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Virtual reality on perioperative anxiety in pediatric patients: A narrative review

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Abstract

Preoperative anxiety is a common response to stress specifically in the pediatric population exhibiting heightened susceptibility to it. High anxiety levels can negatively impact the quality of anesthesia, increase analgesia requirements, and result in significant postoperative pain. The present review synthesizes recent literature regarding virtual reality (VR)'s efficacy in mitigating preoperative anxiety in the pediatric population. Virtual reality is a nonpharmacological intervention that alleviates pain and preoperative anxiety through cognitive distraction, redirecting patients' focus away from discomfort. Neurophysiologically, VR engages the prefrontal cortex, influences pain pathways, and reduces pain-related activity in the thalamus, insula, anterior cingulate cortex, and primary and secondary somatosensory cortices. Evidence indicates that VR is more effective in reducing anxiety compared to other nonpharmacological strategies, particularly benefiting younger children, who tend to exhibit higher levels of engagement in magical thinking compared to adolescents. Virtual reality presents numerous clinical applications, including facilitating postsurgical recovery, assisting in physiotherapy for neuromuscular disorders, and providing nonpharmaceutical analgesia. However, its integration into healthcare faces several challenges, such as the high costs of acquiring and maintaining the equipment, particularly in resource-limited settings. Moreover, the limited number of studies examining VR exposure with small nonrepresentative sample sizes further constrains its recommendation as an anxiety-reduction technique. Despite its limitations, substantial evidence suggests that VR has the potential to alleviate preoperative anxiety and mitigate the psychological responses of pediatric patients. Standardized research protocols featuring larger sample sizes and expanded access to VR across various levels of care are necessary.

Keywords

Virtual reality, anxiety, pediatrics, preoperative anxiety, pediatric surgery

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Introduction

Virtual reality (VR) is an emerging technology designed to create a computer-generated, three-dimensional immersive environment where users can interact as if it were real.[1] Virtual reality is increasingly used in healthcare for medical training and treatment. It has been used to treat chronic pain, improve balance in poststroke patients, and manage symptoms of depression.[2] Additionally, VR is increasingly integrated with cognitive-behavioral therapy (CBT) for treating post-traumatic stress disorder, addictions, and phobias and is beginning to be used for patient distraction during medical procedures.[2,3] Distraction is a common nonpharmacological technique used for alleviating anxiety and pain in

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pediatric patients.[4] Evidence suggests VR may be more effective than traditional nonpharmacological procedures,[5] as well as producing comparable results in pain reduction when compared to opioid analgesics.[4]

Unrelieved pain can trigger negative effects on the cardiovascular system and immune system, as well as causing anxiety, fear, and depression. Managing pain and anxiety in children is particularly challenging due to their complex nature, involving physical, psychosocial, and cognitive factors.[6] Additionally, perioperative anxiety can increase the need for anesthesia, heighten pain perception, and contribute to the emergence of delirium, in addition to causing postoperative maladaptive behaviors, including enuresis, withdrawal, feeding difficulties, and apathy.[7,8] Managing perioperative anxiety and pain in children with medications also poses challenges, including side effects, addiction risks, and variable effectiveness. Midazolam, commonly used for anxiety, can cause sedation, drowsiness, or respiratory issues.[9] Opioids for pain management present risks such as respiratory depression, sedation, and constipation, with a non-negligible risk of dependence even in children.[10] Nonopioid analgesics, such as NSAIDs, may lead to gastrointestinal problems, highlighting the need for cautious use and consideration of alternative strategies.[11]

Challenges of pharmacologic management, coupled with the emergence of VR as a form of pain and anxiety relief, highlights the need for summarizing existing evidence. Virtual reality shows promise as a nonpharmacological treatment for perioperative anxiety and pain in children, offering a way to avoid the side effects and addiction risks associated with traditional medications. However, several barriers hinder its adoption, including limited resources, technical challenges, and a lack of evidence demonstrating its added value in clinical settings.[2] Due to the lack of implementation and limited use of the models designed for children, VR's clinical evidence for pediatric patients is lacking.

