OPEN ACCESS

Effect of virtual reality (VR) therapy on pain sensation in patients undergoing hand surgery under ultrasound-guided regional anesthesia: a randomized controlled trial

Kristof Nijs,[1,2] Thibault Treunen,[3,4] Hassanin Jalil,[5] Mathijs Lensen,[3,4] Helena Wintmolders,[6] Bram Keunen,[5] Maarten Vanloon,[5] Ina Callebaut ,[5,7] Laurien Geebelen,[5] Marc Van de Velde,[2,8] Björn Stessel [5,7]

[1]Department of Anesthesiology and Pain Medicine, Jessa Hospital Campus Virga Jesse, Hasselt, Flanders, Belgium
[2]Department of Cardiovascular Sciences, KU Leuven, Leuven, Flanders, Belgium
[3]Department of Anesthesiology and Pain Medicine, Jessa Ziekenhuis vwz, Hasselt, Flanders, Belgium
[4]Department of Anesthesiology and Pain Medicine, UZ Leuven, Leuven, Flanders, Belgium
[5]Anaesthesiology and Pain Medicine, Jessa Ziekenhuis vwz, Hasselt, Belgium
[6]Department of Anaesthesiology and Pain Medicine, Jessa Ziekenhuis Campus Virga Jesse, Hasselt, Flanders, Belgium
[7]Faculty of Medicine and Life Sciences, UHasselt, Diepenbeek, Belgium
[8]Anesthesiology and Pain Medicine, KU Leuven, Leuven, Belgium

Correspondence to
Ina Callebaut;
ina.callebaut@jessazh.be

Received 24 January 2025
Accepted 9 May 2025

To cite: Nijs K, Treunen T, Jalil H, *et al*. *Reg Anesth Pain Med* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/rapm-2025-106418

ABSTRACT

Background and objectives During ultrasound-guided regional anesthesia and surgery, patients receive sensory input, which combined with stress and anxiety, can exacerbate or cause pain. Virtual reality therapy could provide digital sedation. Our aim is to assess the effect of virtual reality therapy on pain levels during the placement of regional anesthesia and surgery.

Methods This prospective randomized controlled superiority trial enrolled 120 patients undergoing elective hand surgery to investigate the effect of perioperative virtual reality therapy, consisting of a visual and audible three-dimensional, passive program. Patients were randomized to virtual reality therapy (n=60) or no virtual reality therapy (n=60) during regional anesthesia block placement and surgical procedure. Mean pain score (11-point numerical rating scale) during ultrasound-guided regional anesthesia placement was the primary outcome. Secondary outcomes were the mean pain score during surgery, heart rate variation during ultrasound-guided regional anesthesia placement and surgery, perioperative opioid use, anxiety (11-point numerical rating scale where 0=no anxiety at all and 10=extremely anxious), virtual reality immersion and presence (Igroup Presence Questionnaire), adverse events and patient satisfaction (11-point numerical rating scale where 0=not satisfied at all and 10=extremely satisfied).

Results Mean pain scores during ultrasound-guided regional anesthesia placement were 3.9±2.4 in the control group and 3.6±2.4 in the virtual reality group, with a mean difference of −0.3 (95% CI −1.2 to 0.5; p=0.22). Heart rate variation during ultrasound-guided regional anesthesia placement and surgery was non-significantly different. Anxiety during ultrasound-guided regional anesthesia placement showed no significant difference; however, it was significantly different during surgery (control: 1.5 (0.0, 4.0) vs virtual reality: 0.0 (0.0, 2.0), p<0.01). Virtual reality immersion showed a total mean score of 4.2±0.9. Seven patients (11.9%) suffered from adverse virtual reality effects. Patient satisfaction during surgery and perioperative opioid use showed no significant difference. Satisfaction with virtual reality was high: 9.0 (8.0, 10.0).

Conclusion Our results show that the use of virtual reality therapy during ultrasound-guided regional anesthesia placement and hand surgery does not result in lower pain scores. A perioperative significant positive effect on anxiety was measured, combined with a clinically significant effect on perioperative anxiety. The clinical influence of different virtual reality therapy systems on pain and anxiety should be further investigated in (other) elective procedures.

Trial registration number NCT05183412.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Limited studies concerning the effect of virtual reality (VR) therapy on pain relief and anxiety in orthopedic surgery are present.

WHAT THIS STUDY ADDS

⇒ In the current study, we could not demonstrate VR therapy to reduce elicited pain during placement of US-guided regional anesthesia nor during surgery using objective heart rate variability measurement results. However, measurements of anxiety during surgery showed to be significantly different in favor of VR therapy.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These results indicate that further research on the clinical effect of VR therapy on anxiety is necessary.

INTRODUCTION

Ultrasound (US)-guided regional anesthesia (RA) is widely used in orthopedic surgery and is regarded as the golden standard due to its safety and reliability.[1 2] For various procedures, RA is sufficient to manage pain during surgery. However, patient expectations and anxiety can vary,[3 4] and studies have shown that psychological variables can impact the perception of pain, and the needle-related process of RA is often accompanied by dread or worry.[5] During RA placement and surgery, patients

