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CASE REPORT

# Virtual Reality Treatment of Severe Neuropathic Pain in an Adolescent Child: A Case Report

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We describe virtual reality (VR) used as an effective intervention to treat severe chronic neuropathic pain in an otherwise healthy adolescent boy. The patient presented with severe pain and allodynia in the right foot after calcaneus extension surgery. Multiple medical and psychological interventions were unsuccessful over 3 years, with the pain leading the patient to drop out of school. VR gaming intervention provided the patient with significant pain relief and substantial improvement in functionality.

This case report details the VR intervention and its effect on the patient's severe, medically refractory pain syndrome. (A&A Practice. 2023;17:e01689.)

## GLOSSARY

**NRS** = numerical rating scale; **TENS** = transcutaneous electric nerve stimulation; **VR** = virtual reality

Chronic neuropathic pain after peripheral nerve injury may be severe.[1] Pharmacological treatment often proves inadequate,[2] leaving patients in dire need of alternative treatment modalities.

Virtual reality (VR) has demonstrated efficacy as an adjunct therapy in acute pain management, but only limited evidence exists for its role in the management of chronic neuropathic pain.[3] Recent studies have shown a pain reduction in patients using VR technologies, though with highly individualized results and insufficient evidence of persistent benefit.[4–6]

We describe a successful treatment of severe, persistent neuropathic pain and allodynia in an otherwise healthy adolescent boy. The description of the instigated VR therapy and the results serve to add to the emerging experience of VR as a potential treatment modality for neuropathic pain.

The patient and his parents have provided written consent to sharing his history and images for publication in this case report.

## CASE DESCRIPTION

### Medical History

A 9-year-old boy affected by pain in both feet during physical activity was diagnosed with flat feet during September 2014 and offered corrective surgery. The boy suffered no other illnesses and had a normal upbringing and normal school attendance.

In January and again in April 2015, he was operated on with calcaneus extension, first on the right foot with an autologous fibula bone graft, and later on the left foot with an artificial implant, followed by 6 weeks of healing in X-lite cast. In August the same year, the patient complained of pain and soreness in the operated area on the medial aspect of the right foot. Objectively, he was observed limping and unable to invert the foot.

Immobilization in ROM-Walker was instigated for 6 weeks, followed by physiotherapy and medical treatment with ibuprofen. Unfortunately, the pain persisted, especially during physical activity.

The pain gradually worsened, and in January 2017, the patient, now 11 years old, had developed allodynia along the surgery scar corresponding to the innervation area of the sural and superficial peroneal nerve. This was treated for 6 months with gabapentin 900 mg/d with some effect, and the boy could resume some sports activities.

In October 2017, the pain and allodynia spontaneously worsened. The patient dropped out of school due to the reported severe pain (8 on a conventional 0–10 numerical rating scale [NRS]), and one of his parents was constantly at home taking care of him. This, in turn, challenged the parents' employment situation.

In March 2018, the boy, now age 12 years, was referred for a second opinion by the neuromodulation team at the Department of Neurosurgery, Aarhus University Hospital, Denmark.

### Clinical Findings

The patient came in walking on crutches. He was normally developed, with prepubertal appearance, normal height and weight, and age-appropriate behavior. As soon as he took off his right sock, he reported that an excruciating pain was provoked, and he cried and was visibly in severe distress. The patient described the sensation as burning and stabbing. He demonstrated allodynia when we gently touched the scar on the dorsomedial side of the right foot. The patient reported the pain as up to 8 on the NRS. The

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**Figure 1.** A current image of the patient's foot showing the scar after the calcaneus extension. Image reproduced with patient and parental permission.

area with severe allodynic pain measured approximately 7 × 5 cm (Figure 1). The presumed cause was a lesion of the right sural nerve and possibly the medial branch of the superficial peroneal nerve.

The rest of the somatic and neurological examination revealed normal findings. A functional component of the pain experience was deemed present, but the patient's verbal feedback matched touch allodynia, serving to support the diagnosis of a severe chronic pain of neuropathic origin. The prognosis was uncertain, and the family had been informed by the pain unit that no further treatment options were available.

## Therapeutic Intervention

The therapeutic interventions attempted at our unit were as follows:

1. Transcutaneous electric nerve stimulation (TENS) therapy.
2. Local analgesia by application of topical lidocaine 5% patch (Versatis; Grünenthal, Aachen, Germany). Both of these treatment methods had no effect.
3. Sural nerve blockade (ultrasound-guided) with bupivacaine 0.25%, leading to remission of pain for about 24 hours. This was later followed by neurolysis with intraneural glycerol, which had only partial effect lasting <1 week.
4. Mirror therapy. The patient was puzzled as to how he could touch his painful area on the "left foot" in the mirror. He commented that the experience was like playing a game in VR.
5. VR intervention. Following recommendation, the patient began experimenting with various 3-dimensional VR games, which stimulated him to move his body, including the pain-affected foot (such as "Beat Saber" [Beat Games, Czech Republic]), or activities in which he could see a full-body simulated reflection of himself (an avatar embodiment) such as "VR chat" (Discord), a virtual forum, where you can walk around in cityscapes and see yourself as an avatar. Especially, VR renderings where the patient could see himself in a mirror enabled him to touch his virtual foot without pain, corresponding to mirror therapy.

## Follow-up and Outcome

By immersing himself in the VR gameplay (Figure 2), the patient gradually started experiencing pain reduction, and he began mobilizing the right extremity and foot. Within

**Figure 2.** The patient after 1 month of VR therapy, playing a VR video game, now with socks on his previously allodynic feet. Picture provided by the patient's parents. Image reproduced with patient and parental permission. VR indicates virtual reality.

the first week, the pain had significantly decreased, and the allodynic sensations had almost disappeared.