This narrative review provides a thorough examination of the extensive and contemporary evidence-based literature concerning the efficacy of VR in managing pain and anxiety within medical settings, particularly in pediatric surgical environments. The research aggregates and synthesizes robust data and statistics from relevant studies. This compilation presents new and clinically significant evidence aimed at elucidating the benefits of utilizing VR to reduce preoperative anxiety in elective pediatric surgical procedures.

Methodology

This narrative review aims to explore the outcomes of the pediatric population undergoing elective surgery while using VR tools to alleviate preoperative anxiety through an examination of existing literature. In October 2024, a comprehensive search was conducted across multiple databases, including PubMed, SCOPUS, and Web of Science. We employed search terms that included a combination of our keywords to identify relevant studies published in English up to 2024. The search was further refined using Boolean operators (AND, OR).

Studies with high-quality evidence were included for review if they mentioned pediatric surgery, anxiety, elective surgery, and VR exposure. Studies in adult population, performed in emergency settings, not using VR in the preoperative period and reviewing outcomes different than anxiety were excluded. We concentrated on studies that utilized validated methodological tools, such as blinding, randomization, and risk of bias evaluation, as well as reliable outcomes, including systematic reviews, meta-analyses, randomized controlled trials (RCTs), and comprehensive reviews. These were analyzed and qualitatively synthesized to identify current clinical practices, challenges, and outcomes that contribute to bridging the gap in understanding how VR can effectively alleviate anxiety in the selected population.

Background on pain and anxiety management

Preoperative anxiety is a common response to the stress of surgery, and children are particularly susceptible to it; however, the degree of anxiety and the physiological responses vary depending on their age and stage of cognitive and emotional development.[12,13] Younger children may exhibit more visible distress (such as crying or clinging to parents), while older children and adolescents may express their anxiety through verbal concerns or refusal to engage. These signs can be objectively quantified using a preoperative anxiety scale, and these scores can be compared.[12–14] Several studies report that prevalence rates of anxiety in pediatric patients during the perioperative period range from 40% to 80%, especially among those undergoing elective, ambulatory, or outpatient surgery.[13] Evidence suggests that urological surgeries are the most common surgical procedures studied in pediatric patients with preoperative anxiety, followed by orthopedic, otorhinolaryngology, ophthalmology, dental, and other general elective surgeries.[12,13,15] Understanding the relationship between increased preoperative anxiety levels in pediatric patients is important for healthcare providers in improving the surgical experience.

Anxiety levels can be measured using the Modified Yale Preoperative Anxiety Scale (mYPAS).[14,15] The mYPAS is a relevant tool for assessing VR efficacy, focusing on behaviors and verbal expressions that indicate anxiety in the following categories: activity, emotional expressivity, state of arousal, and vocalization. It has a scoring range of 22.92 to 100, with higher scores indicating more significant anxiety.[14] Studies indicate that VR can significantly reduce mYPAS scores compared to control groups in RCTs, demonstrating its ability to reduce preoperative anxiety.[15]

An increase in preoperative anxiety can negatively impact the quality of anesthesia, increase the analgesic demand, and lead to greater postoperative pain.[16] This is because anxiety activates the sympathetic nervous system, interfering with the body's response to anesthetic drugs, potentially requiring higher doses for adequate sedation. Anxiety also amplifies pain sensitivity, referred to as hyperalgesia, and causes muscle tension. The increased perception of pain, combined with alterations in pain processing pathways, means individuals with preoperative anxiety are more likely to experience greater postoperative pain. Therefore, these factors result in longer hospital stays, higher healthcare costs, and a more uncomfortable recovery.[17]

Some treatments manage preoperative anxiety and pain, including pharmacological and nonpharmacological options.[15] Premedication is the most common pharmacological approach; however, this often has adverse effects as sedatives can have undesirable consequences and cause negative behavioral changes in up to 20% of patients.[13] Regarding perioperative pain, it may require higher doses of analgesics and opioids, and in some cases, it can become chronic, persisting for months after surgery. This can result in a three-fold increase in the consumption of analgesics in patients with higher levels of preoperative anxiety.[13,15] In contrast, nonpharmacological interventions are based on pleasurable activities such as VR, music, painting, games, movies, tablet apps, video games, CBT, meditation, and aromatherapy, offering engaging and low-risk alternatives with no adverse effects.[13,15] The advantages and disadvantages of both pharmacological and nonpharmacological treatments for preoperative anxiety are summarized in detail in Table 1.