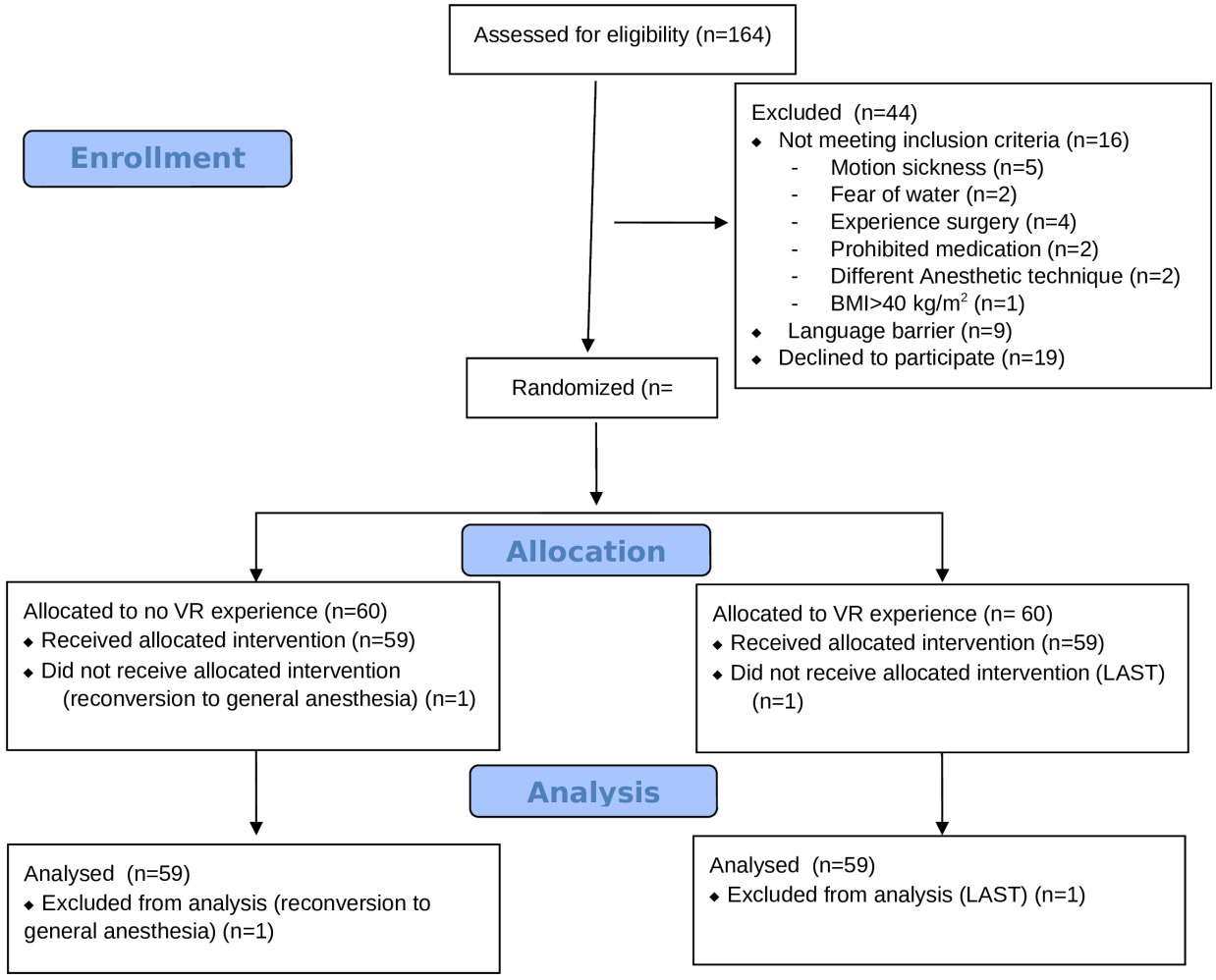

Figure 1 CONSORT diagram. BMI, body mass index; CONSORT, Consolidated Standards of Reporting Trials; LAST, local anesthetic systemic toxicity; VR, virtual reality.

may receive sensory input. Combined with stress, anxiety and fear, this can exacerbate or possibly cause pain.[5]

Sedatives and/or systemic opioids are often administered to increase the efficacy of RA blocks. Nevertheless, these partially neutralize the advantages of RA.[6] Recent data showed that 64,3% of patients prefer to stay awake during RA if possible.[3] Non-pharmacologic analgesic techniques (eg, hypnosis, music) sometimes referred to as 'Digiceuticals' have been promoted as useful adjuncts to pharmacological anesthesia. Finally, there is an increased interest in immersive virtual reality (VR) tools as a distraction to alleviate pain and distress during medical procedures.[7] VR is a computer-generated simulation, with images and sounds that represent a real place or situation that can be interacted with in a seemingly real or physical way by a person using special electronic equipment.[8] By distancing patients from reality, VR might potentially alleviate pain sensations caused by hazardous stimuli.[9] Two important concepts of VR for pain reduction are presence and immersion.[10–12] Presence can be defined as one's sense of being in an artificial environment, and immersion is the physical/sensory stimulus offered by the artificial environment.[10–12] Previous research showed that a high level of VR presence correlated with increased analgesic effects[9] and should be quantified when conducting clinical research using validated measurements (Igroup Presence Questionnaire (IPQ)).[13] VR has become a desirable complementary option in pain management in conjunction with RA. Various VR therapy systems are available; however, the effectiveness of VR therapy can vary depending on the specific system used.

A few studies have been focusing on the pain relief effect of VR in orthopedic surgery.[14–16] However, major limitations in previous research were the focus on subjective measurements of stress, pain and anxiety, whereas the objective measurements were limited. Ideally, objective parameters of stress, pain and anxiety within an operative, anesthesiologic framework should also be assessed. An objective parameter of sympathetic activity is heart rate variability (HRV).[17] HRV is the fluctuation in length between consecutive heartbeats and refers to the heart's ability to react to a wide range of physiological and environmental stimuli. Hence, HRV is a good indicator of sympathetic activity and indirectly correlates with stress.[18 19]

This study aims to assess the effect of VR therapy on pain levels of patients undergoing ambulatory hand surgery performed under US-guided RA.

We hypothesize that the use of VR in elective hand surgery under US-guided RA provides a significant decrease in procedural pain scores. Also, a possible effect of VR on HRV and subjective levels of anxiety will be evaluated.

