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A Narrative Review: Transforming Pediatric Oncology Care Through Virtual Reality - Pain Management and Enhanced Patient Experience

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Abstract

Virtual reality (VR) technology has received considerable interest in the healthcare field, particularly in pediatric oncology. The purpose of this study was to examine the existing and future applications of VR in reducing the discomfort associated with pediatric oncology procedures such as bone marrow biopsy, bone marrow aspirate, and lumbar puncture. A comprehensive search was conducted across numerous databases from 2005 to 2023, embracing several study designs to provide a strong evidence foundation. Using diversion and relaxation strategies, VR can help pediatric cancer patients cope with the emotional issues they confront during operations. VR has shown significant potential for lowering pain and anxiety during several pediatric medical procedures. Patient feedback focused on VR's empowering and anxiety-reducing benefits, while healthcare staff reported increased patient participation and procedural efficiency. VR implementation challenges include the cost of specialized technology, the need for specific virtual settings, and the need for training healthcare workers. VR shows promise in improving the pediatric cancer experience, but more study and cooperation are required to realize its full potential.

Keywords: Virtual reality, pediatric oncology, bone marrow biopsy, bone marrow aspiration, lumbar puncture

Introduction

Virtual reality (VR) is an advanced technology that immerses users in computer-generated environments, simulating visual, auditory, and even haptic sensory experiences. Its prospective healthcare applications are extensive. VR can restructure medical training and education by providing medical students and professionals with realistic and risk-free simulations that can improve their skills and decision-making abilities.[1] VR can also be used for pain management and therapeutic interventions. The use of VR as a distraction technique for patients undergoing painful procedures effectively reduced their perception of pain and anxiety.[2] These applications illustrate the prospective role of VR in transforming the healthcare landscape and

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enhancing patient outcomes, particularly in specific patient populations, such as the pediatric oncology population.

Bone marrow aspiration, bone marrow biopsy, and lumbar puncture (LP) are essential for the diagnosis and management of hematologic malignancies in children.[3] Fear and anxiety associated with the anticipation of pain render these procedures challenging to perform. Hence, the importance of identifying additional methods to alleviate patients' suffering above and beyond the use of analgesics and sedation.

VR has shown considerable promise in reducing pain and anxiety during pediatric medical procedures.[4] By providing an immersive and engaging environment, VR can serve as a potent distraction tool, diverting the patient's attention away from the discomfort of the procedure. In a randomized controlled trial by Gold et al.[2], the use of–VR during painful medical procedures such as intravenous line placement reduced pediatric patients' pain perception and distress: when VR was applied, children, parents, and nurses reported no significant differences in affective pain in the Faces Pain Scale with intravenous line placement, compared with a four-fold increase in affective pain with topical anesthetic with no distraction.

The purpose of this literature review was to examine the current and potential applications of VR technology in bone marrow aspiration, bone marrow biopsy, and LP procedures in pediatric oncology.

Methodology

Search Strategy and Inclusion Criteria

This original review was conducted in August 2023. The authors performed a search through PubMed, Scielo, Cinahl, Web of Science, and ScienceDirect using the following keywords: "Virtual Reality" "Pediatric Oncology" "Bone Marrow Biopsy" "Bone Marrow Aspiration" "Lumbar Puncture".

The inclusion criteria for the articles considered in this review were as follows:

1. Publication Language: Articles published in English were included.

2. Publication Date: Articles published between 2005 and 2023 were considered to ensure coverage of the recent research and developments.

3. Study Design: Various types of studies were included, such as case-control studies, cross-sectional studies, cohort studies, and review articles. These diverse study designs were chosen to capture several evidence on the topic.

Selection Process

Two authors independently conducted the literature searches, ensuring a comprehensive search across the specified databases. Duplicate articles were automatically detected and removed using Zotero. After eliminating duplicates, the remaining articles underwent further screening by Rayyan. During this screening process, the authors independently evaluated the titles and abstracts of these articles, excluding any literature that did not meet the inclusion criteria. The reasons for exclusion at this stage included studies not related to the topic, non-English articles, and those published before 2005.

Following the title and abstract screening, the full text of the accepted articles was reviewed to determine their eligibility for inclusion in the study.