Meta-analyses and systematic reviews provide strong evidence that VR is more effective than other nonpharmacological methods in reducing preoperative anxiety, and this effect is more pronounced in pediatric patients than in adults.[18] This is why VR is currently widely employed across various fields of medicine, particularly for pediatric patients before surgery. Virtual reality is a novel approach for reducing pain and preoperative anxiety with significant advantages and promising results, as described recently.[16] Such effectiveness can be attributed to virtual characters, which provide children with an enjoyable experience and engaging audiovisual content that allows for interaction with the virtual space.[17] These elements offer sensory stimulation, distraction mechanisms, and other neurophysiological effects. They reduce anxiety and decrease its impact on the sensory pathways of pain, making it a superior technique, improving outcomes, and serving as a valuable focus for our study.[15,18]

Mechanisms of VR in managing pain and anxiety

Virtual reality can be used in a healthcare setting to produce a hypoalgesic effect through cognitive distraction, where a patient's focus is shifted away from discomfort and pain and toward engaging virtual stimuli.[19] Cognitive distraction is achieved by immersing the individual in a virtual environment that offers a multisensory experience. This allows individuals to interact with engaging stimuli through vision, hearing, and touch, redirecting their focus away from mental processing and conscious feelings.[20]

Virtual reality targets various brain regions by immersing an individual in a multisensory environment. It interacts with the prefrontal cortex to strengthen neural pathways, enhancing activation to help individuals regulate feelings of anxiety alongside cognitive distraction.[21] Virtual reality has been suggested to reduce neural activation in pain pathways by interacting with various associated brain regions. Evidence shows that virtual reality decreases pain-related brain activity in the thalamus, insula, anterior cingulate cortex, and primary and secondary somatosensory cortexes.[22] Virtual reality interventions aim to engage brain regions involved in fear processing and emotion regulation, which can help relieve feelings of anxiety.[23] Exposure to VR environments desensitizes individuals to feared situations by activating brain regions involved in fear extinction, such as the ventromedial prefrontal cortex and anterior cingulate cortex.[23] Thus, VR has the potential to be used as a nonpharmacological approach for alleviating pain and anxiety in therapeutic settings, improving outcomes for patients. Figure 1 visually represents these evidence-based neurological impacts of VR and their combined potential ability to decrease anxiety through emotional and fear regulation.

Virtual reality can be manipulated to distract patients from or expose patients to various aspects of a healthcare setting, including before, during, or after treatment. By immersing patients in a virtual environment, VR can help them emotionally detach from stressful procedures. This induces relaxation and mindfulness, alleviating feelings of anxiety or pain.[24] Virtual reality can also expose patients to specific procedures and treatments preoperatively, which further alleviates anxiety. By attempting to predict sensory information and consequences, VR provides patients with a model of the real world to facilitate cognitive remodeling.[25] This prepares patients for procedures by familiarizing them with the procedure, potentially reducing anxiety throughout their healthcare experience.[26] Virtual reality limits pain signal processing by offering distraction, redirecting attention away from painful stimuli and thus significantly influencing pain perception and anxiety.[20,22]

The effects of virtual reality on preoperative anxiety can be measured clinically using a variety of techniques. As mentioned, the mYPAS is used to quantitatively measure pediatric anxiety levels using nonverbal techniques.[27] In the context of using virtual reality preoperatively, lower mYPAS scores may suggest that the pediatric patient is immersed in the virtual reality experience such that cognitive resources allocated to fear and anxiety have been

Table 1. Advantages and disadvantages of pharmacological and nonpharmacological treatments for preoperative anxiety.