METHODS

This prospective, monocenter, randomized controlled superiority trial was approved by the ethical committee of the Jessa

Table 1 Baseline demographics

	No VR group N=60	VR group N=60
Age (years)	52.5 (45.3, 59.0)	55.5 (45.3, 59.0)
Gender (male)	23 (38.3%)	25 (41.7%)
BMI	25.5 (22.7, 28.5)	27.5 (24.8, 30.3)
ASA	1.0 (1.0, 2.0)	1.0 (1.0, 2.0)
Smoking		
No	29 (48.3%)	32 (53.3%)
Yes	15 (25.0%)	14 (23.3%)
Ex	16 (26.7%)	14 (23.3%)
Alcohol consumption		
Never	23 (38.3%)	21 (35.0%)
<10 units/week	33 (55.0%)	33 (55.0%)
>10 units/week	4 (6.7%)	6 (10.0%)
Working status		
Unemployed	5 (8.3%)	5 (8.3%)
Volunteer	0 (0.0%)	0 (0.0%)
Student	1 (1.7%)	0 (0.0%)
Retirement	8 (13.3%)	5 (8.3%)
Incapacitated (>6 months)	5 (8.3%)	8 (13.3%)
Paid employment	35 (58.3%)	38 (63.3%)
Self-employed	6 (10.0%)	4 (6.7%)
Education		
Elementary school	2 (3.3%)	4 (6.7%)
Secondary school	47 (78.3%)	34 (56.7%)
Bachelor's degree	10 (16.7%)	18 (30.0%)
Master's degree	1 (1.7%)	4 (6.7%)
Pain (NRS)	2.4±2.8	2.1±2.5
Expected pain during block (NRS)	4.0±2.6	3.5±2.7
Expected pain during surgery (NRS)	0.6±1.2	1.1±2.1
Anxiety (NRS)	2.7 (0.0, 5.0)	2.0 (0.0, 4.0)
Surgical fear		
Short term	1.7 (0.5, 3.0)	1.0 (0.0, 3.0)
Long term	0.3 (0.0, 1.7)	0.5 (0.0, 1.7)
Heart rate variability	N=50	N=48
HF (ms^2)	425.5 (165.1, 704.3)	334.1 (170.1, 643.2)
RMSSD (ms)	43.3 (27.8, 64.1)	40.6 (27.6, 61.9)
Type of surgery		
Carpal tunnel syndrome	28 (46.7%)	25 (41.7%)
Trigger finger	11 (18.3%)	7 (11.7%)
Dupuytren's contracture	11 (18.3%)	14 (23.3%)
Fracture	1 (1.7%)	1 (1.7%)
Tendon repair	1 (1.7%)	0 (0.0%)
Cyst	1 (1.7%)	2 (3.3%)
Burton-Pelligrini	0 (0.0%)	1 (1.7%)
De Quervain	1 (1.7%)	4 (6.7%)
Mallet finger	2 (3.3%)	1 (1.7%)
ROM	1 (1.7%)	0 (0.0%)
Prosthesis	2 (3.3%)	2 (3.3%)
Skier's thumb	1 (1.7%)	2 (3.3%)
Corpus alienum	0 (0.0%)	1 (1.7%)
Type of regional anesthesia		
Distal peripheral forearm nerve block	44 (73.3%)	44 (73.3%)
Axillary brachial plexus block	16 (26.7%)	16 (26.7%)
Earlier VR experience	14 (23.3%)	10 (16.7%)

Data are expressed as median (25%, 75%), mean±SD or frequencies (%). A difference between groups was measured with the Mann-Whitney U test, a Student t-test or χ^2 test. ASA, American Society of Anesthesiologists' ; BMI, body mass index; HF, high-frequency power; NRS, Numeric Rating Scale ; RMSSD, root mean square of successive differences; ROM, removal of osteosynthesis material; VR, virtual reality.

Table 2 Procedural information

	No VR	VR	P value
Duration of VR during US-guided block placement	/	11:13±07:52	/
Duration of VR during surgery	/	19:20±12:41	/
Needling time	04:42 (03:27, 06:52)	04:28 (03:08, 06:00)	0.58
Surgical time	08:48 (05:27, 15:51)	08:43 (05:41, 18:45)	0.69

Data are expressed as median (25%, 75%) or mean±SD. Time in minutes. A difference between groups was measured with the Mann-Whitney U test. p<0.05 is considered statistically significant.
US, ultrasound-guided; VR, virtual reality.

Hospital, Hasselt, Belgium (Chairperson Dr K. Magerman, registration number B2432021000031 on 21 December 2021, registered on clinicaltrials.gov on 5 January 2022 (NCT05183412) and executed according to the Declaration of Helsinki. After obtaining informed consent, we recruited 120 consecutive patients between 18 and 65 years with an 'American Society of Anesthesiologists' (ASA) physical status of 1 to 3, scheduled for elective hand surgery using US-guided axillary brachial plexus block (ABPB) or US-guided distal peripheral forearm nerve block (DPFNB) between 26 January 2022 (first patient enrolled) and 6 September 2023 (last patient enrolled).[1 20] This study is reported according to the Consolidated Standards of Reporting Trials (CONSORT) statement.[21]

Exclusion criteria were an ASA physical status >3, <18 years old, >65 years old, bilateral surgery, a body mass index (BMI) ≥40, a local site infection, pregnancy,[22] a history of neurological disorders, motion sickness, chronic pain symptoms, allergy to local anesthetic, taking medication that affects the heart rhythm (beta blocker), opioid use within the past 3 months, mental impairment, heart transplant patients, patients with diabetic neuropathy, patients with myocardial infarction (or having passed through it) and/or tetraplegic patients,[23] patients with autonomic nervous system dysfunction,[24] the inability to experience the VR experience (vision disorders and self-reported difficulties in perceiving VR visuals clearly) and the inability to understand and adhere to the study design.

Baseline assessment parameters included patients' demographic data such as gender, age, BMI, 'ASA' physical status classification, level of education and work status. Baseline and expected pain

Figure 2 Mean NRS pain scores. Evaluation of the superiority of VR therapy versus the control group. NRS, Numerical Rating Scale; VR, virtual reality.