The patient was continuously encouraged to engage in VR-based exercises of his own choice on an average of 1 to 2 hours per day. During the initial VR treatment, the parents also helped him use VR during the night to alleviate his pain.

Two months later, he was able to walk without crutches, and the allodynic sensations had disappeared.

By August 2018, he could cooperate with a physiotherapy training program with biking, hot water swimming, and sports exercises such as basketball. By now, his NRS score was 3. The painful area on his right foot had decreased considerably (approximately 5 × 1 $cm^2$) to the area located along the central part of his scar.

By October 2018, he was back to school full-time, and by January 2019 at the final follow-up session in the neuromodulation outpatient clinic, he was practically without pain (NRS 1–2) and fully mobilized.

As of 2021, the boy, now 15 years of age, is fully engaged in his schoolwork and sports activities. He still actively uses VR gaming without experiencing restraints, and he is pain-free. He can feel increased pain when touched directly on the scar of his foot, but is otherwise a normal, physically active adolescent.

An overview of the treatment course can be found in the Table.

## DISCUSSION

We report a beneficial role of VR immersion and engagement as a possible new treatment modality for severe neuropathic pain after surgery with peripheral nerve lesion in an adolescent patient.

**Table. Treatment History**

| Year and Month | |
|---|---|
| 2014–September | 9-y-old boy diagnosed with flat feet |
| 2015–January | Calcaneus extension left foot |
| 2015–April | Calcaneus extension right foot |
| 2015–August–September | Complaints of pain in surgery area on right foot ROM-Walker immobilization without effect |
| 2016–All year | Continuing pain in surgery area on right foot and decline in physical activity |
| 2017–January | Diagnosis of allodynic pain along the surgery scar |
| 2017–October | Persistent allodynic pain despite medical treatment |
| 2018–March | Second opinion, neurosurgical neuromodulation team |
| 2018–April–May | TENS, topical local analgesic (Versatis), and glycerol neurolysis with no effect |
| 2017–May | VR play and gaming intervention |
| 2018–August | Physiotherapy added to VR–NRS 3 |
| 2018–October | Return to school–NRS 3 |
| 2019–January | Final follow-up in neuromodulation team |
| 2021–June | Video conference follow-up for this case report |

Abbreviations: NRS, numerical rating scale; TENS, transcutaneous electrical nerve stimulation; VR, virtual reality.

The literature on the effectiveness of VR in the treatment of neuropathic pain is still limited.[7] A recent systematic review and meta-analysis on the effect of VR in pediatric patients concluded that VR was most often used for distraction and anxiety suppression during medical procedures.[8] The same conclusion was reached in a review of VR applications used in a hospital setting on pediatric patients.[9]

A review study in adults focused on VR treatment of neuropathic pain after spinal cord injury also showed pain reduction.[4] In a systematic review of 13 trials of VR on chronic pain from different etiologies in adults, such as ankylosing spondylitis, mastectomy, limb, and phantom limb pain, VR was deemed effective.[10] Likewise, a systematic review on 20 VR trials suggested that VR could reduce pain in adults during the intervention, but evidence for a lasting effect was lacking.[11] A weakness in these reviews is the lack of a clear distinction between patients with chronic neuropathic pain and patients with chronic nociceptive pain.

Different theories about the pain alleviation mechanism of VR have been suggested. The underlying mechanism processes are generally divided into 2 main types. One theory is that VR provides a short-term analgesic effect via pain distraction and anxiety reduction, as the patient's attention is diverted to another stimulus.[12,13]

Another mechanism, which may be a consequence of the short-term analgesic effect, is that neuroplasticity is the underlying mechanism contributing to the analgesic effect of VR by inducing a long-term structural change in neuron populations in sensory and motor brain regions. In accordance with this theory, functional magnetic resonance imaging studies have shown that VR intervention reduces pain-induced responses in the central nervous system pain matrix areas.[13,14] More precisely, it is assumed that a long-term analgesic effect originates from cortical modulation with increased activity at brain regions—that is, the anterior cingulate cortex, primary and secondary somatosensory cortex, and orbitofrontal region—and decreased activity at the posterior insula.[3] Embodiment and immersion in the virtual world, moreover, enhances virtual presence and reduces sensations of pain.[15]

We thus hypothesize that the embodiment and immersion in virtual gaming and play in the present case modulated the central pain sensitization of the patient's right foot neocortical representation, thereby reducing and ultimately abolishing his chronic pain.

The case shows promising prospects for the use of VR to treat chronic neuropathic pain where other medical treatments failed. The results presented in this case study emphasize the importance of further studies investigating the potential of immersive and embodying VR technologies in the treatment of neuropathic pain.

## DISCLOSURES

**Name**: Jens Christian Hedemann Sørensen, MD, PhD, DMSc.
**Contribution**: This author conceived the idea; prepared the next drafts of the paper with significant contribution from K.M. and I.M.; and revised, contributed to, and approved the final manuscript.

**Name**: Maria Vlachou, MD.
**Contribution**: This author prepared the first draft of the paper with J.C.H.S.; and revised, contributed to, and approved the final manuscript.
**Name**: Ioanna Milidou, MD, PhD, MSc.
**Contribution**: This author contributed to the manuscript from a pediatric view; and revised, contributed to, and approved the final manuscript.
**Name**: Anne Lene Knudsen, RN.
**Contribution**: This author treated the patient with J.C.H.S.; gathered data for the paper; and revised, contributed to, and approved the final manuscript.
**Name**: Kaare Meier, MD, PhD.
**Contribution**: This author edited the draft; prepared the final version of the paper; and revised, contributed to, and approved the final manuscript.
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**Informed Consent:** The patient and his parents have provided written consent to sharing his history and images for publication in this case report.

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