Treatment type	Advantage	Disadvantage
Pharmacological treatments		
1. Sedative medications (e.g., Midazolam)	• Quick onset of action[18] • Effective in reducing anxiety and facilitating smooth preoperative procedures[13] • Can be administered orally or via injection[15,18]	• Potential for side effects (sedation, respiratory depression)[13,18] • Delirium, agitation or behavioral changes[12] • Requires careful dosing based on age and weight[13,15] • May cause grogginess or memory impairment postprocedure[18]
2. Anxiolytics (e.g., Diazepam)	• Reduces anxiety and muscle tension[15] • Simple to administer[13] • Can be used in combination with other therapies[18]	• Nausea, vomiting[13] • Risk of dependency or misuse if overused • Potential cognitive or motor side effects[12] • Not suitable for all children (e.g., those with respiratory issues or allergies)[18]
Nonpharmacological treatments		
1. Cognitive Behavioral Therapy (CBT)	• Long-term benefits for managing anxiety[12] • Noninvasive, no side effects[13] • Empowers children with coping strategies for future procedures[12]	• Requires trained professionals, which may not be readily available[12,15] • Time-consuming; requires multiple sessions before significant results[15] • May not be feasible for emergency or short-term procedures[18]
2. Distraction Techniques (e.g., Games, Music, movies, painting, etc.)	• Noninvasive, safe, and immediate reduction of anxiety[16] • No side effects or medication dependency[17] • Improves patient cooperation during medical procedures[12]	• May not be effective for all patients, especially those with severe anxiety[19] • Requires equipment or resources (VR headset, music devices, etc.)[12] • Requires parental or staff involvement for best results[16]
3. Virtual reality (VR)	• Provides an immersive distraction, which can effectively reduce anxiety[18,20] • Can be tailored to the child's interests, making it engaging and enjoyable[13] • Safe and noninvasive, with no medication-related side effects[21] • Helps improve patient cooperation during medical procedures[16,20] • Offers a novel approach that may be more appealing to children than traditional methods[20]	• Requires specialized equipment (e.g., VR headset, software), which may not be available in all settings[12,18] • Some children may experience motion sickness or discomfort while using VR[16,20] • May not be effective for children with severe or uncontrollable anxiety[20] • May require staff training to set up and monitor the use of VR devices[15] • Not all children, especially younger ones, may adapt well to technology[13]
	• Simple to teach and implement[19]	

(continued)

Table 1. Continued.

Treatment type	Advantage	Disadvantage
4. Relaxation Techniques (e.g., Deep Breathing, Meditation.)	• Promotes calmness without medication[21] • Can be used in conjunction with other treatments[12,17]	• May not be effective in high-stress situations or severe anxiety[17] • Requires the child to be willing and able to engage in the process[13] • May take time to learn and apply effectively[15]

CBT: cognitive behavioral therapy; VR: virtual reality.

reduced. Neurophysiological modulation can further be measured clinically by measuring physiological markers including heart rate and cortisol levels. Higher heart rate, greater heart rate variability, as well as higher cortisol levels, are linked to increased anxiety due to the autonomic nervous system stress response. Therefore, measurement of these physiological factors could give indication to a pediatric patient's preoperative anxiety levels. This can be applied clinically when using virtual reality to measure its effectiveness in alleviating anxiety and pain sensations.[28]

Effectiveness of VR in reducing preoperative anxiety comparison to alternative modalities

Researchers, as mentioned earlier, have explored nonpharmacological interventions to reduce preoperative anxiety in pediatric patients. For example, designed a RCT that provides evidence of a reduction in anxiety for children and adolescents using augmented reality prior to the induction of general anesthesia.[15,20,22] The analysis included pediatric patients aged 5–17 years, scheduled for elective day surgery under general anesthesia, who were randomly assigned to either the augmented reality group (37 patients) or the control group (64 patients). Anxiety scores were significantly lower in the augmented reality group compared to the control group at the time of admission (median difference [95% CI]: 6.3 [0–10.4], $p = 0.01$). Additionally, most patients in the augmented reality group reported high levels of satisfaction with the intervention. These findings support the effectiveness of VR for reducing anxiety in pediatric patients.[20,22]

Studies that provided sufficient statistical data were included in the meta-analysis, which evaluated the effect size of a game-based intervention on anxiety levels.[13] All studies used the mYPAS questionnaire and included a sample of 493 children in the intervention group and 471 in the control group. The effect size, calculated as the mean difference in mYPAS scores during anesthesia induction, was −10.62 (95% CI: −13.85, −7.39), favoring the intervention.[20,22] The statistical heterogeneity (I^2 value) across these studies was 84%. They also reviewed RCTs, with a total population of 2525 children across different countries. To evaluate anxiety, most studies used the mYPAS, while others utilized the YPAS-SF or the Yale Preoperative Anxiety Scale (YPAS). These scales were highlighted as key measurement tools for assessing preoperative anxiety.[20,22]