Table 3 Heart rate variability measurements

	No VR group	VR group	P value
HF baseline (ms^2)	425.5 (165.0, 704.3) N=50	334.1 (170.1, 643.2) N=48	0.48
HF placement block (ms^2)	319.1 (151.3, 587.5) N=54	379.6 (199.9, 622.0) N=56	0.33
HF surgery (ms^2)	320.6 (142.6, 501.7) N=54	310.2 (143.5, 558.3) N=55	0.97
RMSSD baseline (ms)	43.3 (27.8, 64.1) N=50	40.6 (27.6, 61.9) N=48	0.59
RMSSD placement block (ms)	38.7 (28.0, 48.6) N=54	37.8 (26.6, 49.6) N=56	0.63
RMSSD surgery (ms)	37.4 (25.9, 45.3) N=54	34.0 (23.7, 44.0) N=56	0.37

Data are expressed as median (25%, 75%). A difference between groups was measured with the Mann-Whitney U test. p<0.05 is considered statistically significant.
HF, high-frequency power; RMSSD, root mean square of successive differences; VR, virtual reality.

scores (using the Numerical Rating Scale (NRS) score), fear of the surgical procedure (using an 8-item surgical fear questionnaire),[25] quality of recovery (using the 1-item Global Surgical Recovery)[26] index and the Functional Recovery Index[27] as well as quality of life, using the 5-dimensional European Quality of Life questionnaire were collected.[28]

Randomization and blinding

Participants were randomly assigned in a 1:1 ratio to either of the two study groups: a group undergoing US-guided RA with VR therapy (n=60) and a group undergoing US-guided RA without VR therapy (n=60). Randomization was performed using a computer-generated random allocation sequence in which stratification for the type of US-guided RA (ABPB or DPFNB) was applied due to differences in procedural pain scores between the blocks.[29] Allocation numbers were sealed in opaque envelopes and were opened by an independent anesthesiologist. Patients were not blinded and two independent assessors gathered outcome data. A blinded assessor obtained the patient satisfaction questionnaire, NRS pain and anxiety scores. An unblinded assessor collected the Virtual Reality Symptom, the IPQ and Simulator Sickness Questionnaire (SSQ). Data processors were blinded.

Study procedures

Preoperative phase

All patients received an IV access with NaCl 0.9% 100 mL at 60 mL/hour in the contralateral arm, standard non-invasive monitoring (non-invasive blood pressure monitoring, ECG, saturation measurement), electrodermal activity and HRV measurement. RA was performed by RA specialists 30 min before surgery.[30] No sedatives were provided during RA placement and surgery. HRV will be analyzed using photoplethysmography (PPG) measured by the Empatica E4 wristband,[31] which will be placed on the contralateral arm and contains PPG sensor to measure blood volume pulse (BVP) from which it extracts HR and the inter-beat interval.[32] Baseline HRV data were measured after 5 min of rest in a supine position for acclimatization. Changes in body positioning can affect HRV and were therefore avoided throughout the monitoring process. Room temperature and relative humidity were constant during the monitoring process, around 20°C–21°C.[31 33–35] HRV data were collected during the placement of the RA and during surgery.

Depending on the surgery, the patient received an US-guided ABPB or an US-guided DPFNB. The US-guided ABPB was performed as described by Hadzic *et al* and the US-guided DPFNB as described by Jalil *et al*.[1 20 29] A General Electric LOGIQe device and a 12 MHz linear echo transducer with a 4 cm footprint were used. The echo probe was taped with a sterile Tegaderm film, and sterile US gel was used. Injection of medication for the ABPB was US guided and injection pressure monitoring and peripheral nerve stimulation (22G Stimuplex Ultra 50 mm (B. Braun Medical, Melsungen, Germany) were used to ensure optimal patient safety. After placement of the RA block, NRS pain and NRS anxiety of the block placement were scored by the blinded assessor.

In the VR group, 5 min before RA placement, VR glasses were adequately placed on the patients' head after verbal reassurance, this is to acquire a better patient immersion. The VR glasses used in this study were Sedakit (Oncomfort SA, Wavre, Belgium). By using this system, the patients were subjected to a visual and audible three-dimensional, passive 360° VR program via a head-mounted display and headphones, watching an underwater view of the ocean following the tail of a whale to induce relaxation, while listening to speeches to induce relaxation and meditation.[36] RA needling started only after 5 min into VR therapy. After placement of RA (an ABPB or DPFNB), the VR glasses were temporarily removed.

Perioperative phase

In the operation room (OR), the VR glasses were remounted to the VR group patients. After the installation of the patient, antiseptic decontamination and placement of surgical drapes, the surgeon and study staff entered the OR. The quality of the block was determined by the surgeon before the start of the operation using forceps prick in the hand dermatomes. Surgery started if the RA was sufficient. When the block showed to be insufficient, more analgesics were provided by initial administration of local anesthetic in the surgical field and/or IV opioids (alfentanil or sufentanil). Conversion to deep sedation or general anesthesia was applied if it was still not sufficient for surgery. Furthermore, all patients received preoperatively IV paracetamol 15 mg/kg (max 1 g), ketorolac 0.5 mg/kg (max 30 mg) and dexamethasone 0.1 mg/kg (max 5 mg). The HRV was measured by the Empatica E4 wristband.[31]

Outcome measures

The primary outcome was the NRS pain score during the placement of the US-guided RA block (mean±SD) with an 11-point NRS, where 0=no pain and 10=worst pain possible).

Secondary outcomes were mean (±SD) NRS Pain scores during surgery (where 0=no pain and 10=worst pain possible), median (IQRs) NRS Anxiety scores during RA placement, and surgery (where 0=no anxiety at all and 10=extremely anxious), perioperative opioid use, patient satisfaction (during RA placement and surgery) and with the use of VR therapy were assessed after surgery with an 11-point NRS scale (where 0=not satisfied at all and 10=extremely satisfied).[37]

VR immersion and presence were measured via the IPQ tool (maximum score is 6) after block placement and at the end of surgery.[13 38] It is a validated measurement, which encompasses four subscales: Spatial Presence, Involvement, Experienced Realism and Overall Sense of Presence.[39] IPQ scores (ranging from 0 to 6) were collected at two time points: after

RA placement and after surgery. Subscales were presented as mean±SD. The Overall Sense of Presence score was calculated by taking the mean of all IPQ items (including those from all subscales).