Data Analysis

Two authors independently extracted data from the included studies. Data extraction encompassed key information such as medical procedures, applications, limitations, main findings, and any information pertinent to the review objectives. This approach ensured that a comprehensive and thorough assessment of the literature was performed.

Following this methodological process, we aimed to identify and select articles that were most relevant to the objectives of this review, thereby providing a robust foundation for our analysis.

Results and Discussion

Medical Procedures in Pediatric Oncology

Bone marrow biopsy and bone marrow aspiration are essential procedures for diagnosing and treating various pediatric hematologic malignancies. However, these procedures often evoke significant anxiety and fear, especially because of concerns about potential pain. Zernikow et al.[5] conducted interviews with pediatric oncology patients (n=265), revealing that one-third of them identified bone marrow aspiration and biopsy as the most painful procedures. Notably, the use of general anesthesia was associated with reduced pain during these procedures.[5]

LP is another common procedure in pediatric oncology used for evaluating cerebrospinal fluid for various conditions, including infection, hemorrhage, or cancer cell presence.[3] LP is particularly crucial for diagnosing and treating central nervous system involvement in leukemia and lymphoma. Pediatric patients undergoing LP often experience anxiety and apprehension due to fear of pain, which is exacerbated by the requirement to remain still during the procedure. Fein et al.[6] conducted a comparative study, which revealed that less than a quarter of the 353 children involved in the study had received any form of pain management before LP. This highlights the challenge of inadequate pain management in pediatric patients, primarily because of the difficulty in assessing their pain. Healthcare providers employ various pain management techniques, including local anesthesia and psychological support, to alleviate anxiety.[6] Additionally, sedation or distraction techniques, such as VR, may be used to mitigate emotional distress and improve the patient experience during LP.[7] Findings of the articles are summarized in the **Table 1**.

Virtual Reality Applications in Healthcare

VR has demonstrated potential across various medical contexts, including surgical training and education, where it simulates complex procedures for medical

professionals' practice and skill refinement in a safe environment.[8] VR has also shown promise in treating anxiety disorders and phobias through virtual exposure therapy scenarios, aiding in desensitization and therapeutic interventions.[9]

Virtual Reality in Pediatric Care

VR has been applied in pediatric settings, including medical procedures, to provide distraction and relaxation, thus reducing the need for sedation.[10] A meta-analysis by Eijlers et al.[8] showed that VR significantly reduced procedural pain and emotional distress in pediatric patients. VR was particularly effective in reducing pain and anxiety associated with various procedures, such as intravenous line placement, blood draw, port access for chemotherapy, and burn dressing.[8] It demonstrated greater effectiveness in younger children, possibly because of their heightened engagement in imaginative thinking.[11]

Moreover, the use of VR prior to, during, and after influenza vaccination in 244 children aged 2-16 years resulted in significant reductions in pain (ranging from 48% to 75%) and fear (ranging from 52% to 71%) compared with standard care.[12] In eleven burn patients aged 9-40 years, VR, along with standard pharmacologic treatment, led to a substantial reduction from 35% to 50% in perceived pain.[13] Similarly, among the 25 patients aged 10-25 years experiencing sickle cell crises, VR contributed to a decrease in pain intensity and descriptors.[14]

Highlights

- Therapeutic interventions using virtual reality (VR) technology are revolutionizing medical care, especially regarding procedures involving painful experiences in vulnerable populations, such as the pediatric population.
- This study conducted a thorough systematic search of various databases for English-language articles published between 2005 and 2023 discussing the use of VR in pediatric oncology procedures.
- VR reduces pain and anxiety during pediatric medical procedures, improving patient and family cooperation and efficiency. Challenges include specialized hardware costs, tailored scenarios, and professional training.

Virtual Reality in Pediatric Oncology

In pediatric oncology, VR is a valuable distraction tool during procedures. Hoag et al.[15] conducted a randomized controlled trial, demonstrating that VR significantly reduced procedural pain and distress during subcutaneous port access in 25 children and adolescents with cancer compared with guided imagery. VR mitigated the impact of pain catastrophizing on the pain experience by alleviating feelings of helplessness and reducing rumination about pain.