Regarding the application of the process, several RCTs describe how it can be implemented. For example, in one study, they highlight that a preoperative VR visit to the operating room was effective in alleviating preoperative anxiety and increasing compliance during anesthetic induction.[16] Similarly, in another analysis, they compared control groups of children who either received oral/written information about the anesthetic-surgical process or remained in a playroom awaiting surgery 7–10 days prior to surgery, demonstrating variability in the process.[29] The results showed a significant effect, with $p < 0.001$. Other authors also discuss the immersion time in VR, which ranges from 5 to 20 min, with most studies favoring sessions of less than 30 min.[12,20,22]

It has also been noted that VR is a promising nonpharmacological pain intervention, as it not only distracts but also modulates pain by immersing the user in a three-dimensional 360° alternate reality. In children, VR has been reported to reduce clinical pain and anxiety during medical procedures.[30] The aim of their crossover RCT was to assess the effect of VR on pressure pain threshold (PPT) and anxiety levels, measured with the mYPAS, in children. Seventy-two children (mean age 10.2 years, range 6–14) were randomized into 24 sequences of four interventions: immersive VR game, immersive VR video, tablet (2D video), and control (small talk). Results showed that PPT increased significantly during the VR game. Additionally, anxiety levels significantly decreased during both the VR game (mYPAS difference: −7 points [−8 to −5], $p <$ 0.0001) and VR video (mYPAS difference: −6 points [−7 to −4], $p < 0.0001$).[20,22,30]

Similar to VR, other nonpharmacologic interventions have shown benefit for patients in the perioperative field, but have limitations in their use in the pediatric population. Interactive music therapy appears helpful for some children upon separation from parents but not such to relieve surgical-related anxiety and anxiety-related outcomes.[31]

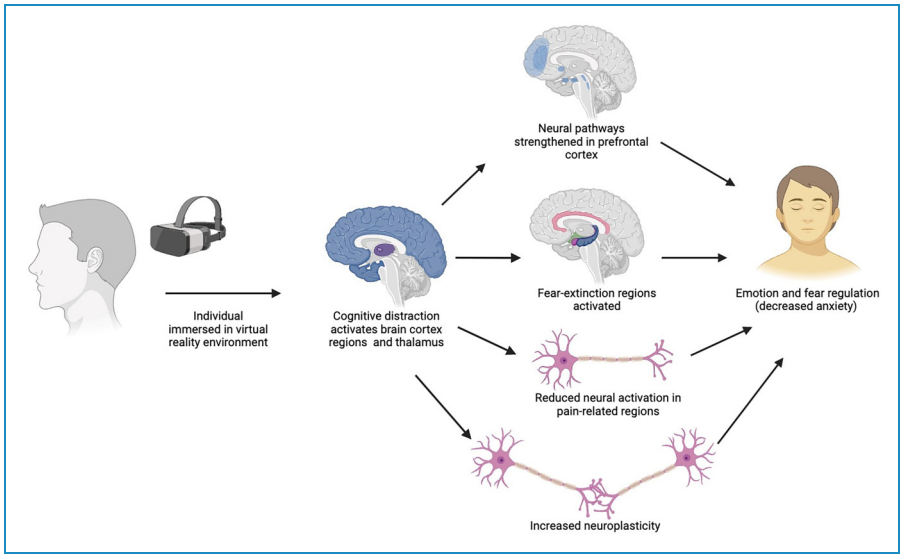

Figure 1. Neurological Mechanisms of Virtual Reality in Pain and Anxiety Regulation. Virtual reality (VR) engages multiple brain regions through cognitive distraction, activating the brain cortex and thalamus. This activation strengthens neural pathways in the prefrontal cortex, facilitates fear extinction processes, and reduces neural activity in pain-related areas. These mechanisms contribute to enhanced neuroplasticity and improved regulation of emotions and fear responses, ultimately leading to decreased anxiety.