HRV was measured at baseline and during placement of US-guided RA and surgical procedure.

Adverse events related to VR therapy (dizziness, headache, oculomotor discomfort and disorientation) were assessed with the VR Symptom Questionnaire and SSQ.[32]

Statistical analysis

Sample sizes were determined for primary outcome with the aim to demonstrate superiority of VR therapy over standard treatment (no VR therapy). A difference in pain NRS score of 1.3 points or more was considered clinically relevant.[40] Based on a retrospective analysis of unpublished data from our hospital, we assumed a mean NRS score of 3.64 during placement of the block with an SD of the NRS scores of 2.51. We determined the sample size for each group to be 59 (α=0.05, power=0.80). To account for possible drop-out, the sample size was increased to 60 patients per group.

Data were analyzed according to an intention-to-treat basis and are presented as mean±SD, median (25%, 75%) or frequencies (%). The normality of the data was tested by the Kolmogorov-Smirnov and Shapiro-Wilk tests. Anxiety scores were presented as median (25%, 75%) due to non-normal data. To determine the superiority of the NRS score pain during the placement of the US-guided RA block, a mean difference with 95% CIs was computed. The other NRS scores for pain and the IPQ scores were compared using the independent t-test.

HRV was analyzed in the two groups using the BVP measured by the Empatica E4 and was determined in Root Mean Square of Successive Differences between consecutive heartbeats (RMSSD) and in High Frequency (HF-HRV).[26 34 39 41] A Mann-Whitney U test was used for comparison between patients with VR glasses and the control group.[42] Statistical significance was reached at p<0.05 and all analyses were performed using IBM SPSS V.28 (IBM Corporation, Armonk, New York). Empatica Manager and Kubios were used in the HRV analysis.

RESULTS

A CONSORT flowchart is presented in figure 1. In total, 120 patients were enrolled and 118 patients were included in the analysis. Baseline characteristics are presented in table 1. Both groups significantly differed in mean BMI (p=0,04) while they were comparable for all other characteristics. Additional information on VR duration during US-guided RA placement and surgery, needling time and surgical time is presented in table 2.

For the primary outcome, VR therapy showed no significant difference in mean pain during the placement of US-guided RA (NRS control 3.9±2.4 vs NRS VR glasses: 3.6±2.4, p=0.22) (mean difference (95% CI) −0.3 (−1.2 to 0.5)) (figure 2). Likewise, the mean NRS pain score during surgery was not significantly different between both groups (No VR: 1.5±2.4 vs VR: 1.1±2.0, p=0.12) (mean difference (95% CI) −0.5 (−1.3 to 0.3)).

No significant differences were found between the control and the VR group regarding HRV measurement results gathered during US-guided RA placement and surgery (table 3) and perioperative rescue opioid need present in three patients of each group (5.1% p=1.00).

Median anxiety scores (measured by an 11-point anxiety NRS score, where 0=no anxiety and 10=extremely anxious), during US-guided block placement were not significantly different between the two groups (No VR: NRS 2.0 (0.0 to 5.0) vs VR: 1.5 (0.0 to 4.0), p=0.07). However, patients in the VR group showed significantly lower levels of anxiety compared with the control group during surgery (No VR: 1.5 (0.0 to 4.0) vs VR: 0.0 (0.0 to 2.0), *p<0.01*).

VR immersion total mean score, assessed with the IPQ in the experimental group (n=59), was 4.2±0.9. Subanalysis showed a spatial presence of 4.6±1.1, involvement of 4.2±1.2 and reality experience of 3.7±1.2. The value 4.3±0.9 corresponds to a percentile range of 56%–86% on the scale from 0 to 6, showing a moderate to high overall sense of presence score.[41]

Three patients in each group received intravenous opioids (n=1: 0.5 mg alfentanil and n=2: 5 µg sufentanil in both groups). One patient in the No VR group was converted to general anesthesia. No conversion to deep sedation was needed.

Seven patients (11.9%) suffered from adverse VR effects. These adverse events varied from general discomfort (n=2, 3.4%), difficulty focusing (n=4, 6.8%), increased salivation (n=1, 1.7%), sweating (n=2, 3.4%), difficulty concentrating (n=2, 3.4%), fullness of head (n=1, 1.7%), blurred vision (n=2, 3.4%), dizziness (eyes open) (n=2, 3.4%), dizziness (eyes closed) (n=2, 3.4%) and vertigo (n=1, 1.7%). Total nausea-related, oculomotor-related and disorientation-related symptom subscores were calculated for the entire VR group (n=59) as 76.3, 113.7 and 222.7 respectively, leading to a total score of 1543.65.

Satisfaction during US-guided RA placement showed no significant difference between study groups (No VR: 9.0 (8.0 to 10.0) vs VR: 9.0 (8.0 to 10.0), p=0.44) nor during surgery (No VR: 9.0 (9.0, 10.0) vs VR: 10.0 (9.0, 10.0), p=0.70). Global satisfaction rates with VR therapy were high (n=59): 9.0 (8.0 to 10.0).

DISCUSSION

In this study, we failed to demonstrate the superiority of VR therapy to reduce elicited pain during placement of US-guided RA nor during surgery. HRV measurement results (during US-guided RA placement and surgery) and perioperative rescue opioid need seemed also not significantly different between groups.

The effect of VR on anxiety during US-guided RA placement showed a slight decrease, but no significant difference in anxiety. However, measurements of anxiety during surgery showed to be significantly different in favor of VR therapy.

Also, no significant differences were found between the control and VR group regarding HRV measurement results gathered during US-guided RA placement and surgery.

