to maintenance costs. Additionally, administrative hesitancy and regulatory complexities may further impede the widespread adoption of VR in clinical settings. A survey study performed by Sarkar et al. found that VR was useful and reliable in decreasing pain levels, but a leading reason for the lack of implementation was the amount of effort, training, and regulation required [25]. Physicians in safety-net hospitals noted that integrating VR as an advanced treatment modality would necessitate substantial changes in management policies, a commitment to technological innovation and education, and targeted fundraising efforts. Successful implementation would require comprehensive training programs to familiarize clinicians with the technology. The addition of VR into already complex algorithms for pain control in patients may lead to further challenges in implementing multimodal analgesia. This could further hinder orthopedic surgeons, physical therapists, and other rehabilitation specialists from implementing VR for orthopedic trauma patients.

Future Directions

Recent advancements in haptic feedback, personalized virtual reality (VR), and biometric integration enhance VR immersion, allowing for an immersive experience. Pairing haptic, or vibrotactile feedback, with visual feedback enhances user presence compared to visuals alone [26]. Multimodal system outputs including visual, auditory, and haptic features increase user engagement [27]. A multimodality approach with personalization of a VR environment can help increase patient engagement. In the small study conducted by Pardini et al., 16 of the 18 participants felt a heightened sense of relaxation after utilizing VR, explaining that the setting evoked nostalgic memories or general comfort [27]. The customizability of VR, combined with its visual and tactile feedback, makes it adaptable to each patient's needs. VR has the capability to adapt to its user using continuous integration. This method utilizes biometric integration, like heart rate, eye movements, hand motions, and skin conductivity, to adapt the scenery according to the user's input [28]. Integrating patient response data can help improve feedback with VR to improve its clinical efficacy. Specialists utilizing VR can tailor these modalities to orthopedic trauma patients. The ultimate goals of VR are to improve patient-reported outcomes, patient recovery, and to improve emotional and psychological factors for the patient.

The research behind VR as a pain management modality shows promise, but there remain limitations, as previously highlighted. Multiple small, randomized control trials highlight the positive effects of utilizing VR to reduce pain both in an acute and chronic setting [29]. However, despite the positive effects, it's not a widespread practice, largely attributed to costs and resource availability. Larger-scale, multicenter trials are needed to investigate the benefits and potential risks of utilizing VR as a treatment modality for orthopedic trauma patients. Studies that compare VR for different types of orthopedic trauma injuries, such as a femur fracture to an upper extremity fracture, would also provide needed insights. Long-term studies are needed to identify any possible associations of outcomes of these treatments with effects like pain relief, rehabilitation, and overall opioid use reduction.

The current guidelines for managing chronic pain emphasize a multidisciplinary approach that incorporates psychological support, behavioral therapy, physical rehabilitation, and substance use management where appropriate [30]. VR technology has the potential to enhance this integrated model by serving as an adjunctive modality. For instance, VR can be used in physical therapy to promote movement and improve range of motion through immersive and engaging exercises. VR can support psychiatric care by offering cognitive behavioral therapy modules or mindfulness therapies in a controlled environment with biometric integration to promote relaxation. By tailoring VR content to address the specific needs of each discipline, it has the potential to become a central component of comprehensive rehabilitation programs. Its ability to target both physical and psychological dimensions of recovery makes it a promising adjunct to traditional pain management strategies.

Conclusion

The current research involving virtual reality for orthopedic trauma patients suggests that it is an effective tool for reducing pain, improving recovery, and decreasing opioid consumption. Clinical trials have shown that VR helps reduce pain scores and overall intensity of pain by stimulating alternative cognitive pathways that modulate pain perception. Additionally, many studies have demonstrated that orthopedic trauma patients utilizing VR had lower opioid use and fewer opioid prescriptions filled compared to those on standard treatment protocols. Patients using VR for recovery and rehabilitation also had improvements in recovery rates, functional ability, and muscle strength. This can be attributed to the versatility and adaptability of VR, since rehabilitation plans can be customized to the individual patient based on their progress and goals, leading to increased adherence, and better overall outcomes. Therefore, VR may serve as a promising adjunct or possibly alternative, tool for pain management in orthopedic trauma patients.

While initial research suggests positive results for the effect of VR on pain management, there are still several areas that need clinical trials and further research. The current trials focus on short-term management, like pain scores postoperatively, and lack comprehensive long-term data on the efficacy of treatment and recovery. These studies are also limited by small sample sizes and lack of generalizability in the sampled patient populations. Therefore, if VR is to be integrated into standard practice, there need to be larger-scale, multicenter trials that focus on long-term benefits and possible risks. These trials should focus on longitudinal data in areas like pain levels, recovery success, and opioid use after VR therapy is utilized for different orthopedic trauma injuries.

The integration of VR offers an exciting and promising complementary tool to traditional pain management methods with the added benefit of decreasing opioid dependence. As research continues to reveal that VR reduces pain scores and opioid consumption in orthopedic trauma patients, clinicians should consider implementing VR into multimodal pain management strategies. The customizability of VR allows therapy to be molded to the specific patient, whether it’s a young athlete trying to return to their sport as soon as possible or an elderly patient focused on being able to walk again. Additionally, VR can incorporate biometric data into feedback systems that will adjust the experience based on the patients’ physical and emotional states. VR’s role in rehabilitation extends far beyond pain control, as it promotes better adherence to recovery protocols, accelerates functional improvement, and addresses psychological distress. However, the implementation and utilization of VR for orthopedic trauma patients requires more investigation.

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