Hypnosis has also been studied as a potential anxiety reduction strategy, and research indicates that this technique can be as effective as premedication with midazolam before surgery, but these studies have been primarily in adults.[32] Acupuncture, which originated as a key component of traditional Chinese medicine, can be a challenge in children due to their lack of willingness to participate, and therefore, research in the perioperative context has focused on acupuncture for parents.[33] There have been no clinical trials investigating the effectiveness of VR in comparison to these other nonpharmacologic interventions for treatment of perioperative pain and anxiety.

These findings support VR as an effective, feasible, appropriate, and valid nonpharmacological management modality for treatment of preoperative anxiety in pediatric patients as supported by statistical evidence.

Current applications of VR in medical settings

There are several clinical settings which have already adopted VR for psychiatric applications, postsurgical recovery, physiotherapy for neuromuscular disorders, and nonpharmaceutical adult and pediatric analgesia. These adaptations are summarized in Table 2. During the COVID-19 pandemic, VR interventions helped reduce psychological disorders in healthy individuals including healthcare workers and patients under lockdown. Virtual reality was used for pain management, as well as physical and cognitive rehabilitation in patients affected during the COVID-19 pandemic.[34] Virtual reality has documented benefits in rehabilitating individuals with moderate to severe disabilities, such as multiple sclerosis and those recovering from orthopedic surgery. These activities improve gross motor function and overall mental health in individuals who engage in virtual games. The immersive VR experience enhances both recovery time and physical strength.[35] Virtual reality has also been used for chronic pain management, including conditions such as chronic neck pain, lumbar pain, and fibromyalgia. Both immersive applications and nonimmersive VR techniques demonstrated favorable outcomes, relieving pain and improving functionality, allowing patients to increase their participation in daily activities.[36] In exposure therapy, VR provides realistic scenarios for patients with severe phobias or high anxiety, helping them build realistic expectations about interventions.[37] For individuals undergoing chemotherapy for breast cancer treatment, VR improved outcomes related to pain expectations, wound care, and adverse effects. In pediatric settings, VR has been adopted during needle sticks and blood draws, documenting high levels of distraction through interactive VR games.[38] Considering the success of these existing applications helps support further efforts to incorporate VR into the pediatric perioperative setting.

Challenges and limitations of VR

Despite its advantages, adoption of VR clinically poses several challenges when compared to other distraction-based techniques. A major limitation in existing literature is the small number of studies, most of which have nonrepresentative sample sizes, limiting generalizability.[2] This diversity of VR systems and the fact that not all medical procedures

Table 2. VR applications in the healthcare area.

Applications of VR in healthcare	Description	Key benefits	Target population	Practical application
Medical Education for Surgeons	VR is used to simulate operating room environments and surgical procedures.	Prepares students for real-life scenarios, improves hand-eye coordination, and helps with exposure to stressful situation.[30]	Medical students and resident physicians in training.	Provides immersive training in high-stakes environments without real-life consequences.
Preoperative Anxiety Management	VR therapy to manage anxiety in patients before surgical interventions, providing realistic expectations and exposure to surgery.[31]	Reduced anxiety, increased relaxation, and better psychological preparation.	Surgical patients with preoperative anxiety.	Preoperative immersive experience about procedure or distraction.
Postsurgical Recovery	VR used as part of rehabilitation programs to aid recovery, including improving physical mobility and reducing anxiety.	Improved dexterity, motor function, and mental health. Neuroplasticity aids recovery even in the untrained limb.[31]	Postsurgical patients, individuals with multiple sclerosis, rehabilitation patients.	Engaging VR games help maintain motivation for rehabilitation, improving both physical and psychological outcomes.
Physiotherapy for Neuromuscular Disorders	VR used to train limb mobility, often with games that require physical movement to stimulate neuroplasticity.	Improved gross motor skills, limb mobility, and overall rehabilitation.	Individuals with multiple sclerosis, neuromuscular disorders.	Effective even for patients who cannot physically perform movements due to immobilization or pain.
Nonpharmaceutical Analgesia	VR as a form of distraction to reduce pain and anxiety during medical procedures, such as wound care, surgery, and chemotherapy.	Reduced pain perception, anxiety reduction, and better emotional preparation for medical procedures.[32]	Adults undergoing surgeries, wound care, chemotherapy, and postoperative recovery.	VR can be used to expose patients to procedures in a controlled manner, decreasing fear and improving coping strategies.
Pediatric Therapy	VR used to treat children with disabilities or those undergoing medical procedures, including pain management and cognitive improvement.	Improved fine motor activity (e.g., in cerebral palsy), improved vigilance in ADHD, reduced anxiety and pain in burn victims, reduced pain and fear during needle procedures.	Children with disabilities, children undergoing medical procedures (e.g., phlebotomy, surgery).	Interactive VR is particularly effective in older children (6+), while passive VR may be more effective for younger children.
Pediatric Pain and Anxiety Reduction	Use of VR to reduce perceived pain and fear, especially during needle-related procedures such as intravenous access.	Reduction in anxiety, pain perception, and fear. Distraction through engaging VR experiences helps children cope better with medical procedures.	Children undergoing needle-related procedures or painful interventions.	Younger children may benefit more from passive VR experiences (e.g., cartoons), while older children engage better with interactive VR.