Seven patients suffered from adverse effects due to the VR therapy, varying from general discomfort to dizziness. However, patients recovered fast from them. Only one patient had to remove the VR glasses during the block placement and did not resume VR therapy during surgery. However, the data were analyzed based on an intention to treat approach. The anesthesia VR experience used by Sedakit (Oncomfort SA, Wavre, Belgium) for this type of procedure, is a passive visual and audible three-dimensional experience and less interactive and challenging for the brain compared with full-immersion VR games. Currently, no absolute definition of what is a mild, moderate or severe adverse effect of VR therapy is available in the literature and future research should investigate this topic further. We have to address that it is challenging to determine with absolute certainty that these adverse effects were solely attributable to VR, as factors such as individual susceptibility, procedural stress or other external influences may have also played a role.

Satisfaction during US-guided RA placement and surgery showed to be not significantly different between the groups. When we investigated the global satisfaction with VR in our patient population, we found a high VR satisfaction rate, showing these patients to be open-minded to new technologies.

To assess the quality of the VR therapy, we took the IPQ test that showed an excellent overall sense of presence score.

Our results are in contrast with current literature on the effect of VR therapy on procedural pain sensation. A previous systematic review in burn patients showed potent analgesic effects of different VR therapy options, being largely based on distraction by full immersion in engaging and interactive environments.[38] However, for orthopedic surgery under RA in combination with sedation, there was only limited evidence on peri-procedural analgesia and anxiolysis using passive VR therapy systems, with only a few controlled trials reporting heterogeneous procedures and outcome measures.[14 43 44] The non-superiority of VR therapy on pain scores during US-guided RA placement for ambulatory hand surgery may be partly explained by the relatively lower levels of pain in this study population compared with previous studies in burn patients. A study by Hoffman *et al* reported a clinically meaningful reduction in worst pain levels from NRS 7 (pharmacologic analgesics) to 2 (passive VR therapy with pharmacologic analgesics) during burn wound care.[45] Future research should focus on the effect of VR therapy systems in other elective more painful surgical procedures and investigate other VR therapy systems available as well-defined patient subgroups may potentially benefit more from one type of VR therapy to another VR therapy system with regard to pain reduction.

Determining clinical significance for anxiety can be challenging. However, based on the previous literature, a commonly used cut-off value for clinically relevant anxiety reduction is 20%.[46] Both our observations showed an NRS anxiety score reduction of over 20% in median NRS anxiety scores, suggesting a clinically significant effect during RA placement and during surgery.

Our results on the effect of VR therapy on procedural anxiety are somewhat in line with the literature. A systematic review of six articles with 356 included patients showed inconclusive evidence on the significance of immersive VR in reducing anxiety for patients with cancer undergoing medical interventions.[47]

A possible explanation for this two-part result is the removal of auditive and visual guidance during RA by using VR therapy. Consequently, the patient may focus on the awaited experience of a painful stimulus, which can lead to augmented stress. After RA had been performed and the patient was reassured that no more painful stimuli followed, VR therapy could have reduced stress perioperatively by omitting auditive and visual surgical input.

Another potential hypothesis is that the two-part result was due to the additional adaptation time of the patient to the OR setting in combination with absence of visual OR input. Patients come to the OR, receive their RA block and due to the time component, become slightly more relaxed, although this was not observed in the VR therapy group. By removing the visual stimuli of the OR itself in combination with the time component, anxiety could have dropped. While the non-VR therapy group had continued visualization of the OR setting. VR immersion measurements were performed by the IPQ to assess the effect of VR on our patients. It encompasses four subscales: Spatial presence, Involvement, Experienced realism and Overall sense of presence. This last one determines the general subjective sense of being in the virtual environment, which is obtained by averaging the mean scores of the Spatial Presence, Involvement and Experienced Realism subscales.[39 48] In our data, the IPQ of the VR group showed a moderate to high overall sense of presence score, suggesting optimal VR therapy conditions were present and optimal VR therapy effect was to be expected.[41]

In the current literature on VR therapy during RA, a major limitation was that outcomes mostly focused on subjective measurements of stress, pain and anxiety. Studies that did measure objective parameters were limited to intraoperative values such as blood pressure and heart rate. Within the cardiovascular system, the balance of the parasympathetic and sympathetic nerve systems results in consecutive heartbeat interval variation or HRV.[17 19] Thus, HRV is a good indicator of sympathetic activity and is indirectly correlated with stress. The HRV can objectively support the subjective experience of the patient as can be provided during verbal questioning. HRV analysis has previously been positively evaluated in neuroanesthesia, quantifying patients' intraoperative stress response during asleep–awake craniotomy.[49] To our knowledge, this is the first study to objectively investigate the effect of immersive VR in orthopedic surgery using HRV monitoring. However, to our surprise, we did not find significant differences between the control and VR group regarding HRV measurement results gathered, although significant differences in anxiety scores were found during surgery. A purely theoretical reason for this could be the short interval of measurements of HRV, however, a 5 min interval allows for approximately 300 total heartbeats and is suggested as a standard to investigate short-term HRV by the Task Force of the European Society of Cardiology.[23] Also, our study was not powered for HRV.

From a practical point of view, we can say that overall, the VR intervention was well integrated into our hospital workflow, but we encountered some minor practical considerations. Setting up the VR system required minimal additional time, but occasional adjustments (headset and VR glasses) were needed to ensure patient comfort and positioning. In a few cases, adverse effects led to early VR removal, requiring brief intervention from the clinical team. While these factors introduced minor disruptions, they did not significantly impact the overall workflow.

This study contains some limitations. First, patients could not be fully blinded to group allocation because of differences in the appearance of the patients with and without VR (observer partially unblinded). Second, our included surgical patients underwent relatively small, elective surgical procedures, a potentially bigger effect of VR on pain scores could be suspected for more painful procedures or procedures with a higher factor of anxiety, for example, burn wounds or cancer surgery. Third, the participation of multiple surgeons might provide external validity, however, could also be a confounding factor in the surgical stimulus or other objective measures, therefore only one surgeon performed all surgeries to avoid intersurgeon variability in evaluating VR therapy. Fourth, it is possible that the duration of VR therapy was not sufficient to see a positive effect on all outcomes, however, the IPG scores showed adequate VR immersion and presence scores.[39] Finally, the generalizability of this study may be questioned due to its single-center design.