In addition, VR simulations play a significant role in educating pediatric oncology patients and their families about procedures. Tennant et al.[16] reported that immersive VR improved procedural knowledge and satisfaction among thirty pediatric oncology patients undergoing computed tomography simulation for radiotherapy.

Virtual Reality Implementation in Pediatric Oncology Procedures

VR implementation in pediatric oncology procedures, such as bone marrow biopsy and aspiration and LP, requires VR headsets and interactive tools.[11] High-quality VR headsets offer a completely immersive experience that transports the patient to a virtual world while obstructing the outside world.

Table 1.
Table summarizing the articles' findings

Author	Findings
Comparcini et al.,[10] 2023	VR has been applied in various pediatric medical procedures because it provides distraction and relaxation, reducing the need for sedation.
Eijlers et al.,[8] 2019	VR was found to be effective in reducing patient-reported pain and anxiety associated with intravenous line replacement, placement, blood draw, port access for chemotherapy, and burn dressing. VR had a better effect on distraction ability than other distraction tools such as music and movie distractions. VR was more effective in younger children than in older children.
Derek et al.,[12] 2002	Younger children are more engaged in magical and creative thinking than older children.
Mack, 2017	The use of VR for a duration of 30 s prior to, during, and after influenza vaccination in children aged 2-16 years has been linked to a significant reduction in pain (ranging from 48% to 75%) and fear (ranging from 52% to 71%) compared with standard care.
Hoffman et al.,[13] 2008	Out of eleven burn patients aged 9-40 years, the use of VR along with standard pharmacologic treatment resulted in a 35-50% reduction in perceived pain compared with pharmacologic treatment alone.
Agrawal et al.,[14] 2019	Out of 25 patients aged 10-25 years experiencing sickle cell crises, the use of VR among children resulted in a 16% decrease in pain intensity and a 33% decrease in pain descriptors.
Hoag et al.,[15] 2022	VR was found to significantly reduce procedural pain and distress during subcutaneous port access in children and adolescents with cancer compared with guided imagery. VR reduced the influence of pain catastrophizing on pain experience by twofold by alleviating feelings of helplessness and reducing rumination about pain.
Tennant et al.,[16] 2021	The use of VR on thirty pediatric oncology patients undergoing computed tomography simulation for radiotherapy showed prompt enhancement in procedural knowledge and retention at the 2-week follow-up. Immersive VR also increased patient satisfaction due to increased procedural knowledge and reduction of anticipatory and procedural anxiety.

VR; Virtual reality

Depending on the type of technology utilized, these headsets may be cordless or attached to a computer.[17] To enhance the VR experience, patients can use tools such as hand controllers or haptic feedback gloves to interact with and manipulate elements of the virtual environment. The design and selection of the virtual scenarios must be adapted to the procedure to maximize distraction and relaxation for young patients.[18]

Substantial training of healthcare professionals performing pediatric oncology procedures is required before integrating VR into the workflow. Healthcare professionals must be familiar with the capabilities and restrictions of VR systems as well as the correct use and maintenance of the equipment. Moreover, it is essential to create virtual situations tailored to a particular procedure to assure their applicability and efficiency. Teaching medical professionals how to introduce VR to their patients, explain its advantages and drawbacks, and respond to any queries or concerns is also needed. Importantly, medical professionals should monitor patients in real time during the procedure to gage their comfort level and modify the VR experience accordingly.[19]

Healthcare centers planning to incorporate VR technology into their pediatric oncology practices should work with VR developers to produce specialized applications that agree with pediatric oncology requirements, including scenarios suitable for patients' age and preferences. These centers should establish dedicated VR spaces equipped with the required technology and offering a relaxing atmosphere. Accessibility and availability should also be taken into consideration.[19]

Importantly, ethical issues regarding the appropriate integration of VR in pediatric oncology procedures need to be addressed. It is necessary to ensure that clients, parents, and legal guardians understand the advantages and drawbacks of using VR before giving informed patient consent. Respecting patients' and families' cultural diversity and viewpoints is essential. Finally, when using VR technology, privacy and security issues pertaining to the preservation of patient data must be addressed.[20]