(continued)

Table 2. Continued.

Applications of VR in healthcare	Description	Key benefits	Target population	Practical application
Exposure Therapy for Phobias	VR used as exposure therapy to simulate situations that cause anxiety, helping patients build coping mechanisms.	Reduction in anxiety by providing realistic expectations and controlled exposure to anxiety-inducing stimuli (e.g., surgeries, medical procedures).	Patients with anxiety, especially related to medical procedures and surgeries.	Beneficial for managing anxiety related to surgery, wound care, and other medical procedures.

ADHD: Attention-Deficit/Hyperactivity Disorder; VR: virtual reality.

are suited to an interactive component complicates research efforts. While VR may produce positive results in some procedures, it yields mixed outcomes in other procedures. The setting and types of surgery influence the pain and anxiety experienced, making it difficult to establish and optimal timing and duration of preoperative intervention. There is also a wide variety of instruments to measure anxiety and pain, necessitating the establishment of objective evaluation.[39] High-performance bias is common due to the lack of blinding in studies, influencing both professional observations and participant behavior.[2,40]

Patient barriers also impact VR effectiveness. Evidence suggests that VR interventions may be potentially more effective in younger children than in adolescents. Virtual reality is especially engaging for younger children, as they are often more engaged in magical thinking.[2] Challenges, such as patient discomfort or motion/cyber sickness from the headsets or sensory limitations such as vision or hearing abilities, represent significant obstacles to VR implementation.[41] Motion sickness, in particular, occurs due to discrepancies between visual and vestibular inputs, leading to nausea, dizziness, and discomfort. For patients with sensory processing disorders, overstimulation during the immersive experience may lead to distress rather than therapeutic benefits causing anxiety or exacerbating preexisting conditions such as migraines. Addressing these patient-specific challenges requires careful tailoring of VR programs to individual needs and robust safety protocols to minimize adverse effects.[39,42]

There are several limitations in the widespread adoption of VR in the healthcare setting. One of the most significant challenges is the high cost of purchasing and maintaining the necessary equipment, software, logistics, and educating personnel.[42] These barriers to accessibility make it problematic to conduct further research on the topic and thus further delay the adoption of VR into the perioperative setting. There are few resources for healthcare providers to learn how to use and integrate VR into practice, resulting in a lack of knowledge and skill to implement VR confidently and efficiently. Additionally, technical barriers such as hardware malfunction, unreliable internet connection, and user-unfriendly interfaces further hinder implementation. The lack of FDA-approved medical devices and insufficient customization to patients' needs and treatment goals makes it challenging to secure acceptance and funding for VR projects, all of which contribute to possible apprehension from hospital administration and patient reluctance to consent to incorporate novel treatment options into the clinical setting.[2,30] Concerns about the cost of a systematic introduction of VR into the preoperative setting inevitably relate to equitable access to these interventions, as VR technology might disproportionately benefit patients from higher socioeconomic statuses who are more likely to be able to afford the cost of the equipment itself, as well as the cost of incorporating the technology into the workplace. This may further worsen social disparities in health for individuals receiving this intervention.

Additionally, a cost–benefit analysis would have to be performed as well. To our knowledge, no studies have investigated the financial incentives of incorporating a high-tech distraction-based method of anxiety and pain mitigation into the pediatric perioperative setting. It should be noted that cost savings and the prevention of potential risks of pharmacologic alternatives, as well as the reduction in time to comfort a crying and anxious child, may offset some of the initial investment in a VR product. It is possible that while the front-end cost may be a limitation, the long-term benefits may justify its use to improve quality measures that hospital systems track, such as total operating room time, turn-over, and patient satisfaction.