CONCLUSION

Our results show that the use of VR therapy during US-guided RA placement and hand surgery does not result

in lower pain scores. A perioperative statistically significant positive effect on anxiety was measured, combined with a clinically significant effect on perioperative anxiety. The clinical influence of different VR therapy systems on pain and anxiety should be further investigated in (other) elective procedures.

Acknowledgements This study is part of the Limburg Clinical Research Program (LCRP) UHasselt-ZOL-Jessa, supported by the foundation Limburg Sterk Merk, province of Limburg, Flemish government, Hasselt University, Ziekenhuis Oost-Limburg and Jessa Hospital.

Contributors Conceptualisation: KN and BS. Methodology: KN, HJ, BK, BS, MvD. Data collection: HW, IC, LG, MV. Data curation: TT and ML. Formal analysis: IC and HW. All authors are responsible for the writing and reviewing of the manuscript. All authors have intellectually contributed to the study.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests One of the authors (MVDV) has, at one point in the past, received a fee for providing consultancy services to the company Oncomfort. The other authors declare no conflict of interest.

Patient consent for publication Consent obtained directly from patient(s)

Ethics approval This prospective, mono-center, randomized controlled superiority trial, was approved by the ethical committee of the Jessa Hospital, Hasselt, Belgium (Chairperson Dr. K. Magerman, registration number B2432021000031 on 21st December 2021). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer-reviewed.

Data availability statement Data are available upon reasonable request.

ORCID iDs
Ina Callebaut http://orcid.org/0000-0002-6666-6783
Björn Stessel http://orcid.org/0000-0002-1422-2777

REFERENCES

1 Jalil H, Polfliet F, Nijs K, *et al*. Efficacy of ultrasound-guided forearm nerve block versus forearm intravenous regional anaesthesia in patients undergoing carpal tunnel release: A randomized controlled trial. *PLoS One* 2021;16:e0246863.
2 Nijs K, Ruette J, Van de Velde M, *et al*. Regional anaesthesia for ambulatory surgery. *Best Pract Res Clin Anaesthesiol* 2023;37:397–408.
3 Nijs K, Jalil H, Callebaut I, *et al*. Patient knowledge and preference in regional anaesthesia: A single-centre cross-sectional survey. *Eur J Anaesthesiol* 2022;39:633–5.
4 Nijs K, Castelein N, Salimans L, *et al*. Perception and knowledge of anesthesia and the role of anesthesiologists : a Belgian single-center cross-sectional survey. *Acta Anaest Belg* 2021;72:73–9.
5 Czech O, Wrzeciono A, Rutkowska A, *et al*. Virtual Reality Interventions for Needle-Related Procedural Pain, Fear and Anxiety-A Systematic Review and Meta-Analysis. *J Clin Med* 2021;10:3248.
6 Nijs K, Lismont A, De Wachter G, *et al*. The analgesic efficacy of forearm versus upper arm intravenous regional anesthesia (Bier's block): A randomized controlled non-inferiority trial. *J Clin Anesth* 2021;73:110329.
7 Combalia A, Sanchez-Vives MV, Donegan T. Immersive virtual reality in orthopaedics-a narrative review. *Int Orthop* 2024;48:21–30.
8 Abbas JR, O'Connor A, Ganapathy E, *et al*. What is Virtual Reality? A healthcare-focused systematic review of definitions. *Health Policy Technol* 2023;12:100741.
9 Triberti S, Repetto C, Riva G. Psychological Factors Influencing the Effectiveness of Virtual Reality–Based Analgesia: A Systematic Review. *Cyberpsychol Behav Soc Netw* 2014;17:335–45.
10 Berkman MI, Akan E. Presence and immersion in virtual reality. In: Lee N, ed. *Encyclopedia of Computer Graphics and Games [Internet]*. Cham: Springer International Publishing, 2019: 1–10. Available: https://doi.org/10.1007/978-3-319-08234-9_162-1
11 Bohil CJ, Alicea B, Biocca FA. Virtual reality in neuroscience research and therapy. *Nat Rev Neurosci* 2011;12:752–62.
12 Sanchez-Vives MV, Slater M. From presence to consciousness through virtual reality. *Nat Rev Neurosci* 2005;6:332–9.
13 Schubert T, Friedmann F, Regenbrecht H. The Experience of Presence: Factor Analytic Insights. *Presence: Teleoperators & Virtual Environments* 2001;10:266–81.
14 Chan PY, Scharf S. Virtual Reality as an Adjunctive Nonpharmacological Sedative During Orthopedic Surgery Under Regional Anesthesia: A Pilot and Feasibility Study. *Anesth Analg* 2017;125:1200–2.
15 Hoxhallari E, Behr IJ, Bradshaw JS, *et al*. Virtual Reality Improves the Patient Experience during Wide-Awake Local Anesthesia No Tourniquet Hand Surgery: A Single-Blind, Randomized, Prospective Study. *Plast Reconstr Surg* 2019;144:408–14.
16 Yang J-H, Ryu JJ, Nam E, *et al*. Effects of Preoperative Virtual Reality Magnetic Resonance Imaging on Preoperative Anxiety in Patients Undergoing Arthroscopic Knee Surgery: A Randomized Controlled Study. *Arthroscopy: The Journal of Arthroscopic & Related Surgery* 2019;35:2394–9.
17 Agrawal S, Nijs K, Subramaniam S, *et al*. Predictor role of heart rate variability in subarachnoid hemorrhage: A systematic review. *J Clin Monit Comput* 2024;38:177–85.
18 Amalan S, Vaishali B, S.p. P, *et al*. Pre-surgery stress monitoring using heart rate variability measures. 2019 41st Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC); Berlin, Germany, July 2019:4592–5. 10.1109/EMBC.2019.8856409 Available: https://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=8844528
19 Anderson TA. Heart rate variability: implications for perioperative anesthesia care. *Curr Opin Anaesthesiol* 2017;30:691–7.
20 Hadzic A. Hadzic's textbook of regional anesthesia and acute pain management. *The Second Edtion McGraw Hill* 2017.
21 Schulz KF, Altman DG, Moher D, *et al*. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. *BMJ* 2010;340:c332.
22 Speranza G, Verlato G, Albiero A. Autonomic changes during pregnancy: assessment by spectral heart rate variability analysis. *J Electrocardiol* 1998;31:101–9.
23 Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Heart rate variability: standards of measurement, physiological interpretation and clinical use. *Circulation* 1996;93:1043–65.
24 Mazzeo AT, La Monaca E, Di Leo R, *et al*. Heart rate variability: a diagnostic and prognostic tool in anesthesia and intensive care. *Acta Anaesthesiol Scand* 2011;55:797–811.
25 Theunissen M, Peters ML, Schouten EGW, *et al*. Validation of the surgical fear questionnaire in adult patients waiting for elective surgery. *PLoS One* 2014;9:e100225.
26 Stessel B, Fiddelers AA, Joosten EA, *et al*. Prevalence and Predictors of Quality of Recovery at Home After Day Surgery. *Medicine (Abingdon)* 2015;94:e1553.
27 Wong J, Tong D, De Silva Y, *et al*. Development of the functional recovery index for ambulatory surgery and anesthesia. *Anesthesiology* 2009;110:596–602.
28 Sonntag M, Konnopka A, Leichsenring F, *et al*. Reliability, validity and responsiveness of the EQ-5D in assessing and valuing health status in patients with social phobia. *Health Qual Life Outcomes* 2013;11:215.
29 Nijs K, Van Rossum M, Ory J-P, *et al*. Ultrasound-guided axillary brachial plexus block versus distal peripheral forearm nerve block for hand and wrist surgery: a randomised controlled trial. *Br J Anaesth* 2023;131:e20–2.
30 Nijs K, Hertogen P 's, Buelens S, *et al*. Axillary Brachial Plexus Block Compared with Other Regional Anesthesia Techniques in Distal Upper Limb Surgery: A Systematic Review and Meta-Analysis. *JCM* 2024;13:3185.
31 Schuurmans AAT, de Looff P, Nijhof KS, *et al*. Validity of the Empatica E4 Wristband to Measure Heart Rate Variability (HRV) Parameters: a Comparison to Electrocardiography (ECG). *J Med Syst* 2020;44:190.
32 Park S, Lee G. Full-immersion virtual reality: Adverse effects related to static balance. *Neurosci Lett* 2020;733:134974.
33 Young FLS, Leicht AS. Short-term stability of resting heart rate variability: influence of position and gender. *Appl Physiol Nutr Metab* 2011;36:210–8.
34 Shaffer F, Ginsberg JP. An Overview of Heart Rate Variability Metrics and Norms. *Front Public Health* 2017;5:258.
35 Laborde S, Mosley E, Thayer JF. Heart Rate Variability and Cardiac Vagal Tone in Psychophysiological Research - Recommendations for Experiment Planning, Data Analysis, and Data Reporting. *Front Psychol* 2017;8:213.
36 Weynants L, Chys B, D'hulst P, *et al*. Virtual reality for pain control during shock wave lithotripsy: a randomized controlled study. *World J Urol* 2023;41:589–94.
37 Thayaparan AJ, Mahdi E. The Patient Satisfaction Questionnaire Short Form (PSQ-18) as an adaptable, reliable, and validated tool for use in various settings. *Med Educ Online* 2013;18:21747.
38 Mallari B, Spaeth EK, Goh H, *et al*. Virtual reality as an analgesic for acute and chronic pain in adults: a systematic review and meta-analysis. *J Pain Res* 2019;12:2053–85.
39 Melo M, Gonçalves G, Vasconcelos-Raposo josé, *et al*. How Much Presence is Enough? Qualitative Scales for Interpreting the Igroup Presence Questionnaire Score. *IEEE Access* 2023;11:24675–85.
40 Cepeda MS, Africano JM, Polo R, *et al*. What decline in pain intensity is meaningful to patients with acute pain? *Pain* 2003;105:151–7.