Patients and Healthcare Providers' Perspectives

Numerous patients have reported positive experiences using VR, citing VR as a potent distraction tool that helped minimize their anxiety and perceived discomfort during bone marrow biopsy, bone marrow aspiration, and LP.[21]

Patients frequently appreciate the option to choose from custom VR experiences tailored to their preferences, including interactive games, tranquil nature vistas, or instructional information. In addition, patients feel empowered by VR, as it gives them a sense of control during otherwise unpleasant medical procedures.[22]

Parents and caregivers have emphasized the value of having a range of VR scenarios to cater to the child's individual tastes in line with their interests and age group. Healthcare professionals have reported notable decreases in patients' anxiety levels and better patient cooperation, which improves procedural efficiency.[20] They also observed that VR has simplified the process of patient preparation, requiring less sedation or immobilization before procedures.[23]

Some healthcare practitioners have expressed skepticism or reluctance to use VR in pediatric oncology procedures.[23] However, as the advantages of VR in terms of patient experiences and procedural outcomes become increasingly clear, there has been a noticeable change in the attitudes of healthcare professionals toward VR, and they are more likely to accept VR technology.[23] Thanks to training programs and workshops, the level of confidence and competence of healthcare workers in using VR during procedures has significantly increased. More healthcare professionals are now adopting and promoting VR as a secure and useful supplemental tool in pediatric oncology.[24]

Limitations of Virtual Reality Use in Healthcare

The technical requirements for specialized hardware and software can be expensive and thus impede the widespread adoption of VR. Moreover, VR simulations may not accurately replicate the complexities of real-world scenarios, resulting in potential disparities between virtual experiences and actual patient situations. Safety concerns and the potential for motion sickness and disorientation must also be addressed. Nonetheless, ongoing technological advancements and expanding research in the field hold promise for solving these issues and further optimizing the use of VR in patient care.

Future Directions and Potential Developments

VR technology is developing rapidly. Future research should focus on advancements in VR hardware, such as higher resolution displays, lighter, more comfortable headgear, and improved haptic feedback systems, which will provide patients with even more engaging and realistic experiences.[25] The incorporation of augmented reality (AR) into VR settings may provide medical professionals with real-time overlays of patient data and procedure-related information during interventions, enhancing procedural accuracy and efficacy. Furthermore, the integration of biofeedback and biometric monitoring into VR settings may enable medical professionals to further customize the experience and enhance its efficacy based on distinct patient reactions.[26]

Although the use of VR in pediatric oncology is promising, there are still many open questions requiring additional research. The implications of using VR during procedures, including its impact on patients' emotional health, coping mechanisms, and general attitude toward medical care, need to be studied over a longer period.[25] Protocols for integrating VR into pediatric oncology procedures are required. It will be important to determine the optimal timing and length of exposure to VR and to adapt VR experiences to patient preferences and age group.[4] Randomized studies will be required to assess VR's efficacy, clinical usefulness, and affordability compared with conventional sedative methods or other distraction strategies.

Collaborations between VR developers and healthcare professionals are essential to advance the development and applications of VR technology in pediatric oncology.

Developers will need input from healthcare practitioners to build realistic and procedure-specific virtual scenarios that accommodate clinical demands and patient requirements.[26] Through collaboration, patient-centered and clinically successful VR platforms can be developed, with the potential to transform pediatric oncology care and improve patient experiences across a range of medical specialties.[27]

Study Limitations

The above results of our study are subject to the inherent limitations of a narrative review. Also, it is important to note that articles from other databases or in languages other than English were not included. Finally, all articles containing animal models were disregarded, which might have affected the results.

Conclusion

Bone marrow biopsy, bone marrow aspiration, and LP are essential procedures for the accurate diagnosis and management of pediatric malignancies. However, these procedures often cause anxiety and pain. VR, as a potent diversionary tool, has demonstrated promising results in easing anxiety, reducing perceived pain, enhancing patient cooperation, and improving patient experience during these procedures. Thanks to the encouraging results in recent studies and the ongoing developments in VR technology, including the creation of immersive, interactive, and tailored experiences, VR can significantly improve pediatric oncology practice. Future studies should focus on refining VR hardware, incorporating AR and biofeedback, and establishing protocols to incorporate VR in the pediatric oncology setting.

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