Additionally, the incorporation of VR into any healthcare setting raises several ethical concerns. Ethical questions regarding patient consent, particularly in vulnerable populations such as children and individuals with cognitive impairments, further complicate the implementation of VR in healthcare, making parental involvement essential.[35] Issues related to data privacy, namely the security of a patient's private health information, should be considered. If the VR software tracks patient information, how will the information be stored? What entities will receive and maintain access? What direct and indirect consequences might exist for the misuse of this personal information? Ultimately, the goal is to limit any

harm associated with the adoption of VR in the clinical setting. Protections from these harms should be the primary focus when adopting such a tool.

Future directions and implications for practice

The potential for VR to enhance preoperative care for pediatric patients is significant; however, broader implementation is contingent on overcoming several key challenges. One primary barrier is the cost of VR technology. If the cost of VR systems could be reduced, their accessibility in healthcare settings would increase substantially, making them viable for adoption in both affluent and undeserved areas.[1] To achieve this, future research should focus on developing cost-effective VR technologies, which could improve availability and make these interventions more affordable for a wider range of healthcare institutions and patient populations.[1,3,9]

Another challenge lies in the lack of awareness among healthcare professionals regarding the benefits of VR in the preoperative setting.[1,3,5,7,9] Educational efforts are needed to demonstrate how to incorporate VR into preoperative care effectively, could enhance their skills in managing pediatric preoperative anxiety, leading to improved patient outcomes.[1,5]

Future studies could explore the proper duration and timing of VR exposure before surgery to determine the ideal window for maximum effectiveness in reducing preoperative anxiety.[1,3] Additionally, standardized protocols should be developed for incorporating VR into preoperative care, ensuring all pediatric patients scheduled for surgery are offered a VR intervention. This could include making VR-assisted anxiety treatment a routine component of the preoperative procedure.[3]

Researchers have prioritized RCTs to establish causality. By randomly assigning pediatric patients to either a VR intervention or a control group (e.g., standard care), they can better assess the impact of VR on preoperative anxiety, pain management, and recovery. A larger samples size is critical to enhance the statistical power of studies and ensure that the results are reliable and applicable to diverse patient populations.[1] This is particularly important for pediatric populations, where variations in age, developmental stage, and underlying health conditions could influence the response to VR interventions. A larger cohort would allow for subgroup analyses, incorporating diverse demographic backgrounds, including varying socioeconomic statuses, ethnicities and geographical locations, and medical conditions.[1,5] Determining the most impactful VR interventions and ensuring that this innovative tool can be universally applied will unlock the full potential of VR in pediatric preoperative care.[5]

Conclusion

Virtual reality has shown surprising efficacy in the treatment of pain and anxiety, especially in pediatrics. Virtual reality offers comparable benefits to opioid analgesics in relieving pain without the associated risks, making it a promising alternative. Although VR applications are promising, further research is needed to establish its role in routine clinical practice. As VR technology continues to evolve, its integration into healthcare could significantly improve the patient experience, especially in sensitive areas such as pediatric care, where minimizing anxiety and pain is crucial. With further research into this preoperative technique, VR could become a standard tool in therapeutic instrumentation, with great advantages for both patients and healthcare professionals. Larger and more diverse studies are needed to confirm the currently available results and to take into account the variability of individual patient responses to VR interventions. In addition, there are logistical issues, such as the cost of VR equipment, the need for specialized technical support, and the training of healthcare professionals, which require further research for the future application of VR.

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Statements and declarations

Ethical considerations

Ethics approval and consent to participate: Given that this narrative review utilized previously published data from studies that had already obtained ethics approval and consent to participate, no additional ethics approval or consent was required for this research.

Author contributions/CRediT

Dr Gabriela has contributed in the abstract and the citation of the whole manuscript, Dr Sabrina together with Dr Daniela have contributed in the introduction and conclusion of the paper. Drs Isabella, Gladys, Paloma, Marisa, and Alexis have contributed in the body of the paper, and Dr Ernesto has supervised and controlled the whole manuscript collaborating when required.

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