41 Tran TQ, Langlotz T, Young J, *et al*. Classifying Presence Scores: Insights and Analysis from Two Decades of the Igroup Presence Questionnaire (IPQ). *ACM Trans Comput-Hum Interact* 2024.
42 Escutia-Reyes D, de Jesús Garduño-García J, Emilio-López-Chávez G, *et al*. Differences in heart rate variability and body composition in breast cancer survivors and women without cancer. *Sci Rep* 2021;11:14460.
43 Faruki AA, Nguyen TB, Gasangwa D-V, *et al*. Virtual reality immersion compared to monitored anesthesia care for hand surgery: A randomized controlled trial. *PLoS One* 2022;17:e0272030.
44 Huang MY, Scharf S, Chan PY. Effects of immersive virtual reality therapy on intravenous patient-controlled sedation during orthopaedic surgery under regional anesthesia: A randomized controlled trial. *PLoS One* 2020;15:e0229320.
45 Hoffman HG, Patterson DR, Magula J, *et al*. Water-friendly virtual reality pain control during wound care. *J Clin Psychol* 2004;60:189–95.
46 Hunot V, Churchill R, Teixeira V, *et al*. Psychological therapies for generalised anxiety disorder. cochrane common mental disorders group. *Cochrane Database Syst Rev* 2007;2007.
47 Chow H, Hon J, Chua W, *et al*. Effect of Virtual Reality Therapy in Reducing Pain and Anxiety for Cancer-Related Medical Procedures: A Systematic Narrative Review. *J Pain Symptom Manage* 2021;61:384–94.
48 Dawes J. Do Data Characteristics Change According to the Number of Scale Points Used? An Experiment Using 5-Point, 7-Point and 10-Point Scales. *International Journal of Market Research* 2008;50:61–104.
49 Conte V, Guzzetti S, Porta A, *et al*. Spectral analysis of heart rate variability during asleep-awake craniotomy for tumor resection. *J Neurosurg Anesthesiol* 2009;21:242–7.